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FY 2009 TECHNICAL PROGRESS REPORTS

October 1, 2008-September 30, 2009

Dry Grain Pulses Collaborative Research Support Program (CRSP)

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TABLE OF CONTENTS

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

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Abstract of Research Achievements and Impacts

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. Our main 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 a 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. Although this project is focused on pulses, this is a very significant result for farmers since maize is the staple food crop in the area.

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.

Results from the replicated experiments were generally similar to those obtained on-farms. However our ability to detect statistically significant treatment differences was limited by high within farm variability and the number of replicates.

Three additional students joined the project during FY09. One student has completed her degree and the 5 remaining will finish by the end of Phase 1. The students have had an excellent exposure to reality in fields (farmers' conditions; experimental difficulties), and have had extensive interaction with a diverse group of scientists who have given them more feedback than most graduate students receive in their Masters training.

Project Problem Statement and Justification

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.

Planned Project Activities for April 1, 2008 - September 30, 2009

<u>Objective 1</u>: 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.

Approaches and Methods:

1. *In Community Farmers Workshops* - KARI will organize and conduct in-community workshops for selected farmers, local extension and NGO personnel with input from the rest of the research team. Farmers invited to the workshop will be selected from an existing characterized group of farmers who had participated in a former Cornell project of the National Science Foundation Biocomplexity Initiative. These farmers' plots fall along a soil degradation gradient of steadily decreasing levels of soil C, N, P, K, Ca, Mg. Participatory approaches will be used to engage participants and facilitate the exchange of farmer and scientific knowledge as well as the rationale behind vigor-enhancing practices (root rot tolerant bean germplasm, seed priming, boma compost, combining/ concentrating organic & inorganic fertilizers, multipurpose pulse crops lablab and cowpea). Farmers will share their own knowledge and may propose additional vigor-enhancing practices to be tested by the group.

2. *On Farm Verification Trials* - Specific strategies that farmers wish to evaluate on their own farms will be facilitated and supported by the project. Given the extremely limited resources of the farmers, it will be necessary for the project to supply sufficient quantities of seed and fertilizers to plant the verification plots. KARI personnel will provide technical backstopping and follow up with the farmers. The vigor enhancing practices will be tested with beans during the long rainy season when farmers plant their main maize/bean intercrop. The drought tolerant indigenous pulses, lablab or cowpea, will be evaluated during the more erratic short rainy season.

Results, Achievements and Outputs of Research:

1. *In Community Farmers Workshops* - The details of our initial workshop and follow-up with the South Nandi core farmer groups was reported in the FY08 annual report.

NGOs were not included in the initial workshop with our core farmers, but we involved them in separate training sessions later (see Objective 2, activity 1). It was our intention to include local extension officers in this effort, but we found that the extension capacity in Nandi is quite poor. While there are Ministry of Agriculture offices at slightly higher administrative levels (i.e. district), we found that the local offices are not currently staffed with field agents.

2. *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, described in the FY08 annual report, 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).

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. A more concerted effort to disseminate this critical seed storage information is planned for FY10.

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 manuring 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 (Table 1). 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. A big impact of the vigor enhancing treatments on maize was also found on most of the farmer trials (see Objective 2, activity 2). Most participants selected the ½ DAP + ½ Lablab treatment as best for maize across the gradient.

Not all the farmers participated in the program during the LR09 season because of conflicts due to early maize planting, leasing agreements or tea expansion plans. However, 15 of the farmers rejoined the program during the current Short Rains season. Lablab, root rot tolerant beans, seed priming and phosphorus fertilizers are being tested again with the initial core group plus 31 new farmers (13 female, 18 male) from the surrounding communities who have expressed interest.

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.

Approaches and Methods:

1. *Create awareness and identify additional NGO and female farmer groups for collaboration and dissemination of vigor enhancing strategies* - Contacts will be made with NGO groups and the many

informal farmer groups which exist within the target area in order to expand the impact of the project to a wider audience beyond the initial pool of selected farmers.

2. *Crop performance evaluation and in season exchange visits* - Farmers will collect crop establishment data (germination and 4 wks post-germination) and volumetric yield data (for maize, beans, and lablab or cowpea) from their verification trial plots in each cropping season. In addition, farmers will be shown how to assess and record the incidence and severity of pests and diseases (root rot, bean fly, others) with easily observed characteristic signs or symptoms. Results will be shared with the project. Each cropping season farmer-to-farmer exchange visits and visits to the replicated researcher-managed experiments will be supported to provide other opportunities for facilitating experiential learning and exchanges about successes and failures. Participant feedback after each group event will be solicited and reported.

3. *Initiate socioeconomic surveys of farmers* - A survey will be undertaken at the end of the long rains in 2009 (one full short rains-long rains cycle) to document farmer reaction to the tested strategies. Perceived benefits and constraints, changes in management approaches and labor requirements, farmer to farmer knowledge dissemination and likelihood of adoption will be assessed. Impacts on livelihood indicators also will be collected as available, such as cost-benefit analysis of the chosen strategy, status of household food self-sufficiency, as well as crop sales and disposition of cash. Input on the survey instrument will be sought from all project collaborators (KARI, Cornell, Universities, CIAT) and incorporated prior to field testing. Socioeconomic data gathered from the NSF Biocomplexity project will serve as baseline information.

Additional baseline information on bean cultivation practices not available from NSF dataset will be collected prior to the In-Community Farmer Workshops.

Results, Achievements and Outputs of Research:

1. *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.

2. *Crop performance evaluation and in season exchange visits*

A. Short Rains 08-09 crop performance results

<u>Bean performance SR0809</u> **-** 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).

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.

<u>Lablab performance SR0809</u> - 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 (Figure 4). For P fertilization, this might be due to the fact that the deep rooted lablab was able to access P that had not depleted by the more shallow-rooted crops typically grown in these cropping systems. As for priming, the lack of consistent treatment response might be due to sufficient rainfall during the establishment period.

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).

B. Long Rains 2009 crop performance results

Bean emergence, stand counts along with bean and maize yields were recorded at each of the on-farm trials during the LR09 season. The data were used to assess the impact of the alternative fertilization treatments on early seedling vigor and to estimate post-emergence mortality of seedlings during the first month after planting.

<u>Emergence and stand establishment</u> - Bean emergence was evaluated 14 days after planting and 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.

At Kiptaruswo and Bonjoge, emergence was generally complete by 14 days after planting. However, rainfall was spottier at Kapkarer and Koibem and stands did not become fully established until 21 days after planting. At Kapkarer, bean emergence was especially delayed in the two treatments where lablab residues were incorporated, as evidenced by the increased germination that occurred between 14 and 21 days (Figure 5). This may have been due either to the bulky nature of the incorporated residues where there is poor soil to seed contact or to the fact that the residues were more effective than seeds at absorbing limited soil moisture. 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 meant that they placed the seed and DAP too close to one another in the planting furrow and the fertilizer damaged the germinating bean seed.

Post-emergence mortality - 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 (Bonjoge and Koibem); and (2) at the lower fertility sites, the highest bean seedling mortality occurred in the lablab, farmer practice, and compost treatments and the lowest was found in the sole inorganic fertilizer or organic-inorganic fertilizer mixtures. 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) and Otsuyla *et al*. (1997)). 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 6). Greater bean mortality in the sole lablab treatment may thus have been caused by the presence of higher 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. Thus incorporation of lablab residues could also increase inoculum density, as well as inoculum potential. Finally, residue management and quality factors also have the potential to contribute to increased seedling mortality. Planting too soon after the incorporation of low C/N residues may cause scorching of the seedlings, while planting too soon after the incorporation of high C/N residues causes nutrient immobilization.

LR09 bean and maize yields - Beans produced minimal amounts of grain at all sites across the gradient. Mean yields ranged from 0.25-0.75 kg per plot, with slightly higher yields at Kapkarer. However, despite poor yields, yield trends were consistent across sites (Figure 7). 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 superior yields obtained with the organic-inorganic mixtures are likely related to these treatments' ability to deliver available nutrients over a longer period of time, as well as enhanced early root development due to the added P.

All of the alternative fertilization strategies that farmers experimented with gave consistently superior bean yields compared to the yield obtained with their own practice, except sole lablab (Kiptaruswo, Koibem) and compost only (Koibem). The alternative fertilization strategies increased bean yields 33-133% at Kapkarer, 100-200% at Kiptaruswo, 100-200% at Bonjoge and 67-100 % at Koibem compared to farmer practice. Simple scatter plots (Figures 8 and 9) indicate the impact of half compost DAP and sole lablab treatments relative to farmer practice on individual farms. A majority of the farms reported higher yields with half compost DAP (Figure 8) compared to farmer practice. The same is true for the sole lablab treatment (Figure 9) with some exceptions.

The yield trends for the companion maize crop were quite similar across sites (Figure 10). Unlike the beans; however, the sole lablab treatment was also consistently a top performer. All of the alternative fertilization strategies that farmers experimented with gave superior maize yields compared to the yield obtained with their own practice; the range in percent increase was 24-44% at Kapkarer, 11-67% at Kiptaruswo, 3-39% at Bonjoge and 26-46% at Koibem. Although this project is focused on pulses, this is a very significant result for farmers since maize is the staple food crop in the area.

Implications of the results for farmer capacity building - The trends observed in the LR trials suggest we need to increase farmers' awareness about potentially important management issues related to the alternative fertilization strategies introduced to them. These include:

- How to apply DAP safely (to avoid seed scorching)
- How to improve compost quality
- Ensuring that compost is not allowed to dry out so that it is moist at the time of application
- How to minimize negative effects of incorporating fresh lablab residues (i.e. by not planting too soon after incorporation)

These messages can be passed by field staff and will also appear in the extension materials that will be produced in the upcoming months.

C. Farmer-to-farmer exchange visits

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. We hoped this would sensitize farmers on the need to either preserve their current high level of soil fertility to avoid future problems associated with degraded soils or to rebuild soil fertility to improve the current low level of productivity.

The visits and post-visit discussions were facilitated by a KARI team having expertise in natural resource management, socio-economics and community mobilization. Both visits have provided an opportunity for the trial farmers to learn from one another by sharing observations and experiences.

SR 0809 exchange visits - The main objective of the short rain exchange visits was to provide an opportunity for the trial farmers to assess: (i) the extent of soil degradation at different points on the soil degradation gradient; (ii) the performance of the different vigor enhancement options across the gradient; (iii) observe the impact of pests and diseases, particularly root rots, and their interaction with soil fertility.

The visits took place in November 2008. Farmers from Bonjoge, the medium high soil fertility cluster had exchange visits with their counterparts from Kapkarer, the low soil fertility cluster, while farmers from Koibem the high soil fertility cluster and their counterparts in Kiptaruswo, the medium soil fertility cluster, visited one another. 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. Differences in general soil fertility status between their own and the visited sites resonated with all of the farmers participating in the tour and generated quite a lot of discussion.

Farmers also discussed issues related to site-specific pulse performance, such as which treatments had a consistent versus variable performance. In this regard, Kapkarer farmers observed that the beans at Bonjoge had poorer vigor than on their own farms despite the fact that soil fertility was noticeably better at Bonjoge; they attributed this to hailstone damage. They saw that KK8 and lablab were relatively late and had less biomass compared to their own farms but that, similar to their own farms, the KK8 + TSP fertilization treatment was also the best performer at Bonjoge. At Kapkarer, the Bonjoge farmers observed that although the soil fertility status was clearly poorer, lablab was doing much better. They concluded that the lablab might be more suited to low fertility conditions. They also observed several similarities between the two sites, namely that KK8 performed much better than the farmers' own varieties and that the overall best vigour was obtained when KK8 was planted with TSP.

During their visit to Koibem, Kiptaruswo farmers noted that all options were doing equally well; they attributed this to the area's relatively high soil fertility status. Beans at Koibem were more vigorous and had more pods per plant. They observed however that, despite the higher fertility level at Koibem, lablab biomass accumulation was not as good as in their own farms. Koibem farmers noted that the Kiptaruswo farmers' beans, particularly GLP2 (a root rot susceptible variety) was doing poorly and had few or no pods per plant; they attributed this to diseases and low soil fertility.

At the end of each visit, farmers discussed the take away messages that they had learned from the visit. Points that arose during the general discussions at the end of these visits included: (i) that growing more root rot tolerant beans can have a large impact on improving their livelihoods; (ii) that there is a need for them to put more effort on soil conservation, as well as soil-building by using composts and FYM; (iii) that more farmers need to receive the training to learn how to improve soil and crop productivity; and (iv) that there is a need for community based seed multiplication to ensure access to disease free KK8 bean and lablab seeds.

<u>LR09 exchange visits</u> - 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.

In the Bonjoge - Kapkarer group, participants observed that the best performing treatments for maize were, in descending order, the half lablab DAP treatment, the half compost DAP treatment and lablab only, which farmers thought was outperforming DAP and farmer practice. They made special note of the fact that although the region had experienced hailstorms, the maize in the plots with the vigor enhancement strategies remained standing strong while that in the farmer practice plot had lodged.

At Kapkarer, farmers commented that beans were performing poorly because they had been attacked by aphids before flowering. Farmers noted that local maize varieties performed well with the vigor enhancing strategies. This resonated with them strongly because they realized that, if they had their own seeds and had lablab biomass or boma compost, they could have high productivity even if they did not have the money to purchase external inputs (hybrid seed, fertilizer).

Bonjoge - Kapkarer farmer discussions about lablab utilization revealed that all had used lablab grain for food. The farmers universally liked the taste of lablab grain and leaves. One farmer however said he did not use it for vegetable, since he wanted to get enough biomass for incorporating in the soil. Farmers recommended planting KK8 beans in the short rather than the long rains. They agreed that lablab improved soil fertility/crop productivity and also made the ground soft for tilling. They encouraged each other to use compost manure and lablab because they are cheap and easily available. However, they felt it was important to get more youth involved in farming as the new strategies they had learned (compost preparation, lablab incorporation) were more labor intensive. They noted that the performance of maize and beans at the two communities were almost similar and that crops that were planted earlier had fared much better than those planted late. They 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. They felt that the exchange visits had served as an eye opener and requested that they be able to visit other sites within or outside the region.

Bean yields were very poor in the long rains compared to the short rains at Koibem and Kiptaruswo farms. Farmers blamed late planting, poor climatic conditions, root rot and aphids in both areas. They found that the half lablab DAP was the best and most consistent treatment in both communities. The half compost DAP treatment was good as well but had more variable performance. Farmers associated the latter results with variation in compost storage and quality. Koibem-Kiptaruswo participants noted differences in spacing and number of seeds planted. The vigor of the farmer practice (planted with two or more seeds) was poor and was likely to give low yields compared to the other strategies with the improved spacing.

Local maize seed plus lablab incorporation was among the best performing among farms. Participants encouraged each other to continue with the practice for better results at lower cost. The farmers blamed dry conditions on the poorer performance of the crops planted with sole compost. The majority of the farmers said they were attracted to the multiple uses of lablab and were willing to scale up to other farms.

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.

3. *Initiate socioeconomic 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. Ms. Eunice Onyango is conducting these surveys as part of her Masters research program at Moi University.

A Focus Group Discussion (FGD) approach was employed first to collect feedback from the four farmer groups across the gradient. The aim of the FGD was to probe the extent of farmers' knowledge on soil fertility, pulse crop production constraints and their perceptions of the introduced vigor enhancing strategies. Participants were also asked to give their opinions about the dissemination process.

Ms. Onyango completed the FGD in late July 2009 involving a total of 56 farmers. Unfortunately the majority of the participants were male, thus biasing the findings towards men's perceptions. 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)+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.
- The project dissemination process (workshop, farmer testing, exchange visits, KARI technical backstopping) was rated good to excellent by all participants.

- Agricultural extension services are largely absent in South Nandi as are farmer groups. Four NGOs working in the area were identified but were rated very poor by the farmers.

Ms. Onyango is currently completing individual household surveys as a follow-up to the FGD. Using an oral interview approach, each of the 64 farmers who participated in the workshop and on-farm validation is being surveyed along with an equal number of non-participant households from the surrounding communities. A concerted effort is being made to survey more women, in order to correct the gender disparity that occurred with the FGD.

The objective of the individual surveys is to obtain specifics on: (i) household food security status, (ii) production costs, (iii) individual experiences with the vigor enhancing strategies and (iv) farmer-to-farmer knowledge dissemination. From the results we expect to be generate more insight concerning the costs and benefits of the vigor enhancing strategies, which will help us to explain technology adoption and diffusion trends in the upcoming seasons.

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

Approaches and Methods:

1. *Project Initiation Workshop* - Complex experimental designs will be used to test responses to the full complement of vigor enhancing strategies and to tease apart interactions among management practices, soils, crops and pests/diseases. All project collaborators (KARI, Cornell, Universities, CIAT) will convene to develop and detail the specific research questions, experimental design and data to be collected from the replicated trials. Research questions will likely emphasize incidence and severity of pests and diseases, characterization of soil chemical characteristics and agronomic evaluations of system productivity

2. *Implement replicated experimental trials* - KARI will establish and oversee the management of the replicated experiments on representative maize and bean fields at 4 sites across the soil degradation gradient. Farmer collaborators from each represented gradient zone will help to identify the most appropriate site within that zone and the farmer who owns the field will be fully compensated in cash and kind. These replicated experiments will be carried out over the life of the project.

3. *Data collection and evaluation* - Data from the replicated experiments as identified during the Project Initiation Workshop will be collected by KARI staff. At the end of the short rains 2008 and long rains 2009 cropping seasons, results will be collected and shared among all collaborators.

4. *In-season field visits and annual meeting review of results* - Each cropping season site visits will be made to the replicated trials by project collaborators during early crop growth to assess the effectiveness and impacts of the tested vigor enhancing strategies. Observations and comments will be reported. Project collaborators will meet after one full short rains-long rains cycle to review and synthesize results from farmer and replicated experiments. Successful and unsuccessful features of the vigor enhancing strategies and impacts will be identified. Areas needing additional attention or modification will be identified.

5. *Collection and nutrient analysis of grain and edible leaf samples* - KARI staff will gather grain sub-samples from farmer and replicated trials. Samples will be sent to Cornell Unversity for mineral nutrient analysis (Ca, Mg, P, K, S, Zn, Cu, Mn) and calculation of cropping system yields and nutrient outputs.

6. *Pursue opportunities for germplasm testing and exchange* - Phosphorus efficient bean germplasm (2-3 lines) will be obtained from the Pennsylvania State University (PSU) project and tested during the long rains season in observational plots across the soil degradation gradient. Commonly adopted root rot tolerant bean varieties from the target area will be sent to PSU for P efficiency trait testing. Likewise

early and late maturity cowpea cultivars will be obtained from University of California Riverside (UCR) and tested during the short rains for biomass and grain production.

Results, Achievements and Outputs of Research:

1. *Project Initiation Workshop* - The outcomes of the project initiation workshop in June 2008 were reported in the FY08 annual report.

2. *Implement replicated experimental trials* – One Main experiment and two smaller Satellite experiments were carried out by KARI staff in collaboration with Master students from Moi University and the University of Nairobi during the SR0809 season. Larger farms from each of the four soil fertility clusters in South Nandi district were chosen in order to accommodate the size of these experiments.

The intent of the Main experiment during the SR was to evaluate the effect of seed priming and phosphorus application on lablab productivity and disease/pest severity. Satellite trial #1 was set up to assess impacts of phosphorus fertilizer sources (no P, TSP, MRP) on lablab productivity and pest/diseases. Satellite trial #2 was established to determine the effects of phosphorus fertilizer sources (no P, TSP, MRP) with and without seed priming on bean productivity and pests/diseases.

Only the Main experiments were continued during the LR09 season. The purpose of the LR Main experiment was to evaluate the individual and combined impacts of lablab residues from the previous SR season (no lablab, lablab removed-only roots remaining, lablab incorporated-aboveground biomass incorporated), boma compost+DAP and bean variety (root rot susceptible and tolerant lines) on maize-bean intercrop productivity as well as bean pests and diseases.

A second year of the Main experiment was planted at the same sites during the first week of September 2009.

3. *Data collection and evaluation* - Data from 2008-09 Short and Long Rains crops have been collected, compiled and shared amongst all collaborators. The datasets include plant emergence and mortality, lablab, bean, maize grain and biomass yields, as well as severity ratings for bean root rot, halo blight, bean fly maggot (*Ophiomyia* spp.), aphids (*Aphis fabae*) and chafer grubs (*Schizonycha* spp). Pest and disease severity results on lablab and bean from the SR0809 experiments formed the basis of Francesca Lusweti's recently completed Master thesis (Univ. of Nairobi). Impacts of seed priming and phosphorus fertilizer on SR0809 lablab productivity and subsequent residual effects on LR09 maize-bean productivity will be the subject of Crispus Njeru's Master's thesis (Moi University).

The following sections summarize our findings from the first year's results.

<u>SR0809 Main Experiment (Lablab)</u> - Lablab grain yields benefited from seed priming at the two low fertility sites (Kapkarer, Kiptaruswo) but not at the high fertility sites (Figure 11(left)). Seed priming alone significantly increased lablab yield at Kapkarer by 87% over the other treatments. At Kiptaruswo, seed priming alone or with TSP fertilizer increased lablab yields on average by 38%, but this effect was not statistically significant. Grain yield response to TSP was limited to Bonjoge (11% increase over control) and Koibem (20% increase over control).

Lablab biomass yields only showed a response to the seed priming treatments at Kiptaruswo, (Figure 11 (right)). TSP increased lablab biomass by 15-37% at all sites, although the effect was only significant at Kiptaruswo. There did not appear to be any synergistic effect of combining seed priming and TSP at any of the sites.

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. One possible explanation for these results is that under low soil fertility conditions, a greater proportion of growth is allocated to biomass production at the expense of grain; whereas under higher soil fertility the opposite situation occurs. Temperature and precipitation differences between the sites may have also contributed to the observed effects - Kapkarer and Kiptaruswo are generally warmer and drier than Bonjoge and Koibem (Kimetu et al, 2008).

Sacrificing grain for biomass has adoption implications for farmers at low fertility sites if grain is preferred to biomass. However the multipurpose qualities of lablab still allow farmers in low soil fertility areas ample material for regenerating their depleted soils while also addressing their livestock feed and household vegetable needs.

Seedling emergence 2 weeks after planting was quite good ranging from 83% at Bonjoge to 92% at Koibem. Despite the good start, post-emergent plant mortality of 33 to 46% was found by final harvest. Higher plant mortality in Kapkarer and Bonjoge was partially attributed to hail damage that occurred ~3 weeks after planting. There was no effect of seed priming or phosphorus treatments on emergence or plant mortality.

Diseases and pests of lablab were assessed in the Main Experiment starting 2 weeks after planting (Table 3). Across the gradient, bean fly and bean root rot were of low to intermediate severity, with the highest scores found at Kapkarer and Bonjoge for bean fly and at Kapkarer for root rot. These findings are consistent with higher plant mortality found at Kapkarer and Bonjoge. Seed priming and phosphorus treatments had no impact on bean fly and root rot severity at any of the sites, except Kapkarer where seed priming significantly reduced bean fly severity. Aphids and halo blight were quite low at all the sites with no impact of treatments.

<u>SR0809 Lablab Satellite Experiment</u> - Minjingu Rock Phosphate is most effective as a local and less expensive P fertilizer under acid soil conditions. Thus we expected to see a response to MRP in South Nandi where soil pHs range from 5.2 to 6 (Kinyangi, 2007). Indeed MRP increased lablab grain yields quite substantially (61-120% over the control) at Kapkarer and Kiptaruswo (Figure 12 (left)), but these responses were not significant due to high within site variability (CV 46-50%). There was no lablab yield response to TSP across the gradient, which was also observed in the farmer verification trials.

Lablab biomass results from this experiment were equally variable and statistically inconclusive (Figure 12 (right)). Good biomass responses to TSP were found at Kiptaruswo and Koibem which were consistent with the Main Experiment findings, but only the Koibem result was significant. MRP appeared to increase biomass at Kiptaruswo relative to the control, but surprisingly lablab biomass at Kapkarer was depressed by MRP and TSP.

Seedling emergence was good ranging from 81-90%, but TSP depressed lablab emergence at 3 of the 4 sites. Lower emergence and the overall lack of yield responses to TSP implies that lablab is sensitive to the TSP fertilizer form at germination. Efforts to mix the TSP more with soil at planting may help to ameliorate this problem.

Post-emergent plant mortality was lower in the Satellite than in the Main Experiment (21% versus 40%) with no effects by treatment. This is explained by low to intermediate pest and disease severity found at all sites.

<u>SR0809 Bean Satellite Experiment</u> - No bean yield data were collected from Kapkarer because of premature harvesting by the farmer. At the other sites bean production increased 12-50% with TSP compared to the no P control, but this effect was only statistically significant at Koibem (Figure 13 (top left)). There was little or no benefit of MRP on bean yields across the gradient. Seed priming had no

impact on bean yields at Kiptaruswo or Koibem, whereas at Bonjoge seed priming appeared to depressed yields relative to the non-primed control (Figure 13 (top right)).

We expected higher bean yields at all sites with KK8, the root rot tolerant line, but this result was found only at Koibem, where KK8 yields were 4 times greater than the root rot susceptible variety, GLP2 (Figure 13 (bottom)). At Kiptaruswo and Bonjoge bean yields were roughly the same between the two varieties, which suggests that bean root rot was not the dominant problem at these two sites and that KK8 was equally susceptible compared to GLP2.

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 (Table 4). Bean root rot was moderate at all sites except Koibem which was low. Bean fly severity was high at Bonjoge but low at the other sites. Moderate to high severity of both root rot and bean fly at Bonjoge likely explains the absence of a response in yield by KK8 at this site. Higher severity of aphids and halo blight could have also led to the poor response of KK8 at Kiptaruswo and Bonjoge.

Few statistically significant effects of the treatments were found on pests and diseases but some consistent trends were noted. 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.

<u>LR09 Main Experiment (Maize-Bean Intercrop)</u> - 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 (Figure 14 (left)), making treatment inferences questionable. Kapkarer experienced less bean mortality (44%) than the other sites, because of earlier planting and less rainfall. Although the variability was also quite high (CV 50%), we were able to distinguish some impacts of the treatments.

Lablab residue treatments at Kapkarer depressed bean yields 23-25% relative to the no lablab residues control (Figure 14 (left)). A number of possible explanations for this effect have already been discussed in LR09 on-farm verification trials section. The researcher-managed trial results suggest that interactions with the root rot organisms will need further scrutiny in future trials as a closer look at Kapkarer bean yield responses by variety revealed that this impact was primarily with GLP2, the root rot susceptible line (Figure 15). KK8 produced 2.7x more yield than GLP2 and only a slight depression in yield was found with the lablab residue treatments.

The compost+DAP treatments reduced Kapkarer yields slightly but not significantly (Figure 14(right)). However, consistently higher yields were found with the compost+DAP treatment at Kiptaruswo, Bonjoge and Koibem despite the very low results.

Bean fly, root rot, aphid and chafer grub severity were assessed on the beans approximately 1 month after planting (Table 5). 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.

Lablab residue and fertilizer treatments had no significant impacts on bean fly or root rot severity at any of the sites, but bean variety did show an effect. 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.

Chafer grubs were monitored because previous experience in Trans Nzoia district (Medvecky et al., 2006) indicated elevated grub damage to beans when lablab residues were incorporated. We were not able to detect significantly higher grub incidence in the lablab residue treatments of the LR09 Main Experiments in South Nandi. However, our results did show that chafer grub counts were significantly lower in the compost + DAP treatment relative to the unfertilized treatment at Kiptaruswo, Bonjoge and Koibem, which was also a finding in the farmer verification trials.

Lablab residue treatments increased maize yields at Kapkarer, Kiptaruswo and Koibem, but only the Kapkarer results were statistically significant (Figure 16 (left)). Maize yields increased 16-34% at Kapkarer, 26-46% at Kiptaruswo and 10-16% at Koibem. We attribute the low responses to lablab residues at Bonjoge and Koibem to the lower quantities of biomass incorporated (6 t/ha versus 11-12 t/ha at Kapkarer and Kiptaruswo).

The compost+DAP treatment only increased maize grain yield significantly at Koibem (17% over the unfertilized control) (Figure 16 (right)). At Kapkarer and Kiptaruswo there was little or no response in maize yields to compost+DAP and a slight but insignificant increase at Bonjoge.

<u>Implications from replicated experiment results</u> - Results from the replicated experiments confirm several of the responses found on the farmers' plots to the vigor enhancing strategies: (i) TSP increased bean yields but did not consistently impact lablab yields; (ii) responses to MRP were variable in both beans and lablab; (iii) lablab response to seed priming was variable across sites; (iv) green manuring with lablab residues depressed bean yields, but increased maize yields; and (v) higher bean and maize yields were found with compost-DAP mixtures. Despite these consistencies, substantial spatial variability at each of the replicated experiment sites has often made it difficult to detect statistically significant treatment differences. Having only 3 replicates per treatment (due to farmer landholding size constraints) has aggravated the situation. Modifications to the experimental design will be required in the next phase to address this problem.

4. *In-season field visits and annual meeting review of results* – Cornell, KARI and the university partners made field visits to the replicated experiments and farmer plots in October 2008, March 2009 and August 2009. The August field visit was a joint activity during the annual project meeting.

KARI staff, University faculty and students and 3 Cornell partners participated in the annual project meeting August 5-6, 2009 in Kisumu. Experiences and results from the farmer verification trials were summarized along with results from the replicated experiments. Four of the Masters students made presentations of their research achievements, and 2 new students presented their research proposals for discussion.

5. *Collection and nutrient analysis of grain and edible leaf samples* – Lablab and bean grain/leaf materials were gathered during the SR0809 season from farmers and the replicated experiments at each of the sites along the soil fertility gradient. The materials were delayed in being sent to Cornell for nutrient analysis because of a late SR harvest, lack of labor availability and phytosanitary certificate complications,. A total of 244 samples were finally sent and are currently undergoing grinding and nutrient analysis at Cornell.

6. *Pursue opportunities for germplasm testing and exchange* – Silvester Odundo, a Masters student at Moi University, undertook the initial assessment of 35 cowpea cultivars obtained from the Univ. of California Riverside which was reported in the FY08 annual report.

After generating sufficient quantities of seed for undertaking a more complete assessment, Mr. Odundo has set up replicated experiments across the soil fertility gradient in the current SR0910 season. He will be comparing the agronomic responses of 5 UCR lines and their responses to increasing phosphorus levels (0, 15, 30 kg P/ha).

The nutrient efficient bean germplasm from the Zamorano-Pennsylvania program was tested during the LR09 season at the KARI-Kakamega station on a soil deficient in phosphorus. Stand counts, days to flowering, disease and pest rankings, days to maturity and yield were measured. Bean mosaic necrotic virus caused complete yield loss in about a third of the lines. Yields from the remaining lines ranged from 42 g/2m row to 432 g/2m row. Further evaluation and selection is being done with the top nineteen performing lines in the current SR season. Trials to assess performance across the soil fertility gradient are planned once sufficient seed is generated.

Objective 4: To facilitate and support on-farm participatory research opportunities for Kenyan agricultural scientists and graduate students.

Approaches and Methods:

1. *Coursework in selected fields* - One student from each of the three Kenyan Universities will receive support to undertake a 2-year Masters Degree program in the areas of soil science (Egerton Univ.), plant protection (Univ. Nairobi) or agronomy (Moi Univ.). Staff from KARI, the Ministry of Agriculture and NGOs will be actively sought as students, thereby benefiting these institutions directly when the students complete their degrees and return to work. One staff member from KARI-Kakamega has already been nominated to work with Dr. Okalebo at Moi University. Once selected the students will be enrolled and undertake Master's level coursework during the first year of the project.

2. *Develop and implementation of student research projects* - Each student will prepare a student research proposal guided by the discussions during the Project Initiation Workshop and in consultation with their faculty advisor. The proposals will be shared with project collaborators for inputs and comments prior to initiation of the research. The researcher-managed and/or the farmer-managed trials will form the backbone of the students' thesis research. As needed students will establish additional satellite trials. For example, missing element experiments may be set up to assess the role of other limiting nutrients in these soils.

3. *Sharing of results in annual meetings* - Students will present results (as available) from their research projects during the project annual meeting for discussion and suggestions. Results will be incorporated into the project annual report as they become available.

Results, Achievements and Outputs of Research:

1. *Coursework in selected fields* - Initially our project funds budgeted support for 3 students, one each from Univ. of Nairobi, Moi University and Egerton University (FY08 cohort). We saved sufficient funds for an additional student at the Univ. of Nairobi by recruiting a second year student who had already completed her coursework. In addition the HC Capacity Building grant provided funds for 2 more second year students (FY09 cohort). In total, 6 students (4 women, 2 men) have been supported for Masters degrees to date.

2. *Develop and implement student research projects* - All students currently in the program have prepared research proposals which have been reviewed and approved by faculty from their respective institutions. Cornell and KARI collaborators provided extensive comments during the proposal preparation stage. The current progress of each student's program is as follows:

FY08 student cohort
(i) Francesca Lusweti completed her Masters degree in Plant Protection at the University of Nairobi in September 2009. Her research objective was to assess the impacts of seed priming and phosphorus fertilizer on root rot and bean fly damage to lablab and bean across the soil fertility gradient.
(ii) Crispus Njeru is a student of Moi University in Soil Science. Mr. Njeru has studied the productivity of lablab across the soil fertility gradient, the impact of lablab biomass incorporation on soil fertility and on subsequent productivity of a maize-bean intercrop. He has completed the data collection phase of his research program and is currently analyzing the results and drafting his thesis.
(iii) Belinda Weya is enrolled at Egerton University in Soil Science. She initiated her thesis research in September 2009 to test whether seed priming with added nutrients can effectively address soil deficiencies of phosphorus or molybdenum for lablab and common bean.

FY09 student cohort
(i) Silvester Odundo is a student from Moi University in the field of Soil Science under the supervision of Dr. Robert Okalebo. Silvester is now carrying out his thesis research with the cowpea germplasm materials obtained from the University of California, Riverside.
(ii) Eunice Onyango is enrolled at Moi University in the Department of Applied Environmental Social Sciences and supervised by Dr. Reginalda Wanyonyi. She is employed at KARI-Kakamega in the Social Science Division. Ms. Onyango is currently conducting socioeconomic research to document South Nandi farmers' reactions to vigor enhancing strategies for pulse crops.
(iii) Caren Oloo is a second year student from the University of Nairobi supervised by Drs. Muthomi and Nderitu in the Plant Protection field with emphasis on plant pathology. She is employed by the Kenyan Ministry of Agriculture where she works as an Extension Officer. Ms. Oloo is building on the findings of Ms. Lusweti's Masters project and has initiated field research investigating the impact of seed priming and phosphorus fertilizer on root rot of common bean.

3. *Sharing results in annual meetings* - All 6 students gave presentations on their research results/ proposals at the annual project meeting August 5-6, 2009 in Kisumu, Kenya.

Explanation for Changes

No changes

Networking and Linkages with Stakeholders

1. USAID Mission Nairobi - Courtesy visit on March 12, 2009; met with the Director of Regional Economic Growth and Integration and advisors from the Agriculture, Business and Environment Office. Julie Lauren gave a presentation on project progress including some initial beans and lablab results from Short Rains farmer verification trials.

2. Collaborations with 2 NGOs (REFSO, ARDAP) and one CBO (Avene) working were initiated in February 2009 (see Objective 2, activity 1).

3. Established collaboration 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 will help us to supplement our project seed needs, while increasing their capacity to supply quality pulse crop seeds to East African farmers.

Leveraged Funds

Name of PI	Description of Project	Dollar Amount	Donor Agency
Beth Medvecky	Great Lakes Cassava Initiative- Developing Farmer Training Modules	30,000	Catholic Relief Services
Christopher Barrett	Global Livestock CRSP	390,000	USAID
Christopher Barrett & Beth Medvecky	Food Systems and Poverty Reduction Integrative Graduate Education and Research Training Program	3.5 million	National Science Foundation

List of Scholarly Activities and Accomplishments

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.

Contribution of Project to Target USAID Performance Indicators

We exceeded our targets for degree training by recruiting 3 additional female students. Five of the six students are mid-career professionals working at either KARI or in the Ministry of Agriculture-Extension. Collaborations with local NGO/CBO groups more than doubled our goal for short term training along with the households benefiting from this intervention.

All of the 8 projected vigor enhancing strategies are currently under field testing by farmers, plus we have added research on 2 technologies (cowpea and nutrient efficient bean germplasm) that we had not projected earlier. We will not been able to achieve the target of providing technical assistance to women's groups because none of these organizations are operating in the project area. All four HC partner organizations: KARI, University of Nairobi, Moi University and Egerton University continue to benefit from the project.

After only one year experimenting with our vigor enhancing strategies, approximately 25% of the farmers have started to scale up within their farms. Due to the small size of these farms, this only constitutes a cumulative area of 2 hectares compared to the projected 10 hectares. We anticipate more scaling up within farms over time.

Lastly one public-private partnership has been achieved through linkages with the Leldet Seed Company.

Contribution to Gender Equity Goal

Women have been a major target of trainings and the on-farm validation trials. An additional 85 women were added to the project through new collaborations with the NGO/CBO groups and new farmers in the South Nandi project area. Women comprise 48% of the lead participants to date. In a few cases a husband-wife team is sharing leadership.

Two female KARI staff members have actively participated on the project to date. One is a Post Harvest-Value Addition specialist. The other KARI staff member is a social scientist, who is currently surveying farmers as part of her Project sponsored Masters degree program.

A total of three mid-career, professional women have been sponsored for Masters degrees at the University of Nairobi and Egerton University. One student has completed her degree and has resumed work at the Ministry of Agriculture as an Extension Officer. The others will also return to work as Extension Officers when they complete their degrees.

Progress Report on Activities Funded Through Supplemental Funds

A number of host country capacity building activities were undertaken during FY09:
(1) Up-grading communication - A new computer server was purchased to modernize and strengthen electronic communication between KARI and the collaborating partners. In addition, a wireless 3G Router was acquired to improve access to email and internet facilities at KARI Kakamega Centre. Through a monthly subscription, this equipment is now connected to the Safaricom mobile network to facilitate faster and more reliable access to internet and email services. Substantial improvement in communication has been achieved as a result.

(2) Training for KARI laboratory staff - While KARI-Kakamega has most of the equipment and instruments needed for providing soil analytical services to farmers and students, the KARI laboratory staff lacked the knowledge and skills necessary for operating the available equipment and instruments. To improve the situation, a five-week training course was conducted for KARI laboratory staff 10 February to 27 March 2009. The training was conducted by Justin Magangah and Nicholas Kungu, two highly qualified and experienced laboratory technologists from Moi University and KARI Muguga, respectively. The training covered both theory and practical aspects and focused on the use of UV Spectrophotometer, Atomic Absorption Spectrophotometer, and Segmented Flow Autoanalyzer.

(3) Additional MSc students - HC Capacity Building funds supported the Master research projects of Silvester Odundo and Eunice Onyango (see report under Objective 4 above).

(4) Additional farmer exchange visits - A second farmer exchange visit program was undertaken in late June-early July 2009 during the Long Rains season. HC Capacity Building funds were used to supplement the main project budget in order to carry out the exchange visits.

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Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

Project Title: **Using Improved Pulse Crop Productivity to Reinvigorate Smallholder Mixed Farming Systems in Western Kenya**

	Abbreviated name of institutions											
	Cornell			KARI								
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1	Develop and assess farmer capacity for improving vigor and growth of pulse crops ...											
Select farmers from NSF project pool												
Report on workshop & follow up meetings												
Farmer trials established				x	✓							
Objective 2	Disseminate and evaluate through participatory approaches simple, low cost strategies for vigorous establishment											
Identify additional farmer groups												
Exchange visits conducted & technology evaluated				x	✓							
Survey instrument developed & initiated	x	✓		x	✓							
Objective 3	Research factors (nutrients, pest/diseases and their interactions) affecting pulse productivity across a soil degradation gradient											
Research design and plan												
Research trials established				x	✓							
Seasonal research results reported	x	✓		x	✓							
Site visit trip reports	x	✓		x	✓							
Annual meeting report	x	✓		x	✓							
Nutrient analysis reports	x											
Observational trials with germplasm established	x	✓		x	✓							
Objective 4	To facilitate and support on-farm participatory research opportunities for Kenyan agricultural scientists and graduate students											
Students selected & registered				x	✓							
Student research proposals developed	x	✓		x	✓							
Student research inititated				x	✓							
Research reports at annual meeting				x	✓							
Faculty progress reports				x	✓							
Name of the PI reporting on benchmarks by institution	J.G. Lauren			J.O. Ojiem								

Name of the U.S. Lead PI submitting this Report to the MO: Julie G. Lauren

Julie G. Lauren — **Signature** 9/30/2009 — **Date**

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

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

Lead U.S. PI and University: Julie G. Lauren, Cornell University
Host Country(s): Kenya

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women	1	2	1	4
Number of men	2	1	2	2
Short-term Training: Number of individuals who have received short-term training				
Number of women	32	30	80	115
Number of men	32	34	36	124
Technologies and Policies				
Number of technologies and management practices under research	2	1	0	2
Number of technologies and management practices under field testing	6	5	8	8
Number of technologies and management practices made available for transfer	0	0	3	3
Number of policy studies undertaken	0	0	0	0
Beneficiaries:				
Number of rural households benefiting directly	64	64	116	239
Number of agricultural firms/enterprises benefiting	0	0	0	1
Number of producer and/or community-based organizations receiving technical assistance	0	0	4	3
Number of women organizations receiving technical assistance	3	0	4	0
Number of HC partner organizations/institutions benefiting	4	4	4	4
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	0	0	10	2
Number of public-private sector partnerships formed as a result of USAID assistance				1

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

Principle Investigator

Robert Mazur, Iowa State University, USA

Collaboratoring Scientists

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Patricia Murphy, ISU, U.S.
Michael Ugen, NaCRRI, Uganda
Hilda Vasanthakaalam, KIST, Rwanda
Barnabas Kiiza, Makerere, Uganda
Agnes Nakimuli, VEDCO, Uganda
Mark Westgate, ISU, U.S.
Manju Reddy, ISU, U.S.

Abstract of Research Achievements and Impacts

The research team is operating effectively to address all project objectives as planned. Activities to help 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 greatly 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. We are in the process of determining processing techniques that best enhance protein and carbohydrate digestibility. Development of protocols for making bean flour and identification of its key properties are progressing well. 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, and marketing constraints in the bean value chain. For the fourth strategic objective, accomplishments regarding increasing capacity, effectiveness, and sustainability of the universities include formalizing partnerships with complementary research and practitioner institutions, training of six M.S. students at Makerere University and two Ph.D. students at Iowa State University, training of 67 farmers (58 female), and active multi-institutional collaboration in all aspects of project design, implementation, documentation, analysis, monitoring, and reporting.

Project Problem Statement and Justification

Agriculture in East Africa is characterized by women and men working in small scale, rainfed production, averaging 2 hectares per household (FAO 2006). Erratic bimodal rainfall patterns in recent years further challenge cropping results (ARB 2007). 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 (Ehui & Pender 2005). Private traders operate on a small scale with limited investment capability. Availability and use of processed products at present remains very modest. As a result of low production levels, hunger is widespread (WFP 2006) and the vast majority of the rural population lives in absolute poverty (KDA 2004).

Our recent efforts to introduce new agronomic practices and technologies demonstrate encouraging progress (Sseguya, Mazur & Masinde 2009; Butler & Mazur 2007). 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 (Sseguya 2007). The main crops grown in Kamuli district are maize, beans, sweet potatoes, cassava, bananas, rice and coffee (Sseguya & Masinde 2005). Most (90%) of participating households produce beans, but only 20% sell 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 (Ellis 2000). In combination with SL approaches, scientific knowledge, improved technologies, financial assistance, and changes in government policies can have significant positive local impacts (Helmore & Singh 2001). Participatory research methods can generate knowledge that people are able to apply for improving their individual and collective well-being (Selener 1997).

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.

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

Central Problems Limiting High Yields of Quality Beans

- Declining soil fertility and inefficient cropping systems unable to utilize available resources effectively and efficiently
- Limited accessibility and affordability of quality seeds, non-seed inputs and other yield improving technologies
- Effects of drought and other weather related factors compromise productivity and quality

- Diseases (root rot, anthracnose, angular leaf spot, common bacterial blight, viruses, rust, ascochyta blight) and insect pests (bean stem maggots, aphids, 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.

The nutritional value of beans is negatively affected by anti-nutrients -such as phytates, trypsin inhibitor, lectins, polyphenols, saponins, oligosaccharides and hemaglutinins (Kebede et al., 1995). However, treatments such as de-hulling, soaking, milling, fermentation and germination or malting and cooking enhance digestibility and nutritional value (Matella et al. 2005; Martín-Cabrejas 2006; Shimelis & Rakshit 2007; Nergiz & Gökgöz 2007; Cevdet & Gökgöz 2007).

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.).

Planned Project Activities for April 1, 2008 - September 30, 2009

Objective 1: To Improve Harvested Bean Quality and Yields.

Approaches and Methods:
*Objective 1a***:** Determine and Prioritize Key Production Constraints of Six Priority Bean Varieties

Approaches and Methods

- Conduct participatory rural appraisals (PRA) to determine current local knowledge, attitudes and practices related to planting, weeding, soil fertility/nutrient management, and mitigation/control strategies for diseases and pests in four varieties of common bean in Kamuli district, Uganda, and two common bean varieties in Nyagatare district, Rwanda
- Prioritize constraints to increased production
- Prioritize constraints to improved quality

Objective 1b. Improve Quality and Yields of Beans through Evaluation of Better Production Practices

Approaches and Methods

- Evaluate yield and quality of the beans (NABE 6 [white dry bean, small seeded] and K131 [carioca dry bean] and K132 and NABE 4 [red mottled beans] in Kamuli and Luweero districts in Uganda, and RWR 1668 and RWR 2245 in Nyagatare district in Rwanda)
- Evaluate practical management strategies to increase and stabilize seed yield and seed quality in participatory field research
- Carry out on farm demonstrations for farmers on better agronomic practices

Objective 1c: Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices

Approaches and Methods

- Promote adoption of recommended practices to increase yield of quality beans through RDE and farmer training, and facilitating access to superior varieties and priority inputs

Results, Achievements and Outputs of Research:
Objective 1a: Determine and Prioritize Key Production Constraints of Priority Bean Varieties
Characteristics of the Bean Varieties in the CRSP Project in Uganda

Geographic Coverage
K132 and NABE 4 are grown all over the country with various names given to them, except in Karamoja and part of Teso areas (both in the northeast). NABE 2 and K131 are mostly grown in the north generally including West Nile and mid-western Uganda (Masindi area) with much more heavy concentration in Apac and Lira districts. NABE 6 is grown more in the north including West Nile (northwest) and Midwestern region (Masindi/Hoima area). There is also some scattered production in Eastern, Central and Western Uganda for commercial purposes only.

Rainfall
While climate change is affecting the timing of rain onset and cessation, total annual rainfall has remained approximately the same. On average, rainfall in Uganda varies from 510 mm in parts of Karamoja to 2160 mm or more in Sese Islands (southern, in Lake Victoria). More than 1520 mm fall on Mt. Elgon (eastern), Kabale (southwestern), the highlands of Bundibugyo (western), Gulu (northern) and on the Island and shore of Lake Victoria (southern). More than 1100 mm fall along a 225-mile arc around Lake Victoria, from Tororo (eastern) to Rakai (southwest), and between Tororo (eastern) to Gulu (northern). This amount also falls in the highlands of West Nile, West Ankole (southwestern), and along the belt of high ground from Rwenzori to Bunyoro (western). The best planting period for Kamuli needs to be investigated, given recent and extended changes in rainfall patterns.

Minimum Temperature
The geographical pattern of temperature minima for the year is associated with altitude. Minimum temperature in the highlands varies from 10 to 12.5^{o} C and may occasionally be less than 5^{o} C on the mountain tops. In the lowlands, the temperature varies from 12.5-20^{o} C.

Maximum Temperature
Varies according to altitude from 22.5 (highlands) to 32.5^{o} C (lowlands) with most places in the range of 27.5 to 30^{o} C. Higher temperatures may be experienced in the Karamoja areas and other parts of northeastern Uganda.

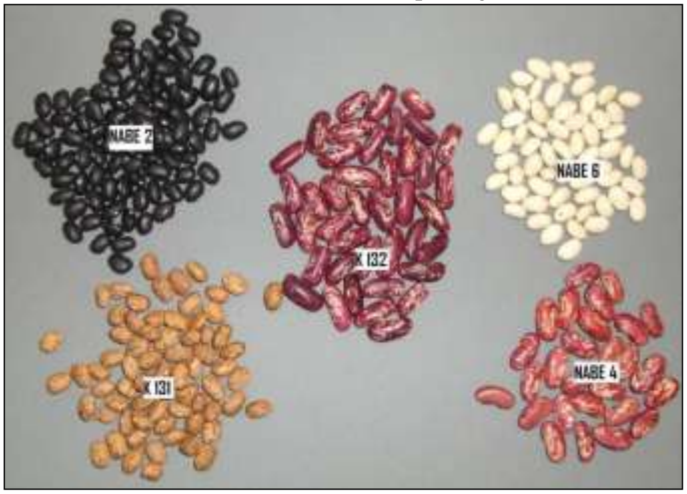
Typical Planting Dates
Planting dates have varied recently due to climate change. Generally, most farmers in Uganda plant beans in March/April (first season) and August/September (second season). There are exceptions in some places, where second season rains come early and planting is done in June (e.g., Apac, Lira, part of West Nile and part of Masindi). Early second season planting has also been recently observed in Kamuli. Actual planting takes place earlier or later than those mentioned days depending on prevailing and anticipated weather conditions.

Favorable Soil Conditions
Beans generally grow in a wide range of soils, with good performance under loam soil conditions of pH 6-7.5, although some tolerate lower pH of 5-6.

Table 1. Characteristics of Six Key Beans Varieties in Uganda

Variety [Local name]	General	Characteristics
K131 [Kazibwe]	• Altitude: 1000-1800m • Maturity: 90 days • Seed rate: 50-60 kg/ha • Expected yield: 2 – 2.5 ton/ha • Growth habit: Trailing (Type II)	• Light brown mottled • Good taste, good yield • Resistant to Bean common mosaic virus (BCMV), Bean Rust (BR) and Anthracnose. • Susceptible to root rot • Performs relatively well under extreme environments
K132 [Nambale Omuwanvu]	• Altitude: 1000-1800m • Maturity: 80 days • Seed rate: 90-100 kg/ha • Expected yield: 1.5 – 1.8 ton/ha • Growth habit: Erect (Type I)	• Large red mottled seed • Resistant to BR • Susceptible to Anthracnose and root rot • popularly grown in most parts of Uganda
NABE 2 [Obujjanjalo Obudugavu]	• Altitude: 1000-1800m • Maturity: 90 days • Seed rate: 50-60 kg/ha • Expected yield: 2-2.5 ton/ha • Growth habit: Trailing (Type II)	• Black small seeded beans • Resistant to BCMV, BR, and Anthracnose • Susceptible to root rot
NABE 4 [Nambale Omumpi / VEDCO]	• Altitude: 1000-1800m • Maturity: 80-85 days • Seed rate: 90-100 kg/ha • Expected yield: 1.5-2.0 ton/ha • Growth habit: Erect (Type I)	• Red mottled • Resistant to major bean diseases • popularly grown in most parts of Uganda • Susceptible to root rot and anthracnose
NABE 6 [Obweru]	• Altitude: 1000-1800m • Maturity: 90 days • Seed rate: 50-60 kg/ha • Expected yield: 1.5-2.5 ton/ha • Growth habit: Trailing (Type II)	• Small white seed • Resistant to BR • Susceptible to root rot and anthracnose
Farmers Seed [Kanyebwa/ Kabonge]	• Growth habit: Erect (Type I)	• Brick red medium size seed, susceptible to many disease, early maturing

Figure 1. Appearance of Five Bean Varieties Developed by NaCRRI



Local Agronomic Knowledge, Attitudes, and Practices Documented

Key informant interviews were conducted with 87 farmers in Kamuli September – October 2008, and three focus group discussions were conducted (averaging ten people in each group). Farming is the main occupation in Kamuli district, with goals of food security and income earning; livestock (chickens, goats, pigs, and cattle) are also a source of income in many households. 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 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%). The principal challenges in processing beans were lack of awareness of appropriate. technologies (34%), no machines (34%), and lack of firewood (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.

Knowledge, Attitudes and Practices Analyzed and Reported

The key informant interviews included all households that participate in the field trials. Their responses form part of the baseline data that will be used to identify changes over time in knowledge, attitudes, and practices resulting from project training and interventions.

Farmers are very enthusiastic about the bean project. They are all ready to increase acreage of production if they can be linked to markets. From the varieties introduced, farmers are particularly interested in growing K132 (large red mottled) and K131 (light brown mottled). K132 is liked because of its big and well filled beans, while K131 has high yields and is good for Mugoyo, a local delicacy containing a mixture of sweet potato and beans. However, farmers reported that when K131 is stored for long, it is very hard to cook.

Most farmers are very active in their groups. Groups in Butansi sub-county (Tibikoma, Tugezeku and Tugemere Walala) demonstrated very impressive work, doing all field activities together, and are involved in other self help projects that they work on as groups. Farmers have developed a culture of experimenting with new practices. One of the host farmers (in the Tibikoma group) picked particular interest in the trials and set an experiment comparing intercropping versus monocropping groundnuts. Her preliminary evidence suggests that the monocropping approach was more productive. The project team will continue to encourage and support farmers' experimentation with innovative methods and techniques, and explore ways of incorporating them in future research and trainings.

Farmers are very grateful to the project team for the new knowledge and equipment that they have received to date through the project, and look forward to opportunities for continuing learning and benefits to their livelihoods as the project activities continue.

Research Partners and Field Site Visited by US Team

Three ISU-based members of the project team traveled to Uganda during Y2 for meetings focused on the CRSP project and ISU's broader CSRL program operated in partnership with VEDCO and Makerere University. Project PI Mazur traveled in March 2009 with Co-PI Westgate and Dr. Eric Abbott, an experienced development communications specialist, and several other ISU faculty associated with CSRL (specializing in horticulture, agricultural education, animal science, and anthropology) to review accomplishments and challenges of the first five years of program activities in Uganda and engage in strategic planning for 2010-2014. The review 'Learning Forum' involved participants from a range of Ugandan and East African organizations whose focus is research (including the Association for Strengthening Agricultural Research in Eastern and Central Africa - ASARECA), development practice, business (including the Uganda National Farmers Federation), and a grant making foundation (Ford). The strategic planning workshop involved participants from ISU, VEDCO, and Makerere University. Prior to the review and planning meetings, Drs. Mazur and Abbott traveled to Kamuli to meet with VEDCO staff and farmers participating in the CRSP project and CSRL program. They reviewed existing communication methods and patterns, and identified strategies to enhance the effectiveness of multidirectional communication and information dissemination for innovative practices in agriculture, nutrition, and marketing.

PI Mazur returned to Uganda in August with two additional ISU colleagues - Co-PI Dr. Manju Reddy (Food Science and Human Nutrition) and Dr. Kathleen Delate, a specialist in organic horticulture and agriculture. Meetings at Makerere University, NaCRRI, and in Kamuli focused on the CRSP project but also included broader elements of the CSRL program. Key issues that emerged during that visit are the following: the importance of improving harvest and post-harvest practices to reduce contamination (e.g., dirt, fungus) that directly affect human health; understanding more deeply when and how beans are incorporated into the diet of young children – and variations that depend on the age and nutritional status of the child; documenting and publishing case studies to demonstrate the role of nutrition education and changes in diet (e.g., bean flour) in improving the nutritional status of school age children, possibly through intervention studies. During a meeting with program officers at the HarvestPlus office in Kampala, a follow up to one PI Mazur held there in June 2008, strong interest was expressed by HarvestPlus officials to collaborate with our project, especially when they secure funding for planned research on iron and zinc rich beans. A meeting with HarvestPlus is scheduled when CRSP Program Director Dr. Irv Widders travels with Mazur and a member of the TMAC, Dr. Jill Findeis, in November.

Co-PI Westgate traveled to Uganda as the new Director of CSRL to become more fully acquainted with the work of program partners in VEDCO and Makerere University, and CRSP project partner NaCRRI (Co-PI Ugen). He returned to Uganda in June with CRSP Ph.D. student Gerald Sebuwufu for meetings at NaCRRI, with VEDCO staff and bean farmers in Kamuli, to review data collection and analysis procedures associated with harvesting the first field variety and fertility trials, and for discussions regarding additional opportunities for research collaboration involving researchers and students from ISU, NaCRRI, and Makerere, and staff from VEDCO. He returned to Uganda for additional meetings in September; the team identified on-farm methods for which more detailed documentation was required for analysis, reporting, and updating the training manuals.

Dry Grain Pulse CRSP Program Director Widders visited KIST in January 2009. He met Co-PI Dr. Hilda Vasanthakaalam and administrators at KIST, traveled to the rural community research site and met the farmers and learned about their activities, needs and interests; they also visited the rural site of KIST's Centre for Innovations and Technology Transfer (CITT) which is developing or promoting a range of relevant technologies – maize hand sheller, briquette made from agricultural stalks (from beans, maize and rice), a briquette stove, community cook stove, and community wood oven. Project PI Mazur and Co-PI Nakimbugwe visited KIST in March 2009, administrators at KIST, and visited the Kigali CITT facility. We discussed project research goals and activities with four final year students at KIST who made presentations about their projects, and toured the new science building which has now been equipped with an array of new laboratory equipment.

Objective 1b: Improve Quality and Yields of Beans through Evaluation of Better Production Practices
Irrigation/Fertigation Practices Defined
Limited access to water from boreholes and lack of surface impoundments in Kamuli District precludes establishing an array of field sites to demonstrate the benefits of irrigation/fertigation practices. Discussions with rural development extensionists and VEDCO staff revealed a negative perception about using community boreholes to supply water for general agricultural use.

During a subsequent visit, Co-PI Westgate, VEDCO team leaders, and the VEDCO Executive Director agreed to establish an irrigation/fertigation demonstration site at the VEDCO office in Kamuli. This would overcome numerous logistical, safety, and operational concerns and still meet the goal of giving farmers the opportunity to observe and evaluate a simple irrigation system to make an informed choice of what could be adopted profitably in their areas of operation relative to the value of their crops. We expect that having thorough knowledge of appropriate technologies and demonstrating these will be of great value to farmers. Feedback from farmers will shape the pace and scale of our future training on this.

One irrigation/fertigation demonstration system [drip kit] has been established at the VEDCO Kamuli demonstration garden. This will operate during the long dry season of October 2009 to February 2010. A second irrigation system is under construction. Demonstrations are anticipated for the first crop season in

2010. Systems to incorporate passive water harvesting and a renewable energy source for pumping are being considered in cooperation with the ISU Chapter of Engineers Without Borders.

Irrigation System Prototype

Field Sampling Technologies and Laboratory Procedures Established

Through the efforts of VEDCO and NaCRRI, field sites for March 2009 planting in Uganda were identified. Cooperating farmer teams prepared land for bean planting. Six groups of 10-12 farmers have been involved in the field trials. These groups consist of farmers already engaged in training with VEDCO and the CRSP team project.

Each farmer group is responsible for planting, maintaining, and harvesting common beans in 5 gardens (total of 30 gardens). Three of these gardens 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. Field management is the same for all five varieties, except that optimum harvest will be determined by variety maturity. The two remaining gardens assess 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). In all 30 gardens, each variety and treatment was planted in a 5m x 5m square area in randomized design with two replications. Detailed qualitative information on the previous crop, general field conditions, management procedures, plant development, and occurrence of pests and diseases has been recorded for each site. This complements the detailed quantitative information collected and analyzed statistically.

A training manual has been prepared for this project. Participating farmers have been 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). VEDCO and NaCRRI staff are on hand to provide support for timely and accurate planting. Additional visits to each garden are conducted periodically to reinforce attention to careful field management and record keeping. VEDCO and NaCRRI staff also monitor yields, grain quality, and grain moisture at harvest.

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

The project was initiated at the same time that farmers planted beans during the 'second season' in 2008. In Kamuli, this is several months earlier than in the central region where NaCRRI and Makerere University operate their research station field trials. It is also several months earlier than other crops are planted in Kamuli (typically in September); farmers did so because they view the rainfall patterns during the second season as being too short and unreliable when planting is done later than during June 20th – July 20th. Early planting (late February to early March) during the first growing season is aimed at avoiding heavy rains later in the season. Planting within this time was not possible this year 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.

Before the first planting, farmers were trained in the general principles of research methodology, the design of the project, and expectations for data collection during the season, and harvesting. Farmers who provided land where the sites were established also were trained and supported in proper record keeping. Each field site was arranged into the required number of test plots measuring 5m x 5m each. Details of manure application, planting techniques, and farmer participation were documented. The 25 kg of manure was measured using a weighing scale and evenly applied over each 5m x 5m plot surface by hand and thoroughly mixed in the soil with a hoe prior to planting. The nutrient content of the manure was not measured.

Planting involved the Kamuli VEDCO staff, technicians from the NaCRRI station at Namulonge (Richard Sekabembe and Jane Bakabalanga) and the farmers of the respective groups. Typically, planting at each site was completed within two days. Seeds were planted in rows by hand at a spacing of about 50 cm between rows and about 10 cm within rows (approx. 200,000 pl/ha). Each variety was planted at the same time within a randomized block, replicated at each site. Plot weeding was completed two to three weeks after planting, as required.

Figure 2. Plants during Growth for Four Bean Varieties Developed/Improved by NaCRRI

In all cases, plots were harvested sequentially as soon as the seeds reached physiological maturity (maximum seed dry weight) and the plants were dry, 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. Plants were harvested early in the morning to avoid shattering of the pods during the hot afternoon. Area harvested from each plot was measured to calculate yield per harvested ground area. In plots where crop damage due to mole rats or diseases occurred, only the undamaged areas were measured and harvested. 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. In each case, harvested beans were stored at the host farmer's home for further drying and initial sorting. The host farmer was provided with a tarpaulin, gunny sacks, and cloth bags for each harvested plot.


Traditional threshing and drying


Farmers with sieves and scale


Drying beans with tarpaulins

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. The performance of NABE 6 was not good, especially in Bugulumbya sub-county. Because of this, in some trial sites there was no harvest obtained.

Seed Samples Submitted for Analysis

Seed of NABE 2, NABE 4, NABE 6, K131, and K132 common beans were supplied by NaCRRI and brought to ISU in January. Sufficient seeds (2 kg of each variety) were provided to initiate baseline chemical analyses of these seeds and to conduct controlled environment studies on the stress tolerance of these priority varieties. Seeds provided to CRSP team researches in Food Science and Human Nutrition at ISU have been analyzed for proximate content of major macro and micro nutrients. Two trials have been conducted in the greenhouse to determine optimal growing conditions and preliminary assessment of drought response during seed filling. The data are presented below. Addition field plots were established in Ames in increase the quantity of seed available for nutritional analysis.

Seed samples from all the harvested plots were prepared by VEDCO in collaboration with NaCRRI and submitted to ISU in July and September 2009. The seed samples included K131, K132, NABE 4, Kanyebwa (farmer's seed) and a few samples of NABE 6. The samples submitted were between 100 and

200 grams per harvested plot. Data collected included the yield per plot, 100 seed weight, pods per plant, and seeds per pod. The number of pods was determined from 20 randomly selected plants per plot while the number of seeds per pod was determined from 20 randomly selected pods, one from each of the earlier selected plants. From each clean seed sample, 100 seeds were counted at random to determine the 100 seed weight.

Yields Quantified and Analyzed

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 (Table 2). 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. Those planted late were exposed to drought during flowering and later to diseases from heavy rains. In some instance, low results were due to mole rats that reduced the plant population. Generally, the low yields could be attributed to the poor soil fertility across the trial sites.

Table 2. Analysis of Variance for Yield Parameters Measured on the Five Bean Varieties

Source	DF	Mean Square Value				
		Total Yield (kg/ha)	Recoverable Yield (kg/ha)	100 Seed Wt (g)	Pods/Plant	Seeds/Pod
Location(L)	28	475563***	358051***	87.6***	10.2***	0.6***
Variety (V)	4	153735**	178176***	4862***	70.8***	30.7***
L x V	68	54136**	45113***	30.2*	4**	0.3***

* significant at P = 0.05-0.1, ** significant at P = 0.01-0.05 *** significant at P < 0.01

Generally, K131 had the highest yields, while NABE 6 had the lowest yields (Table 3). While NABE 4 had high total yields, its recoverable yield was lower than the other varieties because it had more poorly filled, discolored and/or damaged seeds than the other varieties. K132 and NABE 4 have big seeds and therefore had a higher seed weight, followed by Kanyebwa, while K131 and NABE 6 with small seeds expectedly had lower seed weight (data not shown). On the other hand, K131 and NABE 6 had significantly higher numbers of pods per plant and number of seeds per pod compared to the other three varieties.

Correlation analysis shows that the total and recoverable yields, number of pods per plant and number of seeds per pod were positively and significantly correlated (data not shown). However, 100 seed weight was negatively correlated to the number of pods per plant and seeds per pod, indicating that an increase in these parameters is associated with a reduction in seed size.

Table 3. Variety Differences in Total Yield, Recoverable Yield, and 100 Seed Weight

Variety	Total Yield (kg/ha)		Variety	Recoverable Yield (kg/ha)		Variety	100 Seed Wt (g)
K131	532A		K131	429A		K132	41.6A
NABE4	505A		K132	338B		NABE4	36.6B
K132	504A		Kanyebwa	338B		Kanyebwa	30.1C
Kanyebwa	452AB		NABE4	316B		K131	16.3D
NABE6	404B		NABE6	272B		NABE6	16.2D

Means with the same letter in each column are not significantly different at p<0.1

This preliminary analysis indicates yields for the tested varieties were typical of bean yields in Uganda. The farmers' popular variety Kanyebwa yielded numerically less, but the difference among varieties was obscured by variation across locations. Variety K131 performed well in terms of total yield and recoverable yield (clean/sorted seeds). Based on the area where K131 was developed and weather conditions encountered during the first season, we anticipate that K131 will perform very well under properly managed conditions in Kamuli and in other regions of Uganda (e.g., West Nile, Midwestern Uganda, and northern districts of Apac and Lira). Conversely, NABE 6 would not perform as well under similar conditions.

The large genotype by environment interaction is a concern under unfertilized conditions. The range in yields was greatly reduced by application of farm yard manure. This indicates is clearly that low soil fertility is a major constraint to bean production in the project area. Farmers rarely add manure in bean fields, so alternatives such as rhizobia inoculation and green manure need to be introduced. Farmers have seen that organic manure improves yield, but are limited by its availability.

Crop and Soil Management Strategies Evaluated

Current approaches and strategies for crop and soil management have been documented in the key informant interviews and focus group discussions conducted with farmer groups.

Some of the common practices for soil fertility and crop management include:

- Use of farm yard manure and kitchen refuse
- Use of green manure and compost
- Intercropping legumes and other crops for risk avoidance, including alley cropping
- Ridging, especially near swampy places
- Mulching, especially when grown together with bananas
- Pesticides (locally made combination of extracts from red pepper, neem tree leave, *Moringa oleifera* and garlic). Dilution for this extract was at a rate of 1 litre of water to 0.5 litre of the extract.

Soil Analysis

Soil samples were collected from each field site prior to planting. Two samples were collected from each site, one from replicates 1 and 2, for a total of 60 samples. Sampling depth was 0-20 cm (typical plough depth using the hand hoe). From each replicate at each site, 5 random samples were collected and mixed together to form one composite sample. The same was carried out for replicate 2. From these composite samples, 250g were used for analysis. The 60 samples were analyzed using routine analytical methods for soil texture (% sand, clay and silt), soil pH (soil acidity and alkalinity), soil organic matter content, total N content, extractable P, and exchangeable K, Ca and Mg. Unfortunately, separate soil samples were not collected from fertilized and unfertilized plots in the fertility trials. This oversight will be corrected in the second set of demonstration sites in this study. Based on the soil nutrient status, fertility trials were set using locally available materials.

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%. The total nitrogen content in the soils was generally low and mostly below the critical value of 0.2%. Extractable (available) phosphorous content in almost all the soils was below detectable range (trace) of 5.0 ppm. Exchangeable Potassium (K), another important plant nutrient was generally above the critical value of 150ppm in most of the locations. Exchangeable Calcium (Ca) and Exchangeable Magnesium (Mg) content in the all the soils was good and above the critical level.

Correlation analysis between soil nutrient levels and recoverable yields revealed positive and significant responses by K131 to calcium and potassium; by K132 to nitrogen; and by Kanyebwa and NABE 6 to potassium (data not shown). The positive response of K131 was evident through its better yields across locations. Considering all varieties, there was a negative correlation between soil organic matter and recoverable yield ($r = -0.28$, $P < 0.1$). This negative correlation was particularly strong for NABE 6 variety ($r = -0.56$, $P < 0.01$). Generally, the low yields reflected poor soil fertility across the trial sites.

Effect of farm yard manure on the yield of the five varieties

The response to fertilizer was tested and analyzed for two groups. The first group compared K131, NABE 4 to the local variety Kanyebwa while the second group compared K132, NABE 6 to Kanyebwa.

Group 1 - K131, Kanyebwa, and NABE 4

Farm yard manure (Table 4) 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, reduced by 117 (35%) Kg/Ha. No significant differences were observed for the other yield parameters. Analysis of Variance results show that there were significant location, location by fertility interaction, and variety by fertility interaction for total yield (data not shown). 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. The number of pods per plant and seeds per pod had a similar trend with significant effects due to location, variety and location by fertility interaction.

Variety	Fertility	Total Yield (kg/ha)	Recoverable Yield (kg/ha)	100 Seed wt (g)	Pods/ Plant	Seeds/ Pod
K131	Control	536B	432B	16.2A	9.5A	5.3A
K131	FYM	704A	550A	16.2A	10.2A	5.1A
Kanyebwa	Control	478B	349B	32.1A	5.6A	3.5A
Kanyebwa	FYM	608A	447A	30.2A	6.0A	3.6A
NABE4	Control	497A	334A	35.3A	5.0A	3.7A
NABE4	FYM	468A	217B	37.2A	5.9A	3.6A

Table 4. Effect of Farm Yard Manure on Total Yield of K131, Kanyebwa, & NABE 4 Beans
Comparisons are between the control and the farm yard manure (FYM) within with each variety. Means with the same letter are not significantly different.

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. Similar response to fertilizer was observed with plants grown in the green house. The appropriate nutrient balance to get greater seed yields for NABE 4 needs to be investigated.

Group 2 - K132, Kanyebwa and NABE 6

Application of farm yard manure increased the yield parameters, though not significantly in some instances (Table 5). Farm yard manure increased recoverable yield by 112.1 (39%), 311 (132%), and 119.5 (57%) kg/Ha for K132, Kanyebwa and NABE 6, respectively. The spike in Kanyebwa yields could be due to significant increases in seeds weight and pods per plant. The Analysis of Variance for K132, Kanyebwa and NABE 6 showed that four factors had significant effects on the total and the recoverable yield: location, location by variety interaction, fertility, and variety by fertility interaction (data not shown). The location, variety, and fertility effects were also significant for the 100 seed weight, pods per plant, and seeds per pod. Location by variety interaction also significantly affected the number of seeds per pod.

Table 5. Effect of Farm Yard Manure on Total Yield of K132, Kanyebwa & NABE 6 Bean Varieties

Variety	Fertility	Total Yield (kg/ha)	Recoverable Yield (kg/ha)	100 Seed wt (g)	Pods/ Plant	Seeds/ Pod
K132	Control	413B	284B	41.0A	4.9A	3.0A
K132	FYM	574A	396A	42.6A	5.9A	3.1A
Kanyebwa	Control	316B	236B	28.2B	5.2B	3.4A
Kanyebwa	FYM	698A	548A	30.5A	6.5A	3.6A
NABE6	Control	354A	208B	15.2A	7.8A	5.0A
NABE6	FYM	470A	328A	16.5A	9.5A	5.2A

All three varieties (K132, NABE 6 and Kanyebwa) responded positively to the addition of farm yard manure. The total and recoverable yields increased significantly due to numeric increases in seed weight and pods per plant. Since seed number and size responded to fertilizers, this shows that adequate nutrients are needed for establishing potential yield, completing seed fill, and increasing the quantity of marketable seeds.

In general, realized yields were low compared to potential yields. Our yields were at best 50% of potential yields (section 1.11). Greater emphasis on increasing soil nutrient status is needed. Our soil analysis found deficiencies for all major nutrients, especially phosphorous.

Harvested Bean Quality Quantified

Analysis is well advanced using beans obtained from participating project farmers in Uganda and Rwanda; these were produced under pre-existing conditions during the second season in 2008. Among the characteristics measured and analyzed are the following: length (Vernier calliper method), breadth (Vernier calliper method), thickness (screw gauge method), specific gravity, bulk density, soaking time, cooking time, 100 grain weight, grains per 100 gram have been quantified for the selected varieties taken for the study. These activities are being done following harvest in Uganda in July 2009 of the first season crop produced under project specifications.

Moisture content of the clean seed samples was estimated using a Dickey John Moisture Meter. This meter was previously calibrated for common beans using calibration coefficients provided by the manufacturer. These moisture content values were used to adjust the total harvested yield and clean seed yield values to 13% moisture. The seed weight (yield) was standardized to 13% moisture content in each case. General Linear Model and Correlations for SAS statistical package was used for data analysis (SAS Institute 1999). Seed composition analysis has not been finalized for samples collected from Season 1 field trials.

Preliminary Assessment of Variety Differences in Seed Composition

This analysis included seeds from five varieties grown in the greenhouse at ISU and from plants grown in the field in Uganda. Greenhouse plants were fertilized with a nutrient solution once a week until seed filling to ensure that there was no deficiency. Seeds from three plants per variety were sampled for analysis. Seeds supplied from Uganda by NaCRRI were grown on station at Namulonge. Two samples were taken from each of the variety seed batches supplied for analysis. All samples were oven dried for 2 days at 80^o C to constant weight and ground. Total carbon (TC) and Total nitrogen (TN), were determined by combustion (TruSpec CN, LECO). The inductively coupled plasma emission spectrometry (ICP) methodology was used to determine the seed Phosphorous(P), Potassium (K), Sodium (Na), Magnesium (Mg), Calcium (Ca), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn) and aluminum (Al). The data from the two seed sources were analyzed separately with general linear model and Correlations from SAS statistical package (SAS Institute 1999).

Variety Differences in the Seed Composition for Plants Grown in the Greenhouse

For seeds harvested from plants grown in the greenhouse, there were differences in concentrations for total carbon, phosphorous, potassium, sodium, magnesium, calcium, manganese, and zinc (data not shown). For macronutrients, K132 had higher concentrations of P, K, and Na (Table 6). The Na concentration for K132 was three times more than that for NABE 4. NABE 6 had a significantly higher Mg concentration and relatively higher Ca concentration than the other varieties. For micronutrients, NABE 4 had the lowest Mn concentration, while for Zn NABE 4 had the highest seed concentration. There were no differences in Fe concentration. Correlation analysis revealed a positive and significant association between P and total nitrogen. There were no other significant correlations among the seed nutrients.

Table 6. Variety Differences in Seed Composition of Bean Varieties Grown in the Greenhouse

Variety	TC(%)	TN (%)	P (mg/kg)	K (mg/kg)	Na (mg/kg)	Mg (mg/kg)
K131	41.2A	3.4A	4295C	21933B	130B	1965B
NABE2	41.0AB	3.4A	4956BC	20573B	142B	1963B
NABE4	41.0B	3.4A	5775AB	21953B	87B	1535C
NABE6	40.5C	2.9A	4779C	22907B	106B	2247A
K132	40.5C	3.4A	5851A	28840A	324A	1773B

Variety	Ca (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Al (mg/kg)
K131	925B	25A	123A	19A	32C	46A
NABE2	1036AB	29A	131A	24A	36BC	41A
NABE4	538B	20B	129A	17A	42A	38A
NABE6	1473A	27A	129A	16A	37B	46A
K132	1030AB	27A	131A	22A	32C	41A

Means with the same letters down the column are not significantly different.

Variety Differences in the Seed Composition for Plants Grown in the Field in Uganda

Analysis of seeds grown in the field in Uganda shows that variety influenced total nitrogen, phosphorous, potassium, magnesium, calcium, manganese, copper, zinc and aluminum concentrations (Table 7). NABE 6, NABE 4 and K131 had a significantly higher total nitrogen, P and K concentrations, respectively, than the other varieties (Table 4). For Mg, NABE 6 and K131 had significantly higher concentrations than the other three varieties while for Ca concentration, NABE 6 and NABE 2 were significantly higher than the other three varieties, with NABE 4 having the lowest Ca concentration. Micronutrient analysis shows that there were no differences in the Iron concentration. For copper, K131 had a significantly higher concentration than the others, while NABE 4 and NABE 6 had significantly higher concentrations for Zn. K131 and NABE 2 had the highest and lowest Al concentration, respectively. Correlation analysis shows significant associations between seed total nitrogen and Zn, and between seed P and seed Fe concentrations.

Table 7. Varieties Differences in Seed Composition of Common Bean Varieties in Uganda

Variety	TC(%)	TN (%)	P (mg/kg)	K (mg/kg)	Na (mg/kg)	Mg (mg/kg)
NABE2	41.4A	4.2C	3088D	27240BC	450.5A	1875B
K131	41.3A	4.3B	3202D	33390A	432.5A	1985A
NABE4	40.9A	4.2BC	4859A	26790C	475A	1523C
NABE6	40.8A	4.6A	4244B	28080BC	399A	2070A
K132	40.6A	3.7D	3552C	29500B	198A	1515C

Variety	Ca (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Al (mg/kg)
NABE2	1774A	27B	114A	24BC	28B	53C
K131	1595B	26B	119A	27A	30AB	88A
NABE4	646D	22C	140A	22D	35A	63BC
NABE6	1893A	28A	127A	25B	34A	74AB
K132	1366C	26B	119A	23CD	25B	69B

Means with the same letters down the column are not significantly different.

Comparison of seed composition of seeds grown in the greenhouse to those grown in the field at NaCRRI in Uganda, there were no differences in percent total carbon, but the % N (protein), was dramatically lower in the greenhouse. It is not known whether this reflects an increase in N, starch, oil or other soluble sugars. Phosphorous and zinc increased in the greenhouse, showing that they can accumulate more of these nutrients in response to adequate nutrient supply. Interestingly, genetic variation in seed calcium concentration was far greater than environmental differences. NABE 6 was particularly effective in accumulating Ca in the seed. This genetic variation in seed components could have implications for adjusting nutritional their value as considered under objective 2.

While the greenhouse experiments are a relatively small proportion of the agronomic research being conducted in this project, they are essential for basic characterization of the commercial varieties from Uganda. We anticipate that the differences in physiological responses to stress will partly explain performance of the varieties in the field. Greenhouse characterization will be followed by field experiments, where appropriate. As we continue to learn more from the on-farm field trials and analysis of the bean seeds, our research will incorporate field experiments to improve farmers' management practices. Those in process or being considered are the following: (1) assessment of the effects of farm yard manure on the yield and seed composition of common beans (ongoing); (2) assessing the use of biological nitrogen fixation to enhance soil fertility, yield and improve seed nutrient content (recently funded research led by Co-PI Westgate); and (3) assessing the use of phosphorous seed coating on the establishment, yield and seed composition of common bean (since soil analysis results showed that phosphorous was the most limiting nutrient). These could be less costly alternatives at farm level compared to full fertilizer applications in the field.

To summarize the results of the analyses of data presented in Tables 6-8, the ranking of averages across growing conditions shows that overall NABE4 had a higher nutrient concentration, ranking first for Fe and Zn, and second for % TN (Table 8). NABE 6 follows overall, with the highest calcium concentration, while it ranks second for Fe and Zn. However, NABE 4 had the lowest calcium concentration.

Table 8. Ranking of Varieties according to Average Composition of TN, Ca, Fe, Zn

Variety	Avg. % TN	TN Rank	Avg. Ca (mg/kg)	Ca Rank	Avg. Fe (mg/kg)	Fe Rank	Avg. Zn (mg/kg)	Zn Rank
K131	3.85	1	1260	3	121	5	31	4
K132	3.55	5	1198	4	125	3	28	5
NABE2	3.78	3	1405	2	122	4	32	3
NABE4	3.79	2	592	5	135	1	39	1
NABE6	3.75	4	1683	1	128	2	35	2

Harvest and Storage Techniques Impacts Documented

Analysis was initially conducted using beans obtained from participating project farmers in Uganda and Rwanda; these were produced under pre-existing conditions during the second season in 2008.

Harvested beans were in each case 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. Quality characteristics are depicted in Table 9.

Table 9. Quality of Bean Collected from Farmers Compared to the UEPB (2005)[a] Standards

Parameter	Quality Standard	Quality Results*
Germination percentage	80% minimum	95% minimum
Moisture content	12-15% maximum	14-16% maximum
Damaged seeds	1%	2.3%
Diseased seeds	1%	3.1%
Bean weevils	0	2
Faded (discolored) seed	5%	2%
Foreign matter	1%	2.46%
Other varieties	2%	2.13%
Non-bean varieties	1%	0.87%

**Quality results on samples collected from farmers before they were stored in the laboratory*
[a] From: Uganda Export Promotion Board (UEPB) Product profile on beans No. 12, 2005

Figure 3. Storage Containers Commonly Used by Bean Farmers in Laboratory Experiments


Clay pots


Sisal sacks


Polypropylene sacks


Plastic Jerri cans


Beans on Tarpaulin Sheet


Beans with Common Defects*

(*insect damage, broken/split beans, mixed varieties, foreign material)

If periodically re-sunned (once in two weeks), bean quality – in terms of avoiding insect damage (Table 10) and insect infestation (Table 11) - 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 declines irrespective of the storage facility but more so in less aerated facilities like pots and plastic Jerri cans. Viability of beans is not affected by re-sunning even when moisture content drops to 7% (Table 12).

Table 10. Average Percent Insect Damaged for Re-Sunned and Not Re-Sunned Beans, by Storage Container Type After 4 Months

Storage Condition	Re-Sunning Biweekly % Damaged	No Re-Sunning (Control) % Damaged
Sisal bag	0.19 ± 0.001	5.69 ± 0.49
Polypropylene bag	0.21 ± 0.011	6.30 ± 0.21
Plastic Jerri can	0.23 ± 0.001	7.86 ± 0.32
Pot	0.26 ± 0.014	8.94 ± 0.26

Table 11. Live Insect Infestation in Dry Beans, Re-Sunned and Not Re-Sunned, by Storage Container Type After 4 Months

Storage Condition	Re-Sunning Bi-Weekly Infestation Level	No Re-Sunning (Control) Infestation Level
Sisal bag	C	H
Polypropylene bag	C	H
Plastic Jerri can	C	VH
Pot	F	VH

Key: C – None (0 insects); F – Few (1-3 insects); M – Medium (4-6 insects); H – Heavy (6-10 insects); VH – Very heavy (over 10 insects).

Table 12. Average Germination Percentage of Beans, Re-Sunned and Not Re-Sunned, by Storage Container Type After 4 Months (%)

Storage condition	Re-Sunning Bi-Weekly[e] Germination %	No Re-Sunning (Control)[c] Germination %
Plastic Jerri can	98.5 ± 0.35	98.0 ± 0.00
Polypropylene	98.0 ± 0.71	99.0 ± 0.35
Sisal sack	98.5 ± 0.35	97.5 ± 1.06
Pot	98.5 ± 1.06	99.0 ± 1.41

[e-] Assessment was done on each sample under experiment and expressed as a percentage
[c-] Assessment was done on each sample under control and expressed as a percentage

In Rwanda, analysis of the influence of farmers' storage practices on the survival, growth and multiplication of the bean weevil is in progress in the lab. Two additional research projects are also underway: (a) modified storage atmosphere and (b) identification of insect pests obtained from farmers and culturing one to determine its impact on stored beans. Initially, an entomologist in the Biology Department at KIST committed to this research. Unfortunately, due to lack of appropriate equipment, an entomologist from KARI, Kenya (Dr. Margaret Mulla) was identified and contacted through Co-PI Vasanthakaalam's efforts to network with African women scientists. The insect has been sent to Dr. Mulla for identification.

Objective 1c: Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices

Extension Training Manuals Developed

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. Sections on value addition, utilization, and marketing will be refined before the onset of the first growing season in 2010.

Farmers Trained in Research Methods

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).

Farmers Mobilized for Training

For dissemination of findings, farmers in six groups in Kamuli were mobilized to be trained in proper post-harvest handling in June and September 2009 based on the research findings to date. A total of 70 farmers were trained.


NaCRRI trainer


VEDCO trainer


VEDCO trainer


Farmer trainer

Research Results Incorporated in Training

The following practices are being recommended and supported:

- 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. (While the project experienced a delay in the initiation of the field-based agronomic experiments, work on the activities involved in this objective not only proceeded according to plan but additional new activities were completed on post-harvest handling and are in progress for product development at Makerere University by the B.S. and M.S. students, respectively).

Approaches and Methods:
Objective 2a: Establish the Key Causes of Post-Harvest Losses of Beans

Approaches and Methods

- Conduct participatory rural appraisals of current knowledge, attitudes and practices (KAPs) related to pre- and post-harvest handling
- Establish the basis and magnitude of post-harvest losses associated with different stages of post-harvest handling and storage (harvesting times, threshing method, drying, storage and packaging)
- Correlate knowledge, attitudes and practices with post-harvest losses, based on both the primary information obtained during the survey and the results of laboratory analyses

Objective 2b: Evaluate Impacts of Improved Post-Harvest Practices on Post-Harvest Losses in Study Sites

Approaches and Methods

- Promote adoption of recommended pre- and post-harvest handling practices that address the identified major causes to minimize post-harvest yield and quality losses
- Assess the effect of the above practices on post-harvest losses by comparing between two groups of bean farmers: one group using the recommended practices and the other group not

Objective 2c: Develop Protocols for Bean Products with Enhanced Nutritional and Organoleptic Properties

Objective 2c-1: Determine Digestibility and Utilization, Amino Acid Quality & Iron Bio-Availability

Approaches and Methods

- Determine nutritional and physico-chemical properties of bean varieties, and influences of agronomic and post-harvest handling practices on those properties
- Investigate the effect of pre-treatment of beans (malting, pre-soaking, roasting) on nutritional value of products.

Objective 2c-2: Develop Nutrient-Dense Bean Flour & Value-Added Recipes Utilizing Developed Bean Flour

Approaches and Methods

- Develop a semi-processed bean flour using the response surface methodology using preferred bean varieties from Uganda and/or Rwanda
- Develop recipes for nutritious, value-added products, using the developed bean flour
- Determine the acceptability and shelf-life of the developed products
- Promote the recipes for uptake in communities
- Demonstrate flour preparation for participating farmers to take it up as an enterprise

Results, Achievements and Outputs of Research:

Pre-Intervention Post-Harvest Losses Identified and Prioritized

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. Physical determinants of bean seed quality assessed were moisture content, presence, levels and types of: foreign matter, insect damaged grains, live insects, diseased grains, discolored grains, broken/split grains and, contamination with non-bean grains and shriveled grains.

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 (Table 12).

Farmers in Kamuli were found to generally have sufficient knowledge on good harvesting and post-harvest practices, though they left experienced notable avoidable losses. All farmers harvested their beans at the recommended time after planting (2-3 months), at the recommended time of the day (before 10 am), and dried the crop immediately after harvest. Post-harvest practices with potential to promote bean quality under storage were also reported - proper packaging, re-sunning, keeping the stored seeds off the ground, etc. However, all the farmers interviewed sun dried their grain on bare ground. This is a risk factor for loss due to contamination, spillage, insect attack, rodent attack and various vagaries of nature. A majority of the farmers (69%) stored their beans in their houses where most of them (54%) packaged them in polypropylene bags. Many (69%) of the farmers packed their storage containers off the ground on pallets, stones or logs, and 85% placed them in an upright position, not stacked on top of each other. 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.

Re-sunning was shown to reduce moisture build up and maintain quality of bean seeds during storage. Without re-sunning, moisture build up was highest in grains stored in pots, followed by those in plastic Jerri cans, which was followed by those in polypropylene bags and was least in those stored in sisal bags. However, with re-sunning, a reduction in moisture content was recorded across storage conditions. Moisture loss was highest in samples stored in plastic Jerri cans, which was not significantly different from those kept in pots. These were followed by samples kept in polypropylene bags which were not significantly different from those that were kept in sisal bags.

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 (Table 13).

Table 13. Insect Damage in Samples Stored by Farmers and those Stored in the Lab (%)

Storage Condition	Farmers' Samples Average % Damaged	Lab Samples Average % Damaged	
		Control	Experiment
Sisal sack	2.7	5.2	0.188
Polypropylene bag	3.12	6.0	0.206
Plastic Jerri can	4.7	7.1	0.221
Pot	5.2	8.1	0.255

Without re-sunning, insect infestation was highest in samples kept in pots (8.9%) and lowest in samples kept in sisal sacks (5.7%). In re-sunned beans, insect infestation was minimal in all samples after four months of storage (Table 14).

Table 14. Insect Infestation in Samples Stored by Farmers and those Stored in the Lab

Storage Condition	Farmers' Samples Infestation Level	Lab Samples Infestation Level	
		Control	Experiment
Sisal sack	F	M	C
Polypropylene bag	F	M	C
Plastic Jerri can	M	H	C
Pot	M	H	F

Key: C – No infestation (0 insects); F – Few infestation (1-3 insects); M – Medium infestation (4-6 insects); H – Heavy infestation (6-10 insects); VH – Very heavy infestation (over 10 insects).

Germination percentage for all samples under all storage conditions both re-sunned (experimental) and non-re-sunned (control) bean samples was high (over 96%) after 3 months of storage (Table 15).

Table 15. Germination of Seed Samples Stored by Farmers and those Stored in the Lab (%)

Storage Condition	Farmers' Samples Average % Damaged	Lab Samples Average % Damaged	
		Control	Experiment
Sisal sack	98	98.0	97.5
Polypropylene bag	97	98.5	98.0
Plastic Jerri can	98	99.0	98.5
Pot	96	97.5	98.0

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).

Constraints to proper harvest practices are: inadequate finances to invest in bean production and certain knowledge on proper post-harvest practices. All the farmers interviewed did not access credit facilities for bean production, thus no pesticides were used to control field pests. A few farmers, however, did utilize locally made plant extracts for pest control. Additionally, socioeconomic factors such as labor constraints and division of labor in the household seemed to play a part.

In Rwanda, we have identified sources of post-harvest losses and documented their magnitude. At present, we are continuing our promising research in quantifying the impact of alterative storage methods and technologies on reducing bean seed/grain losses. Analysis of the influence of storage practices on the survival, growth and multiplication of the bean weevil is in progress in the lab. The experiment is designed to address the following objectives: (1) create an integrated biological control strategy to limit further losses due to bruchid bean weevil during storage of common beans, (2) determine suitable options for pest control in stored beans, and improve storage structures used by small scale farmers, and (3) find systems that are suitable and acceptable to specific requirements of small scale farmers. Temperatures and relative humidity are recorded daily. Preliminary analysis of moisture content, bulk density and specific gravity were accomplished. The bean samples were placed under controlled temperatures. The number of eggs laid, number of alive and dead insects, number of holes on the grains and number of live insects and number of dead insects.

In addition, we are considering use of dried marigold plant parts for insect control in the next research phase. These plants are found in farmers' gardens. Interactions with Dr. Margaret Mulla (KARI, Kenya) indicated this as an effective for insect repellant. Thus, in Rwanda we are not yet at the stage of recommending and promoting post-harvest technologies and management practices in partnership with KIST's Center for Innovations and Technology Transfer (CITT). We are planning to carry out these activities during the coming year.

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).

Improved technologies and practices are currently being promoted by farmers who participate in the field trials (specify practices). The potential exists, given additional improved technological resources, to scale up these innovations with the much larger number of farmers being assisted by VEDCO in Kamuli district (2,100 beginning in 2010, up from 800 now) and in eight other districts in Uganda (22,500+ households), as well as through NaCCRI's network of bean producers - (Explanations for items marked 'No').

Innovation Adoption Documented

Despite the fact that is was only possible to initiate our first field trial in Uganda during season 1 (Apr.-Jul.) in 2009 (project start up was too late for season 2 planting in 2008), our team has identified sources of post-harvest losses, quantified their impacts, and promoted loss-reducing innovations; we are currently documenting the scale and results of adopting new technologies and management practices.

Loss Reductions Documented and Analyzed

As a result of the trainings in post-harvest training and farmers practicing the recommended proper practices, all trained farmers reported they had begun realizing reductions in all post-harvest losses of beans that they previously encountered. Assisting farmers by providing tarpaulins on which to dry their beans contributed much to post-harvest loss reduction.

Nutritional/Physico-Chemical Analysis Initiated

The protein, mineral, bean ferritin content, mineral (zinc and iron) bioavailability and antinutritional factor content (phytic acid and total polyphenol) were determined for the five bean varieties supplied by NaCCRI, Kampala Uganda. This lot of beans will act as baseline/reference to which the effect of agronomic practices (in field and greenhouse) will be compared. The crop harvested in the most recent harvest by the farmers in Kamuli, Uganda, as well as samples from abiotic stress studies grown under controlled greenhouse conditions, have been received for chemical and nutritional analysis (analysis ongoing).

Preliminary nutritional and 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. Iron content ranged from 128.5-154.5 µg/g; zinc ranged 27.1-38.7 µg/g, and calcium ranged from 711.9-2160 µg/g. Mineral contents did not show a marked association with bean seed coat color. The darkest varieties NABE 2 (black) and K132 (red mottled) showed least mineral content.

Since polyphenols and phytic acid are mainly responsible for the anti-nutritional effect in beans, algorithms were used for predicting iron and zinc bioavailability based on these factors. Iron bioavailability ranged from 4.3-6.8 µg/g and zinc bioavailability from 9-11.34 µg/g. The predicted bioavailabilities were highest in K131 and lowest in NABE 2. Bioavailability of these elements followed the same trend as polyphenols with bean color. It has been shown that plant ferritin, an iron storage protein, has a high affinity for iron, binding up to 4500 iron ions per molecule and that the associated iron has been shown to be well absorbed. Since beans have considerable amounts of this storage protein, it is important to identify the beans not only for high iron content but also for high ferritin to improve iron bioavailability. Bean ferritin content ranged from 5.14-14.35 µg/g, and was highest in K131 and lowest in K132. The correlation between ferritin and iron was not significant but interestingly significant between ferritin and zinc (R^2=0.64, p=0.04). Although our study didn’t show a significant predicted correlation between iron bioavailability and ferritin content, the K131 beans that showed highest ferritin also showed highest bioavailability. Since bioavailability algorithms are developed for complex meals and not validated for individual components, we will use Caco-2 cell culture model in the future to directly assess iron bioavailability and relate it to the chemical composition of the beans.

In Rwanda, laboratory procedures being used are:

- Sorting and grading - manually sorting and by using standard sieves to grade, with assistance from Rwanda Bureau of Standards
- Proximate analysis – carbohydrates, quantitative and qualitative analysis; proteins - Kjeldahl's method; fat - Soxlet method; moisture - oven method; ash - muffle furnace method (AOAC Method of Analysis, 1995)
- Minerals - flame photometer at KIST, awaiting standards to extrapolate the results for the estimation of iron and calcium
- Determination of carbohydrates, proteins, fats, ash, total sugars and reducing sugar analysis were accomplished at KIST. Results of selected amino acids by amino acid analyzer is anticipated anytime from the University of Pretoria.

Analyzing Benefits for Vulnerable People Initiated

During the key informant interviews and focus group discussions, we learned that improved methods of cultivation, harvesting, storage, and processing of beans can help address very important dietary and nutrition needs among vulnerable people (young children, mothers, those affected by HIV/AIDS, etc.) that are the target population of the community nutrition and health workers (CNHWs) who have been trained and supported since 2005 through ISU's sustainable rural livelihoods program in Kamuli district which operates in partnership with VEDCO and Makerere University. Such improvements can also help households earn more income through increased production and local value-added processing of beans.

Best Processing Techniques Determined

At Makerere University, the effect of processing on chemical composition and nutritional quality of beans was carried out on one reference variety (K131). K131 was chosen for value addition because in spite of its high yield and high nutritional quality, it has very low acceptability due to associated long cooking times (its hard seed coat limits water absorption), poor sensory attributes, and small size. It is envisaged that processing into high value alternative products will increase its utilization, and thus foster food security as well as boost income for farmers.

Nutrient dense bean, quick cooking bean flour is in the final stages of being developed, to encourage bean consumption by providing the beans in an attractive, convenient form. The following activities have been done:

Methodologies

Determination of the Influence of Different Processing Method Combinations

Processing method combinations that maximize the nutritional characteristics of the bean flours as well as enhancing acceptability were evaluated, including:

Soaking → sprouting → de-hulling → dry roasting → grinding

Soaking → sprouting → de-hulling → steaming → drying → grinding

Beans were soaked and their water uptake determined at 6 hour intervals. Maximum water absorption was after 12 hours, which is therefore considered optimal. The beans soaked for 12 hours were then sprouted and the extent of sprouting determined at intervals. The highest percentage of sprouting, without progressing into germination, was found to be 36 hours. Soaked, sprouted beans were steamed for 10, 15, 20 and 25 minutes under pressure (using a pressure cooker) and the optimal steaming time found to be 15 minutes. Soaked, sprouted beans were roasted for 5, 10, 15, and 20 minutes at 170^{o} C and 15 minutes found to be optimum.

While some of the processing methods have been previously investigated individually, the combination studies are novel. Optimal processing conditions were determined. Moisture content was determined according to the AOAC method (1998). Crude protein was analyzed using the AACC (1983) method; crude carbohydrate was determined by methods described by Clegg (1956); and crude fiber was analyzed according to AOAC (1995). Protein digestibility was determined according to methods proposed by Axtell et al. (1981) and modified by Mertz et al. (1984) and starch digestibility according to Negi et al. (2001). Tannins were determined according to Price et al. (1978), phytates according to AOAC official method 986.11 (1988), and trypsin according to the method by Kakade et al. (1974), Bhagya et al. (2006), and Magdi (2007). Bean ferritin content has been determined by protocols developed by Lukac et al. (2009) and zinc/iron bioavailability are being studied using in vitro Caco-2 cell culture models.

Effect of Different Processing Methods on the Nutrient Composition of K131 Beans

Soaking, sprouting, steaming and roasting are the four processing techniques that have been optimized to enhance the nutritional value of the beans (K131) as well as reducing their cooking time. All analyses were done in triplicate.

Methodology

Moisture content was determined according to the AOAC method (1998). Crude protein was analyzed according to AACC (1983); crude carbohydrate was be determined according to Clegg (1956); and crude fiber according to AOAC (1995). Protein digestibility will be determined according to methods proposed by Axtell et al. (1981) and modified by Mertz et al. (1984) and starch digestibility according to Negi et al. (2001).

Crude Carbohydrate

The percentage of available carbohydrate varied with different individual processing methods and various combinations of them. Following soaking, the available carbohydrate was reduced by 14.74%. In a similar study, Zia-ur et al. (2001) showed that the total available carbohydrate component in kidney beans decreased to varying degrees as a result of soaking. The decrease could be explained by a dilution effect as a result of water intake during soaking (Table 16). De-hulling the soaked beans increased available carbohydrates by 25.03%. The apparent increase is due to removal of the seed coat resulting in an increase of the proportion of carbohydrate to the remaining total. The total available carbohydrates of soaked-sprouted-dehulled increased by 11.19% compared to unprocessed beans. These carbohydrate changes as possibly due to an increase in amylolytic activity of the beans and were similarly observed by Mbithi-Mwikya et al. (2001).

Table 16. Changes in Percentage Total Carbohydrate (Means ± Standard Deviation)

Processing Method	**% Carbohydrate (**± S.D.)
No Processing	38.71 (± 1.02)
Soaking	33.01 (± 5.77)
Soaking + De-Hulling	41.26 (± 3.59)
Soaking + Sprouting + De-Hulling	43.04 (± 4.77)

The crude protein levels apparently increased when soaked beans were de-hulled again as a proportionality effect. However, sprouting the soaked beans, followed by de-hulling, resulted in a reduction of crude protein levels (Table 17). This is most likely as a result of mobilization and utilization of the protein by the plant embryo during sprouting.

Table 17. Crude Protein Level and Crude Fiber by Processing Method (Mean ± SD)

Processing	**Avg. % Crude Protein (Means** ± SD)
Soaking	25.41 (± 0.43)
Soaking + De-Hulling	27.61 (± 1.01)
Soaking + Sprouting +De-Hulling	23.98 (± 2.79)

The percentage of crude fiber in beans expectedly reduced after the beans were de-hulled. This is because the testa contains most of the bean fiber.

Table 18. Crude Fiber Level by Processing Method (Means ± SD)

Processing	**Avg. % Crude Fiber (Means ± SD)**
Soaking	4.73 (± 1.098)
Soaking + De-Hulling	0.39 (± 0.28)
Soaking + Sprouting + De-Hulling	0.98 (± 0.17)

Soaking beans for 12 hours resulted in a 17.60% reduction in the phytate content. When the soaked beans were sprouted for 48 hours, phytate levels could no longer be detected. Similarly, phytate levels of sprouted de-hulled beans were also below detection level.

Table 19. Phytate Levels by Processing Method (Means ± S.D.)

Processing	**Average % Phytate (Means ± S.D.)**
No Processing	0.14 (± 0.09)
Soaking	0.12 (± 0.06)
Soaking + De-Hulling	-0.01 (± 0.01)
Soaking + Sprouting + De-Hulling	-0.01 (± 0.00)

Tannin levels were detectable with only soaking but could no longer be detected after soaking followed by de-hulling or soaking followed by sprouting then de-hulling (Table 20). This is probably because tannins are mainly found in the testa of the beans. Similar studies by Deshpande et al. (1982) and Ene-Obong and Obizoba (1996) resulted in a decrease in tannins after de-hulling the African yam bean.

Table 20. Tannin Levels by Processing Method (Means ± SD)

Processing	% Catechin Equivalent Means (± S.D.)
Soaking	1.15 (± 0.22)
Soaking + De-Hulling	0.03 (± 0.02)
Soaking + Sprouting + De-Hulling	0.03 (± 0.02)

The level of zinc reduced when soaked beans were de-hulled and also when they were sprouted. The level of iron, however, increases slightly when soaked beans were de-hulled and then decreased after sprouting (Table 21). A study carried out by Ene-Obong and Obizoba (1996) produced results which contradict the above, i.e., zinc was retained after beans were soaked and de-hulled while iron was not retained.

Table 21. Mineral Composition by Processing Method (Means ± SD)

Processing	Fe mg/kg (± S.D.)	Zn mg/kg (± S.D.)
Soaked	161.70 (± 10.40)	47 (± 3.60)
Soaking + De-Hulling	164.70 (± 15.50)	43 (± 2.60)
Soaking + Sprouting + De-Hulling	153.00 (± 16.10)	42 (± 6.00)

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.

Optimal processing conditions for development of bean flour were 12 hours of soaking, sprouting for 36 hours and steaming for 15 minutes (for the steamed flour) and roasting at 170^{o} C for 15 minutes (for the roasted flour). Consumer acceptability studies are underway to determine favorable end use products and their sensory quality.

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 also 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. Future analysis will include phytate content.

Table 22. Nutrients in Germinated, Steamed and Fermented Beans

Mean Nutrients	Beans (Control)	Germinated and Steamed Beans	Germinated, Steamed, and Fermented Beans
Carbohydrates (g)	59.1	42.2	35.0
Ash (g)	4.5	4.2	4.2
Protein (g)	25.3	24.0	7.8
Fat (g)	1.53	1.53	1.25
Vitamin C (mg)	27.0	27.0	9.8
Reducing sugar (g)	8.11	8.14	7.66
Total sugar (g)	11.46	11.51	(pending)

Work continues on the best processing techniques to be adopted, based on the result of the analysis carried out to date. Puffed beans is the first product processed in this project.

Future work

Acceptability of porridge/soup made from the developed products will be assessed. The influence of processing method combinations on acceptability will be compared.

The potential contribution of bean flour on nutrient intake in the community will be evaluated in a cross-sectional study. Pre-existing dietary intake of different nutrients, in school meals will be assessed and the potential contribution of incorporating bean flour into the diets will be assessed.

Determining the influence of malted bean flour on viscosity and nutrient density of maize porridge for school children is a promising research direction. Adding malted bean flour to maize porridge is expected to greatly increase the nutrient density of the porridge by improving the protein, energy and micronutrient content.

In Rwanda, bean flour from different treatments is analyzed by these methods (AOAC 1995):

1. Crude fat content was determined by the Soxhlet method
2. Protein content was determined by the micro-Kjeldahl method
3. Reducing sugar was determined by the Lane–Eynon method)
4. Total sugar was determined by the Shaffer Somogyi's method
5. Crude ash was determined by incineration in a muffle furnace
6. Total carbohydrate was determined by the Phenolic Acid method

Bean Flour Development Initiated

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. Preliminary analyses of the effect of processing on the nutritional quality of the bean flour have been conducted and results are presented in this report (Tables 16-21). Planned work involves determination of viscosity and nutrient density of maize porridge to which bean flour is added and the potential role of the malted bean flour on reducing viscosity and increasing nutrient density of porridges.

Bean Flour Protocol Development Initiated

A protocol for the processing of dry beans into quick-cooking flour is being developed from the K131 bean variety obtained from NaCRRI. Different processing pre-treatments are being tested for their ability to enhance nutritional value. The processing treatments being tested 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 for the K131 bean variety 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 170^{o} C for 15 minutes.

Product Acceptance Data Generated and Analyzed

This work has been delayed because the product development process is still on-going. The activity will be done in the next period during which the newly recruited Agricultural Extension/Education and Agriculture Economics/Agribusiness (George Jjagwe) and Food Science student (Catherine Ndagire) will team up to do the consumer surveys, as a prelude to development of value-added products from the bean flour developed by the first M.S. Food Science student (Aisha Musaazi) who is completing her M.S. research. Preliminary (cross-sectional) assessment of the potential contribution of bean flour on nutrient intake in the community is in progress. The planned approach for the assessment is to compare the current nutrient intakes of school age children, receiving maize porridge at school, to the nutrient content of porridge made with the quick-cooking bean flour.

Processing Protocols Refined and Promoted

Since the product development process is on-going, refining and promoting the processing protocols is delayed. It will be initiated by the first M.S. student and continued by the second M.S. student (Catherine Ndagire) in conjunction with the 2nd M.S. Agricultural Extension (George Jjagwe) student during 2010.

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

Approaches and Methods:

Objective 3a: Identify Solutions to Production and Marketing Constraints Faced by Producers of Beans

Approaches and Methods

- Conduct baseline surveys of producers to generate information on production and marketing constraints, and terms of trade between farm and non-farm sectors
- Analyze value chain components and linkages to identify strengths and weaknesses
- Identify barriers and challenges farmers face in accessing emerging markets
- Initiate and facilitate farmers' interaction with small, medium and large scale wholesale and retail enterprises to promote distribution and purchase of beans and value-added bean products
- Train farmers and farm groups to more successfully market beans
- Identify ways to improve packaging methods, packaging materials and storage conditions

Objective 3b: Characterize Consumer Demand and Preferences for Beans and Agro-Processed Products

Approaches and Methods:

- Participatory appraisals and baseline surveys of producers and consumers to determine knowledge, attitudes and practices regarding processing and human consumption of beans

Objective 3c: Increase Consumer Awareness of Benefits of Consuming Beans and Value-Added Products and their Access to New Products

Approaches and Methods
- Train community members on the benefits of consuming beans
- Demonstrate value addition in beans and preparation of bean recipes to community members

Results, Achievements and Outputs of Research:
Building on existing information about crop production, post-harvest management, and value addition, our project is designed to enhance farmers' understanding of the bases for yield and storage losses, awareness of feasible interventions, and ownership of on-farm implementation and evaluation of improved management strategies for bean production, storage, processing and marketing. Our team's collaborative efforts and interactions with smallholder farmers contribute to capacity building of farmers, farmer groups and their associations, NGO extension staff, and researchers and, thus, to sustainable improvements in the bean sector.

Value Chain Analysis Initiated
Bean farmers in Kamuli are not fully participating in the market, perhaps due to the existence of high transaction costs. Differences in transaction costs among households is a result of asymmetries in access to assets, market information, extension services and remunerative markets (Makhura *et al.* 2001). Access to markets for smallholder farmers in Kamuli is crucial to exploit the potential that bean production presents for increased incomes and improved livelihoods. The bean sector is constrained by lack of information on bean markets and prices. This has given chance to the middlemen to manipulate prices and offer low prices to farmer. The extent to which price fixing by traders occurs depends, at least in part, on the bean yield during the harvest season.

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 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.

Results
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.

Implications

Continuing efforts to enhance farmers' capabilities through training in production, harvesting, storage and marketing are likely to yield significant positive results. Development of storage facilities may help bean producing farmers to earn more by enabling them to control the timing of their sales, thereby obtaining better market prices. Linking farmers to an increasing range of markets and processors should further enhance their motivation and success in marketing beans.

The new master's degree student, George Jjagwe, Agricultural Extension and Agricultural Economics at Makerere University, is initiating research for his thesis on "Evaluating the Market Potential of Value-Added Bean Products and the Economic Impact on Rural Bean Producers in Kamuli District." The research is being conducted during 2009-2010. The objectives are to: (1) conduct consumer research to inform product development (quick-cooking bean flour, a composite flour, an extruded flour, and an extruded product); (2) develop models for organizing farmers to supply adequate (quality and quantity) raw materials for producing value-added bean products; (3) conduct market research to support successful introduction and maintenance of value-added bean products on the market; and (4) determine the influence of successful commercialization of bean products on livelihoods of rural bean producing farmers.

Education and Training Priorities Developed

The key informant interviews provided information on farmers' knowledge, attitudes and practices. This has been supplemented by insights gained during the orientation and training with farmers regarding the specific methods and procedures to be used in the field trials. This is guiding incorporation of additional materials to be used in future training and support. The project team plans to conduct household enterprise management training with further emphasis on operation of a farming enterprise utilizing business principles. Incorporating development of simple feasibility studies will enable farmers to conduct comparative analysis of costs and benefits for beans and other crops.

Trainings may also include technical and enterprise performance indicators that smallholder farmers can compare. Training will also include exchange activities such as small exhibits of equipment and packaging. VEDCO's Kamuli team organized a very successful (750+ participations) 'farmer field day' in July 2007 and sees the value of periodically organizing such activities. This could serve as an excellent opportunity to popularize and encourage the establishment of bean enterprises among a large number of households and farmer groups.

VEDCO Market Price Board

Beans Sold at Market

Farmers Trained and Facilitated for Marketing

Six farmer groups have been facilitated and trained in marketing. The training was conducted by Anthony Malinga of VEDCO and Simon Okiror, M.S. student in Agricultural Economics at Makerere University, both attached to the project.

Conducting Bean Farming as a Business

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 it has bean realized from the survey that beans yield higher income compared with other crops grown by the farmers. 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.

Sorting of Beans Before Sale

Farmers were trained how to sort their harvest appropriately before selling, as this adds value to the beans and enables them to fetch a better price for the beans marketed. As part of post-harvest handling and marketing, participating farmers were each given a tarpaulin for safe drying, while each group was given three sieves for sorting and one weighing scale. During the harvesting period, farmers were also trained to estimate moisture content and in proper storage methods.

Groups and Associations for Collective Marketing

Traditionally, farmers marketed their beans individually with limited or no information on current market prices. Training covered market chain linkages and actors, marketing information and its interpretation, and emphasized the roles and functioning of farmer groups and associations in benefitting smallholder farmers by enhancing the effectiveness and profitability of their participation in the bean market at every level. Associations may be able to establish common facilities along the bean value chain for grain testing, packaging, labeling, and business label registration.

During a visit to the University of Pretoria in South Africa in August, supported by CRSP supplemental funding, the Uganda and Rwandese Host Country PIs met with executive members of the South African

Dry Bean Producers Association. It facilitates linkages between farmers and large markets through bulking, sorting, grading, cleaning, transporting and negotiating prices. This 'model' represents a more advanced form of VEDCO's program activities in Kamuli and its other project districts, in which it supports the formation and operation of groups and then facilitates formation of enterprise based associations in Kamuli and other districts. The Bean Producers Association also produces certified bean seed, has developed and promoted recipes, and has experimented with value addition activities. The project team will later work with farmers using methods for value chain empowerment (Mundy 2006) and participatory agro-enterprise development (Ferris et al. 2006).

Packaging and Labeling of Beans for Sale
Farmers were trained to sort, package and label beans in consumer sized packs rather than selling in bulk. This adds value and opens up opportunities to target supermarkets, thus fetching better prices.

Farmer-to-Farmer Exchange Visits
Farmers are encouraged to hold regular farmer-to-farmer visits to exchange information regarding successful farm practices among smallholder bean farmers and scale out recommended farming and marketing practices.

Consumer Preferences and Demand Characterized
In rural areas of Uganda and Rwanda, key informant interviews and focus group discussions provided very useful information. 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. Desirable attributes are: good taste, easy to cook (short cooking time), good sauce (color, thickness), and good flavor. In both countries, the project team plans to assess consumer acceptability of porridge/soup made from the developed flour in the new phase.

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. In the mixtures, beans constituted the smallest proportion. According to farmers, the aroma of beans in the flour isn't pleasant.

According to farmers in Kamuli, there are potential products that can be derived using bean grain as primary raw material: cakes, biscuits, bean cookies, samosa and pure bean flour. Farmers have been limited in developing these products due to lack of knowledge and experience regarding means of processing, and lack of capital for processing equipment.

Nutrition Awareness Level Determined
During the key informant interviews and focus group discussions, we learned about current levels of nutrition awareness regarding beans. VEDCO's Nutrition and Health officer has been providing training and support since 2005 to 27 community nutrition and health workers (CNHWs) who, in turn, provide outreach services to community members in Kamuli district. In addition, results are pending from several recent student-initiated research projects (facilitated but not funded by CSRL) which will complement results from on-going analysis of household interview data collected 2006-2009 regarding food consumption patterns in rural Kamuli among VEDCO-assisted households

Product Improvement Strategies Identified
Procedures for improving post-harvest handling practices among farmers have been demonstrated and implemented in mid-2009 when the harvest for the first growing season was ready. These have led to improved bean quality.

In addition, improvement of nutritional quality is expected as a result of on-going research of malting to increase nutrient bioavailability, reduce anti-nutrients, increase protein and carbohydrate digestibility. Ideas regarding indigenous and/or exogenous methods to improve storage conditions are being sought. Experimentation with the most promising ideas and technologies will be integrated into post-harvest training and demonstration, and monitored for their anticipated effects in terms of reducing loss in bean quality and quantity. Successful methods and technologies can then be disseminated widely in the district and beyond.

Community Training on Bean Consumption

Community based trainings regarding bean consumption were conducted in Bugulumbya and Butansi sub-counties. The nutritional importance of consuming beans by both the young and the old was emphasized by all the trainers. In addition, beans as a means of food security was also emphasized. These trainings were conducted in collaboration with VEDCO, NaCRRI, and Makerere. In Rwanda, a similar activity will be carried out during the next phase. Once the processing techniques and protocols are finalized, this activity will be conducted in partnership with KIST's Center for Innovations and Technology Transfer.

Follow-Up on Community Trainings

In Uganda, farmers are followed up on a monthly basis in the field to observe the adoption of modern farming techniques. It has been established that farmers adopted very quickly because of their prior training and experience with the sustainable rural livelihoods program in Kamuli, and are enthusiastic to learn more. They appreciated the technical assistance given to them. During these follow-ups, it has been found that farmers have adopted better farming technical such as planting in rolls, spacing, weeding the fields whenever there are weeds, and also record keeping. However, the dry spell in between rains has affected their crops.

In Rwanda, this activity will be carried on in the next phase. Once the initial community trainings are conducted in partnership with KIST's Center for Innovation and Technology Transfer, appropriate follow up trainings will be conducted.

Objective 4: Increase Capacity, Effectiveness & Sustainability of Agric. Research Institutions

Student-led research projects serve as an essential means to accomplish project research objectives. They immediately engage the project's multidisciplinary team (PI and Co-PIs) in refining the project's research objectives, methods of data collection and analysis, and interpretation of results obtained. In an intermediate sense, the specific research projects involve intensive mentoring of student researchers within and across disciplines by the PI and Co-PIs. For the longer-term, the myriad interactions among the PI, Co-PIs, and emerging next generation of research professionals will increase capacity, effectiveness and sustainability of agricultural research institutions in the project region and globally. Moreover, the integration of key research activities with development practitioners enhances both the relevance of research activities undertaken by researchers ('research for development' - R4D) and the applicability of research findings to development activities that are designed and implemented to meaningfully improve poor people's livelihoods.

In addition to the originally planned training at M.S. and Ph.D. level (described below in sections 4.2 and 4.3, respectively), Co-PIs in Uganda and Rwanda have integrated undergraduate research activities and mentoring into project activities.

In Uganda, Co-PI Dr. Dorothy Nakimbugwe was supporting and supervising a 4th year B.S. (Catherine Ndagire) who investigated the effects of post-harvest handling and storage conditions on bean quality. Ms. Ndagire is now enrolled in the M.S. program.

In Rwanda, Co-PI Dr. Hilda Vasanthakaalam at KIST has establish a research team of four the 4th year B.S. students in Food Science and Technology: (a) Felecite Nyirabunani – "Influence of different processing (soaking, germination, fermentation and puffing) on the bioavailability of selected amino acids in dried beans," (b) Annet Kasabiiti – "Development of modified atmosphere to create an environment lethal for the survival of insects in stored beans," (c) Alexis Bikorimana – "Effect of germination and fermentation on the nutritional composition," (d) Emmanuel Mugabo – "Effect of combined treatments on the nutritional composition of beans," and (5) new 4th year students in 2010 - "Changes in the physico-chemical parameters on treated flour and its use in extruded products and complementary flour." Rose Kambabazi's M.S. thesis research at Makerere University will also address this.

Training 5 M.S. Students Ongoing (5 M.S. students enrolled at Makerere University)

Recently Initiated

Catherine Ndagire - M.S. student in Food Science & Technology at Makerere University – her research will utilize the quick-cooking bean flour, developed by M.S. Food Science student (Aisha Musaazi), to develop and optimize a composite flour suitable for use as porridge in school meals for children, and test its nutritional and physic-chemical properties as well as acceptability.

George Jjagwe – M.S. student in Agricultural Extension & Education at Makerere University – his research focuses on evaluating the market potential of value-added bean products and the impact on rural bean producers in Kamuli district. His draft concept (still under review) contains the following objectives: (1) conduct consumer research to inform product development (quick-cooking bean flour, a composite flour, an extruded flour, and an extruded product); (2) develop models for organizing farmers to supply adequate (quality and quantity) raw materials for producing value-added bean products; (3) conduct market research to support successful introduction and maintenance of value-added bean products on the market; and (4) determine the influence of successful commercialization of bean products on livelihoods of rural bean producing farmers.

Rose Kambabazi - M.S. student (from KIST, Rwanda) in Food Science & Technology at Makerere University – her research proposal is currently being developed, with research to be conducted in Uganda and Rwanda. It will focus on "Changes in the physico-chemical parameters on treated flour and its use in extruded products and complementary flour." Her research, and supervision by faculty at Makerere and KIST, will ensure that effective inter-institutional and inter-country collaboration is established and flourishes. Rose is currently on maternity leave.

Near Completion

Aisha Musaazi – M.S. student in Food Science & Technology at Makerere University – her research is focused on development of bean flour. She has completed developing the processing protocol for the bean flour as well as the preliminary analysis of its nutritional properties. The quick-cooking flour aims at reducing cooking time, fuel wood required (1 kg of dry beans requires 7 kg of firewood and 3 hours to cook), and drudgery, and increase consumption of beans and the nutritional benefits derived.

Simon Okiror – M.S. student in Agricultural Economics and Agribusiness at Makerere University – his research is focused on farmers' production and marketing. Simon has submitted a draft of his completed thesis to his supervisors for review. Simon's work will contribute to efforts to understand and address key constraints in the bean value chain and enable farmers to better access markets for improved incomes.

Withdrew

Cyrille Sinayobye - M.S. student (from KIST, Rwanda) in Food Science & Technology at Makerere University – after reviewing the results of the KAP study in Rwanda, his research was expected to focus on either storage of bean or on new food product development.

Training 2 Ph.D. Students at ISU Initiated, Ongoing (2 Ph.D. Students Enrolled at ISU)

Gerald Sebuwufu - Ph.D. Student in Crop Production and Physiology at ISU

Gerald has taken six courses - two in physiology, two in statistics, one in molecular biology techniques, and one in soil and plant relations. The seed physiology course focused on all aspects of seed development, maturation, dormancy, germination and vigor. The crop physiology course focuses on processes essential to biomass production and seed formation (expansion growth, light interception, photosynthesis, respiration, translocation, nutrient accumulation, etc.) and the limitations imposed on these processes by the environment (light, water, temperature). The statistics courses focused on fundamental principles of experimental design including inference space, fixed and random factors, qualitative and quantitative variables, restrictions on randomization, and nesting of experimental factors. In additional, application of these principles to statistical computing using SAS software was also be covered. The molecular biology course focused on DNA, proteomics and cell techniques while soil and plant relations focused on composition and properties of soils in relation to the nutrition and growth of plants.

Gerald's research focus is on the effect of stresses on the yield and quality of five bean varieties from Uganda. The first in a series of planned experiments on water stress is ongoing, focusing on the response of the five bean varieties during pod filling. Further, literature search and review for the proposal and meta-analysis on drought stress continues.

Martin Mutambuka - Ph.D. Student in Food science and Human Nutrition at ISU

Nearing completion of his first year in the Ph.D. program at ISU, Martin has made normal progress in course work and the assembly and registration of his Program of Study committee. His research has been progressing normally and a poster from his initial studies was entered into the 8th Annual Borlaug Poster Competitions, held at Iowa State University on October 12, 2009. Working under Objective 2 (enhancement of nutritional value and appeal of beans), the main focus of his research has been relating iron and zinc bioavailability to chemical composition of beans. To this end, he has acquired considerable experience in novel analytical procedures, some of which have been developed by the research groups with which he is working. Key among these are Caco-2 cell culture models to measure iron and zinc bioavailability and determination of bean ferritin content using a new ELISA technique. These studies are core to understanding the contribution of beans to iron and zinc intake of the local populations which are dependant on beans as a staple. The research is aimed at eventually validating mineral bioavailability algorithms for beans (both in the native and processed forms).

Research Collaboration – ISU, Makerere, NaCRRI, VEDCO, and KIST

All institutions are actively collaborating in work to accomplish project objectives. Members of the Uganda-based team have met together with ISU-based members at Makerere University in January, March, June, August, and September, and periodically in Kamuli.

In addition, Rwanda Co-PI Vasanthakaalam met with CRSP Program Director Dr. Irv Widders, Dr. Jim Kelly, Dr. George Abawi, and Mr. Augustin Musoni at KIST during the visit to Rwanda (Jan. 12-23, 2009). She took them to meet with farmers in Nyagatare. Dr. Vasanthakaalam also hosted a series of meetings with the Ugandan Co-PI Dr. Nakimbugwe and CRSP Project Director (PI) Mazur at KIST in Kigali during March 29-31, 2009.

Research and Development Partnerships Consolidated

In addition to the regular and effective communication among members of the project team, new collaborative partnerships are being established because of the current project.

Building on the collaborative activities in the current CRSP project, Co-PI Westgate assembled a new research team to improve biological nitrogen fixation in legumes grown in Rwanda, Tanzania, and Uganda. The team includes current and past CRSP-funded breeders/physiologists at Michigan State University and Washington State University, as well as new partners at Sokoine University and ISAR. Their proposed research and demonstration project was selected for funding 2009-2012 by DGP CRSP in October 2009.

Assistance to analyze bean samples from Rwanda the Biochemistry Department of the University of Pretoria has been initiated. Assistance was also requested from Engela van Eyssen, the Head of the South Africa Dry Bean Producers Organization, for technical advice in the purchase of the extruder and also the percentage of bean flour to be incorporated in the development of extruded products .

Inter-Organizational Learning Fostered

Members of the team from all institutions are contributing to the collective learning required for achievement of project objectives and, in turn, learning from each other through these collaborative, multidisciplinary activities.

The Rwanda Co-PI Vasanthakaalam and Uganda Co-PI Nakimbugwe had the opportunity to travel to the University of Pretoria to learn about their research initiatives and areas of research interest. They also had the opportunity to interact with the Dry Bean Producers Organization to see their activities and the way they were maintaining standards to compete in the international market in terms of quality and price.

Preliminary Results Dissemination

In Uganda, Catherine Ndagire, recent B.S. graduate in Food Science and Technology, finished her research and wrote a report on post-harvest losses of beans in Kamuli district. She has disseminated her findings to farmers through farmers' trainings.

Simon Okiror, the M.S. student in Agricultural Economics, has also disseminated his findings in community training. He is in the process of writing the thesis of his findings.

In Rwanda, the four student projects are in progress. They are continuing analysis and write up; their reports are expected to be ready by early December 2009. Their findings will inform ongoing research and community-based dissemination activities in the coming year.

Explanation for Changes

Post-Harvest Management Innovations Adoption Documented

Despite the fact that is was only possible to initiate our first field trial in Uganda during season 1 (Apr.-Jul.) in 2009 (project start up in 2008 was too late for season 2 planting), our team has identified sources of post-harvest losses, quantified their impacts, and promoted loss-reducing innovations; we are currently documenting the scale and results of adopting new technologies and management practices. Improved technologies and practices are currently being promoted with farmers who participate in the field trials. The potential exists, given additional resources, to scale up these innovations with the much larger number of farmers being assisted by VEDCO in Kamuli district (2,100 beginning in 2010, up from 800 now) and in eight other districts in Uganda (22,500+ households), as well as through NaCRRI's national network of bean producers.

In Rwanda, we have identified sources of post-harvest losses and documented their magnitude. At present, we are continuing our promising research in quantifying the impact of alterative storage methods and technologies on reducing bean seed/grain losses. Thus, in Rwanda we are not yet at the stage of recommending and promoting post-harvest technologies and management practices in partnership with

KIST's Center for Innovations and Technology Transfer. We plan to carry out these activities during the coming year.

Product Acceptance Data Generated and Analyzed
In both Uganda and Rwanda, our team is continuing research on the effects of various processing methods and technologies on the chemical composition and key nutrients in beans and bean flour. We are making good progress toward identifying the best processing techniques. However, since key elements of this research are ongoing, we are not yet at the point of finalizing the protocols and developing products for testing among consumers in rural and urban areas. We plan to carry out these activities during the coming year.

Processing Protocols Refined and Promoted
See note above, which provides a full explanation.

Community Training on Bean Consumption
Once the processing techniques and protocols are finalized, this activity will be conducted in partnership with KIST's Center for Innovations and Technology Transfer. We are planning to carry out these activities during the coming year.

Follow-Up on Community Trainings
Once the initial community trainings are conducted in partnership with KIST's Center for Innovations and Technology Transfer, we will engage in follow up trainings. We are planning to carry out these activities during the coming year.

Networking and Linkages with Stakeholders

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; VEDCO is coordinating the first workshop for all key value chain stakeholders in Kamuli in January 2010 - this will foster regular interaction and problem solving approaches
- 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

Name of PI receiving leveraged funds: Mark Westgate
Description of leveraged Project: Partial support for Ph.D. student from Uganda in Agronomy
Dollar Amount: $46,089
Funding Source: ISU

Name of PI receiving leveraged funds: Robert Mazur
Description of leveraged Project: Partial support for Ph.D. student from Uganda in Food Science & Human Nutrition
Dollar Amount: $46,089
Funding Source: ISU

List of Scholarly Activities and Accomplishments

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Okiror, Simon. 2009. "Analysis of Factors affecting market participation of smallholder bean farmers in Kamuli district, Uganda." Thesis for M.S. degree. Department of Agricultural Economics & Agribusiness. Kampala, Uganda: Makerere University. (draft)

Contribution of Project to Target USAID Performance Indicators

Our project has a strong record of achieving performance indicators/targets:

We have been mentoring 10 students for degree training, 5 more than originally planned. Of these, 5 of 10 are women (vs. 1 of 5 originally planned). Doubling of the original estimate is due to Co-PI

Nakimbugwe and Co-PI Vasanthakaalam actively involving B.S. students in the project while they undertake the research for their 4th year projects at Makerere University and KIST.

In terms of short term training, 58 women and 9 men have participated in a series of short-term training for farmers in Kamuli. Other members of their six farmer groups (which average 20-25 members each) have also participated in some of the training sessions, according to their respective interests.

We have progressed well in terms of the number of technologies and management practices that are under research (20 vs. 5 planned), and under field testing (8 vs. 5 planned). None is yet ready to be made available for transfer (3 were anticipated).

Before the start of the project, we initially overestimated the number of farmers that would be optimal for training and participating in the project's set of field trial experiments (120 vs. 67 currently). However, CSRL's Kamuli program will be providing assistance to 2,100 farm households beginning in January 2010, making it very easy to disseminate applicable technologies and management practices to a relatively large number of farmers. Moreover, VEDCO's network of 22,500+ farm households in eight other districts and NaCRRI's nationwide network will greatly facilitate even wider dissemination as project work continues and lessons are learned. We are not yet directly collaborating with formally organized agricultural enterprises. We are providing technical assistance directly to six community based organizations (CBOs) and indirectly to an additional eight (16 total were anticipated). Women constitute the majority of members in these CBOs. The number of host country partner organizations benefitting is four, as planned.

The number of additional hectares under improved technologies or management practices (6) is less than originally anticipated (30) because the operative design for the field experiments in which farmers are actively involved emerged after the original workplan was prepared and the partner organizations worked through the details for work on 324 plots.

We have not yet established public-private sector partnerships as a result of this USAID-funded project, but view this as a likely outcome once the value chain stakeholder workshop in Kamuli takes place and research on large scale production and marketing of bean flour and products progresses.

Contribution to Gender Equity Goal

Among the team of research scientists and professional practitioners, there are 7 women and 7 men.

There are 3 women and 5 men among students receiving (or who have received) graduate level training and mentorship in research.

Of the 30 farmers participating directly in the field experiments, 24 are women; similarly, the majority (58 of 67) of farmers participating in project training sessions are women.

Progress Report on Activities Funded Through Supplemental Funds

Supplemental funds were provided for capacity building for Makerere University, included funds to travel to Sokoine University and University of Pretoria. Both trips have been made. The trip to University of Pretoria was especially valuable, resulting collaborative linkages between Univ. Pretoria staff and our project and beyond, some of which are already being followed up. Specifically, discussions are underway to tap into experiences of 'consumer-led product development through pre-product development market research. An option of Computer-assisted Sensory analysis of foods learned is also being pursued and publications obtained during the visit have been shared and are being utilized by the students working on the project.

The supplemental fund was used to top up the tuition fee and stipend fee of the M. Sc student Mr. Cyrille Sinayobye. It was also for networking and strengthening linkages with Sokoine University and the University of Pretoria. In August, Co-PI Vasanthakaalam initiated arrangements for amino acid analysis at the University of Pretoria on treated bean samples. She also sourced quotations in the region for a Keltech Amino Acid Analyzer to build analysis capacity in the lab at KIST.

Tables/Figures Cited in the Report

These are included at appropriate places in the report.

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Capacity Building Activities: P1-ISU-1

Degree Training:

Trainee #1
First and Other Given Names: Martin
Last Name: Mutambuka
Citizenship: Ugandan
Gender: Male
Degree Program for training: Ph.D.
Program Areas or Discipline: Food Science and Human Nutrition
Host Country Institution to Benefit from Training: Makerere University, Uganda
University to provide training: Iowa State University
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes
Supervising CRSP PI: Suzanne Hendrich, Manju Reddy, and Patricia Murphy
Start Date: January 2009
Projected Completion Date: December 2012
Type of CRSP Support (full, partial or indirect): partial
If providing Indirect Support, identify source(s)s of leveraged funds: Iowa State University
Amount Budgeted in Workplan, if providing full or partial support: $46,089
Direct cost: $38,375
Indirect cost: $7,714
U.S. or HC Institution to receive CRSP funding for training activity: Iowa State University

Trainee #2
First and Other Given Names: Gerald
Last Name: Sebuwufu
Citizenship: Ugandan
Gender: Male
Degree Program for training: Ph.D.
Program Areas or Discipline: Agronomy
Host Country Institution to Benefit from Training: National Crop Resources Research Institute, Uganda
University to provide training: Iowa State University
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes
Supervising CRSP PI: Mark Westgate
Start Date: August 2008
Projected Completion Date: May 2012
Type of CRSP Support (full, partial or indirect): partial
If providing Indirect Support, identify source(s)s of leveraged funds: Iowa State University
Amount Budgeted in Workplan, if providing full or partial support: $46,089
Direct cost: $38,375
Indirect cost: $7,714
U.S. or HC Institution to receive CRSP funding for training activity: Iowa State University

Trainee #3
First and given names: Catherine
Last name: Ndagire
Citizenship: Ugandan
Gender: Female
Degree program for training: M.S.
Program areas / Discipline: Food Science & Technology
Host Country Institution to benefit from training: Makerere University, Uganda
University to provide training: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe
Start date: August 2009
Project completion date: August 2011
Type of CRSP Support (full, partial or indirect): partial

Trainee #4
First and given names: Aisha
Last name: Musaazi
Citizenship: Ugandan
Gender: Female
Degree program for training: M.S.
Program areas / Discipline: Food Science & Technology
Host Country Institution to benefit from training: Makerere University, Uganda
University to provide training: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe
Start date: August 2008
Project completion date: August 2009
Type of CRSP Support (full, partial or indirect): partial

Trainee #5
First and given names: George
Last name: Jjagwe
Citizenship: Ugandan
Gender: Male
Degree program for training: M.S.
Program areas / Discipline: Ag. Extension & Education (and Ag. Economics & Agribusiness)
Host Country Institution to benefit from training: Makerere University, Uganda
University to provide training: Makerere University
Supervising CRSP PI: Paul Kibwika and Gabriel Elepu
Start date: August 2009
Project completion date: August 2011
Type of CRSP Support (full, partial or indirect): partial

Trainee #6
First and given names: Simon
Last name: Okiror
Citizenship: Ugandan
Gender: Male
Degree program for training: M.S.
Program areas / Discipline: Agricultural Economics & Agribusiness
Host Country Institution to benefit from training: Makerere University, Uganda
University to provide training: Makerere University
Supervising CRSP PI: Gabriel Elepu and Barnabas Kiiza
Start date: August 2008
Project completion date: August 2009
Type of CRSP Support (full, partial or indirect): partial

Trainee #7
First and Other Given Names: Cyrille
Last Name: Sinayobye
Citizenship: Rwanda
Gender: Male
Degree: M.S.
Discipline: Food Science & Technology
Host Country Institution to Benefit from Training: Kigali Institute of Science & Technology - Rwanda
University to provide training: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe (with Hilda Vasanthakaalam)
Start Date: August 2008
Project Completion Date: May 2009
Training Status: Withdrew
Type of CRSP Support (full, partial or indirect): Partial (Category 2b)

Trainee #8
First and Other Given Names: Rose
Last Name: Kambabazi
Citizenship: Rwanda
Gender: Female
Degree: M.S.
Discipline: Food Science & Technology
Host Country Institution to Benefit from Training: Kigali Institute of Science & Technology - Rwanda
University to provide training: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe (with Hilda Vasanthakaalam)
Start Date: November 2009 (was on maternity leave; will prepare inception report in consultation with Hilda Vasanthakaalam (Rwanda) and then submit to supervisor Dorothy Nakimbugwe
Project Completion Date: August 2011
Training Status: Active
Type of CRSP Support (full, partial or indirect): Partial (Category 2b)

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 - September 30, 2009)

SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

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

	Abbreviated name of institutions in columns below														
	Iowa State Univ.			Makerere Univ.			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	***Improve Bean Quality and Yields***														
PRA tools for KAP study developed															
PRA conducted and data collected															
Local agronomic KAPs documented															
KAPs analysed and reported															
Production constraints prioritized															
Quality constraints prioritized															
Certified seeds of bean varieties establ.															
Locations & farmer cooperators selected															
Site and location visited by US team	x	✓		x			x			x			x		
Irrigation/fertigation practices defined	x	✓					x			x					
Field sampling tech. & lab proced. establ.															
Trials planted, managed and harvested							x			x					
Seed samples submitted for analysis	x	✓		x			x			x			x		
Yields quantified and analyzed	x	✓					x								
Crop & soil mgmt. strategies evaluated	x	✓					x								
Harvested bean quality quantified	x	✓		x			x						x		
Harvest & storage tech. impacts docum.	x	✓		x			x						x		
Farmers mobilized for training															
Extension training manuals developed															
Farmers trained in research methods															
Research results incoporated in training				x			x			x					
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
PRA conducted & KAPs assessed															
Post-harvest losses prioritized															
Post-harvest mgmt. innovations promoted															
Innovation adoption documented							x			x			x		
Loss reductions documented & analyzed	x	✓		x			x			x			x		
Recipes identified and disseminated															
Nutrit./physico-chem. analysis started															
Analyzing benefits for vulnerables initiated															
Best processing techniques determined	x	✓		x									x		
Bean flour development initiated															
Bean flour product protocols dev. initiated															
Product accept. data generated/analyzed	x		✓	x						x			x		
Processing protocols refined & promoted	x		✓	x									x		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
Local stakeholders & partners identified															
Producers' mktg. constraints identified															
Value chain analysis initiated															
Education & training priorities developed	x	✓													
Farmers trained, facilitated for marketing				x			x			x					
Qualities of preferred beans determined															
Consumer pref./demand characterized	x	✓		x						x			x		
Nutrition awareness levels determined															
Product improvement strategies identified	x	✓		x			x			x			x		
Community training on bean consumption				x						x			x		
Follow-up on community trainings				x						x			x		
Objective 4	***Increase Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
Partnerships developed/formalized															
Training 3 MS @ MU initiated, ongoing				x									x		
Training 2 PhD @ ISU initiated, ongoing	x	✓													
Research collaborat. (Univ.,NARO,NGO)	x	✓		x			x			x			x		
Research/dev. partnerships consolidated	x	✓		x			x			x			x		
Inter-organizational learning fostered	x	✓		x			x			x			x		
Prelim. results dissem. (conf., websites)	x	✓		x			x			x			x		

Name of the PI reporting on benchmarks by institution	Robert Mazur	Dorothy Nakimbuwe	Michael Ugen	Henry Musoke	Hilda Vasanthakaalam

Name of the U.S. Lead PI submitting this Report to the MO Robert Mazur

[signature]
Signature

9-29-09
Date

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 - September 30, 2009)

SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

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

Abbreviated name of institutions in columns below

(Tick mark the Yes or No column for identified benchmarks by institution)

	Iowa State Univ.			Makerere Univ.			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
Objective 1	***Improve Bean Quality and Yields***														
PRA tools for KAP study developed															
PRA conducted and data collected															
Local agronomic KAPs documented															
KAPs analysed and reported															
Production constraints prioritized															
Quality constraints prioritized															
Certified seeds of bean varieties establ.															
Locations & farmer cooperators selected															
Site and location visited by US team	x			x	√		x			x			x		
Irrigation/fertigation practices defined	x						x			x					
Field sampling tech. & lab proced. establ.															
Trials planted, managed and harvested							x			x					
Seed samples submitted for analysis	x			x	√		x			x			x		
Yields quantified and analyzed	x						x								
Crop & soil mgmt. strategies evaluated	x						x								
Harvested bean quality quantified	x			x	√		x						x		
Harvest & storage tech. impacts docum.	x			x	√		x						x		
Farmers mobilized for training					√										
Extension training manuals developed					√										
Farmers trained in research methods															
Research results incoporated in training				x	√		x			x					
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
PRA conducted & KAPs assessed															
Post-harvest losses prioritized															
Post-harvest mgmt. innovations promoted															
Innovation adoption documented							x			x			x		
Loss reductions documented & analyzed	x			x	√		x			x			x		
Recipes identified and disseminated															
Nutrit./physico-chem. analysis started															
Analyzing benefits for vulnerables initiated															
Best processing techniques determined	x			x	√								x		
Bean flour development initiated															
Bean flour product protocols dev. initiated															
Product accept. data generated/analyzed	x			x		x				x			x		
Processing protocols refined & promoted	x			x		x							x		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
Local stakeholders & partners identified															
Producers' mktg. constraints identified															
Value chain analysis initiated															
Education & training priorities developed	x														
Farmers trained, facilitated for marketing				x	√		x			x					
Qualities of preferred beans determined															
Consumer pref./demand characterized	x			x	√					x			x		
Nutrition awareness levels determined															
Product improvement strategies identified	x			x	√		x			x			x		
Community training on bean consumption				x	√					x			x		
Follow-up on community trainings				x	√					x			x		
Objective 4	***Increase Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
Partnerships developed/formalized															
Training 3 MS @ MU initiated, ongoing				x	√								x		
Training 2 PhD @ ISU initiated, ongoing	x														
Research collaborat. (Univ.,NARO,NGO)	x			x	√		x			x			x		
Research/dev. partnerships consolidated	x			x	√		x			x			x		
Inter-organizational learning fostered	x			x	√		x			x			x		
Prelim. results dissem. (conf., websites)	x			x	√		x			x			x		

	Iowa State Univ.	Makerere Univ.	NaCRRI	VEDCO	KIST
Name of the PI reporting on benchmarks by institution	Robert Mazur	Dorothy Nakimbuwe	Michael Ugen	Henry Musoke	Hilda Vasanthakaalam

Name of the U.S. Lead PI submitting this Report to the MO: Robert Mazur

[signature]
Signature

28th September 2009
Date

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 - September 30, 2009)

SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

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

	Abbreviated name of institutions in columns below														
	Iowa State Univ.			Makerere Univ.			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	***Improve Bean Quality and Yields***														
PRA tools for KAP study developed															
PRA conducted and data collected															
Local agronomic KAPs documented															
KAPs analysed and reported															
Production constraints prioritized															
Quality constraints prioritized															
Certified seeds of bean varieties establ.															
Locations & farmer cooperators selected															
Site and location visited by US team	x			x			x	√		x			x		
Irrigation/fertigation practices defined	x						x	√		x					
Field sampling tech. & lab proced. establ.															
Trials planted, managed and harvested							x	√		x					
Seed samples submitted for analysis	x			x			x	√		x			x		
Yields quantified and analyzed	x						x	√							
Crop & soil mgmt. strategies evaluated	x						x	√							
Harvested bean quality quantified	x			x			x	√					x		
Harvest & storage tech. impacts docum.	x			x			x	√					x		
Farmers mobilized for training															
Extension training manuals developed															
Farmers trained in research methods															
Research results incoporated in training				x			x	√		x					
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
PRA conducted & KAPs assessed															
Post-harvest losses prioritized															
Post-harvest mgmt. innovations promoted															
Innovation adoption documented							x	√		x			x		
Loss reductions documented & analyzed	x			x			x	√		x			x		
Recipes identified and disseminated															
Nutrit./physico-chem. analysis started															
Analyzing benefits for vulnerables initiated															
Best processing techniques determined	x			x									x		
Bean flour development initiated															
Bean flour product protocols dev. initiated															
Product accept. data generated/analyzed	x			x						x			x		
Processing protocols refined & promoted	x			x									x		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
Local stakeholders & partners identified															
Producers' mktg. constraints identified															
Value chain analysis initiated															
Education & training priorities developed	x														
Farmers trained, facilitated for marketing				x			x	√		x					
Qualities of preferred beans determined															
Consumer pref./demand characterized	x			x						x			x		
Nutrition awareness levels determined															
Product improvement strategies identified	x			x			x	√		x			x		
Community training on bean consumption				x						x			x		
Follow-up on community trainings				x						x			x		
Objective 4	***Increase Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
Partnerships developed/formalized															
Training 3 MS @ MU initiated, ongoing				x									x		
Training 2 PhD @ ISU initiated, ongoing	x														
Research collaborat. (Univ.,NARO,NGO)	x			x			x	√		x			x		
Research/dev. partnerships consolidated	x			x			x	√		x			x		
Inter-organizational learning fostered	x			x			x	√		x			x		
Prelim. results dissem. (conf., websites)	x			x			x	√		x			x		

Name of the PI reporting on benchmarks by institution	Robert Mazur	Dorothy Nakimbuwe	Michael Ugen	Henry Musoke	Hilda Vasanthakaalam
Name of the U.S. Lead PI submitting this Report to the MO	Robert Mazur				

Signature **Date** 28th September 2009

*: *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 - September 30, 2009)

SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

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

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	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
Objective 1	*Improve Bean Quality and Yields*														
PRA tools for KAP study developed															
PRA conducted and data collected															
Local agronomic KAPs documented															
KAPs analysed and reported															
Production constraints prioritized															
Quality constraints prioritized															
Certified seeds of bean varieties establ.															
Locations & farmer cooperators selected															
Site and location visited by US team	x			x			x			x	√		x		
Irrigation/fertigation practices defined	x						x			x	√				
Field sampling tech. & lab proced. establ.															
Trials planted, managed and harvested							x			x	√				
Seed samples submitted for analysis	x			x			x			x	√		x		
Yields quantified and analyzed	x						x								
Crop & soil mgmt. strategies evaluated	x						x								
Harvested bean quality quantified	x			x			x						x		
Harvest & storage tech. impacts docum.	x			x			x						x		
Farmers mobilized for training															
Extension training manuals developed															
Farmers trained in research methods															
Research results incoporated in training				x			x			x	√				
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
PRA conducted & KAPs assessed															
Post-harvest losses prioritized															
Post-harvest mgmt. innovations promoted															
Innovation adoption documented							x			x	√		x		
Loss reductions documented & analyzed	x			x			x			x	√		x		
Recipes identified and disseminated															
Nutrit./physico-chem. analysis started															
Analyzing benefits for vulnerables initiated															
Best processing techniques determined	x			x									x		
Bean flour development initiated															
Bean flour product protocols dev. initiated															
Product accept. data generated/analyzed	x			x						x		x	x		
Processing protocols refined & promoted	x			x									x		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
Local stakeholders & partners identified															
Producers' mktg. constraints identified															
Value chain analysis initiated															
Education & training priorities developed	x														
Farmers trained, facilitated for marketing				x			x			x	√				
Qualities of preferred beans determined															
Consumer pref./demand characterized	x			x						x	√		x		
Nutrition awareness levels determined															
Product improvement strategies identified	x			x			x			x	√		x		
Community training on bean consumption				x						x	√		x		
Follow-up on community trainings				x						x	√		x		
Objective 4	*Increase Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
Partnerships developed/formalized															
Training 3 MS @ MU initiated, ongoing				x									x		
Training 2 PhD @ ISU initiated, ongoing	x														
Research collaborat. (Univ.,NARO,NGO)	x			x			x			x	√		x		
Research/dev. partnerships consolidated	x			x			x			x	√		x		
Inter-organizational learning fostered	x			x			x			x	√		x		
Prelim. results dissem. (conf., websites)	x			x			x			x	√		x		

Name of the PI reporting on benchmarks by institution	Robert Mazur	Dorothy Nakimbuwe	Michael Ugen	Henry Musoke	Hilda Vasanthakaalam
Name of the U.S. Lead PI submitting this Report to the MO	Robert Mazur				

[signature] 28/09/2009.

Signature Date

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 - September 30, 2009)

SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

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

	Abbreviated name of institutions in columns below														
	Iowa State Univ.			Makerere Univ.			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Quality and Yields*														
PRA tools for KAP study developed															
PRA conducted and data collected															
Local agronomic KAPs documented															
KAPs analysed and reported															
Production constraints prioritized															
Quality constraints prioritized															
Certified seeds of bean varieties establ.															
Locations & farmer cooperators selected															
Site and location visited by US team	x			x			x			x			x	√	
Irrigation/fertigation practices defined	x						x			x					
Field sampling tech. & lab proced. establ.															
Trials planted, managed and harvested							x			x					
Seed samples submitted for analysis	x			x			x			x			x	√	
Yields quantified and analyzed	x						x								
Crop & soil mgmt. strategies evaluated	x						x								
Harvested bean quality quantified	x			x			x						x	√	
Harvest & storage tech. impacts docum.	x			x			x						x	√	
Farmers mobilized for training															
Extension training manuals developed															
Farmers trained in research methods															
Research results incoporated in training				x			x			x					
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
PRA conducted & KAPs assessed															
Post-harvest losses prioritized															
Post-harvest mgmt. innovations promoted															
Innovation adoption documented							x			x			x		x
Loss reductions documented & analyzed	x			x			x			x			x	√	
Recipes identified and disseminated															
Nutrit./physico-chem. analysis started															
Analyzing benefits for vulnerables initiated															
Best processing techniques determined	x			x									x	√	
Bean flour development initiated															
Bean flour product protocols dev. initiated															
Product accept. data generated/analyzed	x			x						x			x		x
Processing protocols refined & promoted	x			x									x		x
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
Local stakeholders & partners identified															
Producers' mktg. constraints identified															
Value chain analysis initiated															
Education & training priorities developed	x														
Farmers trained, facilitated for marketing				x			x			x					
Qualities of preferred beans determined															
Consumer pref./demand characterized	x			x						x			x	√	
Nutrition awareness levels determined															
Product improvement strategies identified	x			x			x			x			x	√	
Community training on bean consumption				x						x			x		x
Follow-up on community trainings				x						x			x		x
Objective 4	*Increase Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
Partnerships developed/formalized															
Training 3 MS @ MU initiated, ongoing				x									x	√	
Training 2 PhD @ ISU initiated, ongoing	x														
Research collaborat. (Univ.,NARO,NGO)	x			x			x			x			x	√	
Research/dev. partnerships consolidated	x			x			x			x			x	√	
Inter-organizational learning fostered	x			x			x			x			x	√	
Prelim. results dissem. (conf., websites)	x			x			x			x			x	√	

Name of the PI reporting on benchmarks by institution	Robert Mazur	Dorothy Nakimbuwe	Michael Ugen	Henry Musoke	Hilda Vasanthakaalam

Name of the U.S. Lead PI submitting this Report to the MO: Robert Mazur

Hilda Vasanthakaalam (signature) — 30/09/09

Signature — Date

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

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

Lead U.S. PI and University: Robert E. Mazur, Iowa State University

Host Country(s): **Uganda, Rwanda**

Output Indicators	2008 Target (Apr 1-Sept 30, 2008)	2008 Actual	2009 Target (Oct 1 2008-Sept 30, 2009)	2009 Actual
Degree Training: Number of individuals who **are receiving (or have received)** Degree Training				
Number of women	1	2	1	5
Number of men	4	3	4	5
Short-term Training: Number of Individuals who **are receiving (or have received)** Short-Term Training				
Number of women	0	0	0	56
Number of men	0	0	0	11
Technologies and Policies				
Number of technologies and management practices under research	4	4	5	20
Number of technologies and management practices under field testing	4	0	5	8
Number of technologies and management practices made available for transfer	2	0	3	0
Number of policy studies undertaken	0	0	0	0
Beneficiaries				
Number of rural households benefiting directly	60	72	120	67
Number of agricultural firms/enterprises benefiting	0	0	2	0
Number of producer and/or community-based organizations receiving technical assistance	4	12	16	14
Number of women organizations receiving technical assistance	4	10	16	14
Number of HC partner organizations/institutions benefiting	4	4	4	4
Developmental Outcomes				
Number of additional hectares under improved technologies or management practices	4	0	30	6
Public-Private Sector Partnerships				
Number of public-private sector partnerships formed as a result of USAID assistance				0

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

Principle Investigators

James D. Kelly, Michigan State University, USA
Eduardo Peralta, INIAP, Ecuador
Augostine Musoni, ISAR, Rwanda

Collaboratoring Scientists

George Abawi, Cornell University, USA
Sieglinde Snapp, MSU, USA

Abstract of Research Achievement and Impacts

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; and bean lines were screened for tolerance to drought as part of a doctoral study at MSU. In NY, root rot screening of new germplasm from MSU and Puerto Rico was conducted in the field and selections were made and returned to the research programs for use in breeding; greenhouse screening of lines from Ecuador against Rhizoctonia was also conducted. In Ecuador 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, survey of potential on-farm field sites, 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.

Project Problem Statement and Justification

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-scale 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.

Planned Project Activities for April 1, 2008 - September 30, 2009

Objective 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.

Approaches and Methods:

1. Breeding research activities, past and present was reviewed in Ecuador and Rwanda.
2. Assemble a nursery of 72 bush types that includes collection of advanced lines in March four seed types from
3. Seed was increased in Ecuador for shipping to Rwanda prior to main planting season in September planting main cropping season. The nursery included Andean types from both the U.S and Ecuador.
4. Select parental breeding materials for crossing in Ecuador, Rwanda and U.S.
5. Identify select group of lines from Rwandan breeding for crossing with new introduced lines from Ecuador
6. Cross Rwandan sources of resistance for Fusarium wilt and Pythium and major foliar pathogens into large seeded lines with contrasting colors
7. Utilize markers in early-generation selection for major disease resistant traits in Ecuador
8. Initiate marker-assisted selection in Rwanda
9. Yield evaluation of advanced lines in range of seed types in Ecuador, Rwanda and U.S. Exchange of most promising materials among the three breeding programs
10. Initiate seed increase of most promising lines
11. On farm trials with advanced lines in Rwanda and Ecuador
12. Release of three bean varieties in three commercial classes for production in Michigan

Results, Achievements and Outputs of Research:

- 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.
- 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 F_1 seed derived from new or previous single

crosses for multiple resistances to major diseases were harvested in July 2009. The selected F_1 seed of the different populations were planted in the field along side 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 F_1 Andean recombinant populations for advance in 2010 since screenhouse space is now available at Rubona.

- 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, 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 and a complete description of the lines is available in attached table.
- 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 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 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 resistance (rust, anthracnose, angular leaf spot) were identified and will be further screened for yield, local adaptation and seed quality.

Objective 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.

Approaches and Methods:

1. Four inbred backcross line (IBL) populations will be evaluated in growers field under conditions of drought in Ecuador
2. Identify specific populations for in depth study in Rwanda
3. Advance other IBL populations with specific drought and root rot resistance traits are being developed
4. Evaluate 120 drought tolerant lines in a range of seed types from CIAT in Ecuador; a sub-set of the best lines will be tested in Rwanda
5. Complete characterization of 80 new local traditional lines collected from growers in Ecuador to determine level of drought tolerance
6. Trials will be conducted for root rot resistance sources in Ecuador each season
7. In Rwanda two screening locations have been identified for drought based on lower rainfall levels – no irrigation available; identify field site for root rot evaluation
8. Characterize germplasm for individual root pathogens at Cornell

Results, Achievements and Outputs of Research:

- 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 the 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 form 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.

- The effect of corn, wheat, oat, barely, buckwheat, rye, sudangrass grain crops grown as cover or rotational crops, on survival and infectivity of *Rhizoctonia solani* to beans. A former student 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 our standard crop rotation recommendation for controlling this pathogens (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.
- Relating soil health status and management practices to root health and yield of beans and other crops. We are continuing our 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.

<u>Objective 3</u>: Collect and characterize pathogenic and genetic variability of isolates of root and foliar pathogens in Ecuador and Rwanda.

Approaches and Methods:

1. In Rwanda conduct surveys to diagnose major root diseases and collect isolates of root pathogens for characterization. Initial survey will be conducted in Northern highland production region
2. In Ecuador complete characterization of root rot isolates collected previously in both Northern and Southern production regions at Cornell and Ecuador
3. Access potential for germplasm/isolate interaction in greenhouse at Cornell
4. Collect isolates of anthracnose, angular leaf spot (ALS) in Rwanda for race typing
5. Continue race typing of rust and anthracnose isolates, and initiate characterization of ALS in Ecuador

Results, Achievements and Outputs of Research:

- 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 $Co\text{-}4^2$ 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 assist the breeding process in Ecuador and Rwanda to enhance productivity and marketability of beans under development.

Approaches and Methods:

1. Design and validate sustainable farming practices including integrated nutrient and pest management systems for small farmers in Rwanda
2. Compare and contrast advanced line selection practiced by breeders and farmers in different agroecological regions in Rwanda
3. Evaluation of 10 tests in 10 CIALs each growing cycle in Ecuador
4. Facilitate non conventional seed production in Ecuador
5. Release of two bean varieties using farmer participation in Ecuador

6. Organize visit of Rwandan scientists to Ecuador to participate to interchange experience between investigators, breeding population management, germplasm banks, screening, and crossing at different INIAP research stations; interchange of experience on participatory methods and seed production for local community use with small farmer members in CIALs in Choto and Mira, Ecuador- anticipated date November 2009.

Results, Achievements and Outputs of Research:

- 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 (picture available). 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. 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.

Objective 4: Degree Training

Gerardine Mukeshimana, Citizenship: Rwandan – Major Professor – Kelly; Program started August 2008; Research focus will be on the development and study of drought tolerance in beans and part of the work will be conducted in Rwanda.(Research progress reported herein)

Krista Isaacs, U.S. - Major Professor – Snapp; Program started August 2008; Research focus is on agrodiversification of bean-based cropping systems and nutrition, and part of the research work will be conducted in Rwanda. (Research progress reported herein)

- Multiple research activities were carried out during a two-month visit to Rwanda in June and July 2009 by doctoral candidate Ms. Krista Isaacs. These research activities included the identification of collaborative partners for implementation of on-farm participatory field trials, survey of potential on-farm field sites, 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. These activities and findings were the first stage in ensuring the participatory bean breeding and cropping systems research focus in this project are appropriate to Rwandan scientists' needs and farmer constraints. These activities and particularly the informal focus groups carried out with ~120 farmers have influenced the PhD research design and proposal of the graduate student Krista Isaacs, which will focus on developing sustainable bean cropping systems in collaboration with farmers.
- The national non-governmental organization Northern Rural Development based in Ruhengeri, Rwanda was identified as a collaborative partner for the implementation of on-farm research activities. Both ISAR and DERN have worked together on other projects and DERN has an extensive network of community extension providers and works in close association with farmer organizations. ISAR facilities will be used to conduct on-station trials in the cropping systems component of the project. Initial cropping systems trials will be carried out on-farm in northern Ruhengeri in three communities with farmers' associations of 15 members each. Discussions with scientists from multiple organizations and a literature review of past and current agro-ecology research in Rwanda revealed emphasis on watershed management, new trials on spatial variations in intercrops for eastern Rwanda, and a focus on intensification of cropping systems. Farmer focus groups to gage farmer cropping system constraints and needs were conducted in twelve communities with an average of ten farmers present for each group interview. Results indicate that farmers have soil fertility constraints and some are willing to try green manures as an intervention. It was also found that farmers switched to monocultures of beans and maize due to a misinterpretation of government policy and reported higher yields. However, farmers almost always plant the intercrops with mixed (improved) varieties broadcast, whereas they plant monocultures in row with one improved variety. In addition, farmers that previously planted and ate beans, the staple crop and maize each season, now only harvest one of the crops per season. Farmers expressed interest in trying intercropping with improved varieties planted in rows. There was no indication that farmers used specific varieties of beans for different cropping systems. Challenges and areas for improvement in Participatory Variety Selection (PVS) were identified with ISAR scientists. These include the need to incorporate biological and ecological factors during site screening, training of stable staff that would enable the inclusion of PVS evaluations at earlier stages of bean development, training in the analysis of the data collection, modifications in group activities that encourage women to express their opinions, and additional planning and funding to support these various activities.
- Louis Butare from Rwanda visited the breeding program in Ecuador during November 2008 to study INIAP labs and field facilities and nurseries, visit different CIALs where cooperative work is underway to study participatory research approach and seed multiplication strategies currently working in Ecuador. Experience from that trip has been applied to bean staking studies in Rwanda.

Explanation for Changes

None

Engagement of USAID Field Missions

Kelly has visited the Agricultural Officer, Ryan Washburn in the USAID Mission in Kigali on two occasions to discuss the role and work of the PULSE CRSP in Rwanda and introduce HC partners Mr.

Musoni and Ms. Mukeshimana. The Mission in Quito is aware of CRSP activities in Ecuador and publications of project on variety releases and bean production practices prepared by INIAP were provided to the Mission Director during visit made by PI in 2006.

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. The Director of the Dry Grain Pulses CRSP, Dr. Irvin Widders, and the project PI, Dr James Kelly attended. ISAR collaborates with: Government Extension, Farmers cooperatives and seed production agencies, and NGO in Rwanda; World Vision, CARE, ADRA, CARITIUS, and Catholic Relief Services. NGO in Ecuador; PRODECI, PRODER, CRUZ ROJA, Agricultural Organizations; COPCAVIC, 10 CIALs, Grupo de Evaluadores de Frijol de Bolivar, Assoc. de Productores de Frejol de INTAG. Government Organizations; MAGAP, INIAP, Univ. Tecnia del Norte, and Univ. Catolica de Ibarra.

Leveraged Funds

The bean program in Rwanda continues to strengthen its collaboration with national, regional and international partners. The program leader Mr. Augustine Musoni participated in the Strategy and Priority Setting meetings for the non-staple crop program (NSCP) that was organized by ASARECA in July, 2009. The snap bean breeding project that was among all the ASARECA projects that had been suspended by EU donors was renewed. Leveraged funding, notably by government, national partners such as DERN, PABRA and AGRA, provide support to the project. Two new double cabin pick-up trucks were bought for the bean breeding projects supported by the Alliance for a Green Revolution in Africa (AGRA) and PULSE CRSP from MSU. The bean team leader participated in the PABRA joint ECABREN and SABREN Steering Committee that was held in Kampala in September, 2009. In October, he participated in the first AGRA Program for the African Seed System (PASS) General Meeting that was held in Mali. He presented a paper on the new climbing bean varieties due for release in the drought-prone zones of Rwanda. In Ecuador, the national government approved the project entitled: “Investigation and development of edible grain legumes (bush and climbing bean, peas, broad beans and lentils) to aid in the food security and safety in Ecuador”. The project will strengthen research being conducted by INIAP for a four year period to increase and improve the activities in edible grain legumes as part of the strategy of food security and safety. The project started July 3, 2008 but due to the global recession, funding has been rescinded.

List of Scholarly Activities and Accomplishments

Cichy, K.A., M. W. Blair, C. H. Galeno-Mendoza, S. S. Snapp, and J.D. Kelly. 2009. QTL analysis of root architecture traits and low phosphorus tolerance in an Andean bean population. Crop Sci. 49:59-68.

Kelly, J.D., G.V.Varner, P. O’Boyle, and B. Long. 2009. Registration of ‘Zorro’ black bean. J. Plant Registrations 3:226-230.

Kelly, J.D., G.V.Varner, B. Roman, and B. Long. 2009. Registration of ‘Fuji’ Otebo bean. J. Plant Registrations 3:223-225.

Ohkura, M., Abawi, G. S., Smart, C. D., and Hodge, K. T. 2009. Diversity and aggressiveness of *Rhizoctonia solani* and *Rhizoctonia*-like fungi on vegetables in New York. Plant Dis. 93:615-624.

Tako, E., R.P. Glahn, J. M. Laparra, R.M. Welch, X. Lei, J.D. Kelly, M.A. Rutzke and D.D. Miller. 2009. Iron and zinc bioavailabilities to pigs from red and white beans (*Phaseolus vulgaris* L.) are similar. J. Agric. Food Chem. 57: 3134–3140.

Vallejo, V., and J. D. Kelly. 2009. New insights into the anthracnose resistance of common bean landrace G 2333. The Open Horticulture J. 2:29-33.

Extension publications on new varieties in Spanish in Ecuador.

Contribution of Project to Target USAID Performance Indicators

- The development and release of locally adapted, acceptable and disease resistant bean cultivars for the major production regions in Rwanda, Ecuador and Michigan.
- Increased sustainable productivity and profitability of bean production due to increased yield and reduced inputs.
- Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.
- Increased awareness and knowledge of participatory breeding methods, root health and soil health issues will further improve bean productivity, long-term land management, environmental risk, thus contributing to sustainability of bean production and agricultural communities.
- Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the U.S. market.
- Enhanced human resource development, gender equity and improved infrastructure capacity of participating institutions in Rwanda and Ecuador.

Contribution to Gender Equity Goal

Two women students currently in doctoral training at MSU

Capacity Building Activities: P1-MSU-1

<u>Degree Training:</u>

Student #1

First and Other Given Names:	Gerardine
Last Name:	Mukeshimana
Citizenship:	Rwandan
Gender:	Female
Degree:	Ph.D.
Discipline:	Plant Breeding and Genetics
Host Country Institution to Benefit from Training:	ISAR and National University of Rwanda
Training Location:	Michigan State University
Supervising CRSP PI:	Kelly, James
Start Date:	08/08
Project Completion Date:	08/11
Training Status:	Active
Type of CRSP Support (full, partial or indirect):	Full (Category 1)

Student #2

First and Other Given Names:	Krista
Last Name:	Isaacs
Citizenship:	US
Gender:	Female
Degree:	Ph.D.
Discipline:	Ecology, agronomy, nutrition
Host Country Institution to Benefit from Training:	US and Rwanda
Training Location:	MSU
Supervising CRSP PI:	Snapp, Sieglinda
Start Date:	08/08
Project Completion Date:	08/11
Training Status:	Active
Type of CRSP Support (full, partial or indirect):	Partial (Category 2b)

Short-term Training:

Type of Training:	Participatory plant breeding
Description of training activity:	Organize and conduct participatory plant breeding and root/soil health training workshop in Rwanda planned for third year in 2010 but may be offered earlier in 2009 if possible
Status of this activity:	
Reason if training activity not completed as planned:	
When did the activity occur?:	
Location:	Rubona, Rwanda
Who benefited from this activity?:	
Number of Beneficiaries:	30
Male:	
Female:	
Total:	

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

Project Title:

	Abbreviated name of institutions											
	MSU			Cornell			Ecuador			Rwanda		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1												
Review breeding program												
Andean bean nursery-Increase												
Plant Andean nursery												
Selection parental lines												
Selection elite lines	x	X										
Nursery evaluation							x	X		x	X	
crossing	x	X					x	X		x	X	
Marker assisted selection	x	X					x		X	x		X
Advanced yield trials	x	X					x	X		x	X	
On farm trials	x	X		x	X		x	X		x	X	
Variety Release												
Objective 2												
Advanced Population development	x	X					x	X				
Test Populations in Rwanda										x	X	
Other population development	x	X					x	X				
Characterize CIAT resistance sources							x		X	x		X
Increase, characterize local germplasm							x	X				
Characterize germplasm to root pathogens	x		X	x	X		x	X		x		X

Dry Grain Pulses CRSP

Report on the Achievement of "Semi-Annual Indicators of Progress"

(For the Period: April 1, 2009 -- September 30, 2009)

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Project Title:

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	MSU			Cornell			Ecuador			Rwanda		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 3												
Survey root pathogens in Rwanda				x	x					x		X
Characterize root rot isolates							x		X	x		X
Root Pathogen x germplasm interaction				x		x	x		X			
Collect foliar pathogens in Rwanda	x		X							x	X	
Race characterization	x		X	x		x	x	X		x		X
Objective 4												
Visit of Rwandan scientists to Ecuador							x	X		x	X	
Workshop Participatory in Rwanda												
Evaluation of elite lines in CIALs							x	X		x		X
Variety releases in Ecuador							x	X				
Farmer vs. Breeder Selection										x	X	
Sustainable practices, nutrient mgt										x	X	

Name of the PI reporting on benchmarks by institution	James D. Kelly	George Abawi	Eduardo Peralta	Augustine Musoni

Name of the U.S. Lead PI submitting this Report to the MO: James D. Kelly

James D. Kelly (signature)

Signature — Date: Oct.1.2009

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Ecuador

MSU and Cornell: Research not completed due to the unavailability of characterized root pathogens isolates/genetic variants from the target work areas. The collection, purification, and characterization of pathogen isolates require the direct involvement

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: **Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans for Resistance to Biotic and Abiotic Stresses**
Lead U.S. PI and University: MSU
Host Country(s): Ecuador and Rwanda

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women	1			1
Number of men			1	
Short-term Training: Number of individuals who have received short-term training				
Number of women			1	1
Number of men			2	3
Technologies and Policies				
Number of technologies and management practices under research	8	4	8	14
Number of technologies and management practices under field testing	4	3	4	10
Number of technologies and management practices made available for transfer	8	2	8	12
Number of policy studies undertaken				
Beneficiaries				
Number of rural households benefiting directly	3000	2400	3100	8300
Number of agricultural firms/enterprises benefiting	9	2	9	19
Number of producer and/or community-based organizations receiving technical assistance	54	15	54	110
Number of women organizations receiving technical assistance	8		8	15
Number of HC partner organizations/institutions benefiti	18	8	18	38
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	5400	1200	7000	14000

"Number of public-private sector partnerships formed as a result of USAID assistance." 8

Rwanda: More than 200 T of seed of improved varieties has gone to farmers through ISAR and main partners (RADA, NGOs, CBOs and Farmers)

Ecuador: Over 250 T of seed of improved varieties has gone to farmers through INIAP

MSU & Cornell: Established actively collaboration with USDA-ARS Mayaguez to evaluate root rot germplasm at Geneva NY

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

Principle Investigator

Richard H. Bernsten, Michigan State University, USA

Collaboratoring Scientist

Duncan Boughton, Michigan State University, USA
Cynthia Donovan, Michigan State University, USA
David Kiala, Universidade Agostinho Neto, Angola
Feliciano Mazuze, Instituto de Investigação Agrária Moçambique, Mozambique
Juan Carlos Rosas, Escuela Agricola Panamericana-Zamorano, Honduras

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Abstract of Research Achievements and Impacts

Angola. Markets were visited, a market enumerator was trained. In March 2009, Chaves began his MS studies at Vicosa. Before departing, he visited bean value chain actors (Huambo area) & developed a preliminary value chain diagnosis. Chaves will develop his thesis proposal in late-2009 with Donovan and his Vicosa advisor, using price information & value chain data. Donovan worked with WV on a smallholder survey &identified survey areas with bean marketing. The report from the smallholder survey (WV ProRenda project) is drafted &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--Kiala supervised the research design, Donovan provided input. Mozambique. Due to staff changes at SIMA, the draft report is only partially (to be completed in late 2009). 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. A draft report was prepared--more information is needed before beginning outreach/developing a stakeholders group. The MS student begun her studies at Pretoria; has developed a draft thesis proposal. With information from last year's rapid appraisal & price data collected through SIMA, she will have an excellent data set for her research. Having Donovan in country will be valuable in moving forward this research. Honduras. Organic/sustainable practice certifiers were initially contacted as fair trade bean certification was not available. FLO recently established standards, so TransFair USA was contacted; requirements for fair trade beans were obtained. A workshop in Yojoa Lake region identified farmers' organic practices. Results of trials (organic vs conventional) in several regions depended on farmers' fertilizers/pesticides levels--organic practices are good alternatives, given similar yields & raising fertilizers/pesticides costs. A meeting(s) with ARSAGRO/CIALs 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 at Rojitos obtained information on cleaning/exporting costs & a bean export embargo. 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 requirement.

Project Problem Statement and Justification

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/cowpea production flow into different marketsheds, 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 farmgate 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.

Planned Project Activities for April 1, 2008 - September 30, 2009

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.

Approaches and Methods:
Objective 1.1: Visit Key Informants to Identify Information and Data Sources

Visit key informants in order to identify information and data sources. This includes public sector agents for production and areas in beans/cowpeas. Collect/analyze secondary information to document trends in production, marketing, trade, consumption, etc., and identify information gaps

Objective 1.2: Interview Key Subsector Participants to Develop a Value Chain Diagnosis

Interview key subsector participants (e.g., agricultural scientists, traders, processors, importers/exporters, NGOs) to develop a value chain diagnosis, plus information needed to improve performance and identify constraints to subsector growth.

Objective 1.3: Conduct a Smallholder Survey

Undertake a smallholder survey under the World Vision Smallholder Horticultural Value Chain Development project. It is anticipated that the student will participate, with C. Donovan as design consultant for World Vision. The survey will include information on farmer characteristics and practices, including marketing strategies, trade, and transport—thereby documenting linkages between farmers and markets.

Results, Achievements and Outputs of Research

Objective 1.1: Visit Key Informants to Identify Information and Data Sources

After delays due to visa problems, Donovan traveled to Angola in late 2008 and worked with MS student Chavez. Several markets were visited and Chaves identified and trained a market enumerator, who has continued to collect price information during Chaves's studies in Brazil.

Objective 1.2: Interview Key Subsector Participants to Develop a Value Chain Diagnosis

Prior to departure, Chaves visited with various actors in the bean value chain in Huambo area. He developed a preliminary value chain diagnosis, but will need to revisit the area for further diagnostics. The MS thesis proposal is still being developed, as the student arrived late (in March 2009) at University of Vicosa. According to the study plans at Vicosa, Chaves will be developing his thesis proposal in late 2009, when he has more of the studies completed and a better grasp of the available research methods. Meanwhile, price data are being collected in Angola and should be useful for the thesis. Chaves's MS thesis proposal has not yet been completed due to delays in enabling the student to begin studies in Brazil. The proposal entails work with his designated advisor in Brazil and that will occur in the coming semester.

Objective 1.3: 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 marketing. Given the lack of an agricultural census and 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. As noted earlier, there were delays 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 so extensive training was needed, followed up by careful checking of data. 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, resulting in higher total revenues, even though they produced an average of only 112 kilograms, selling 75% of production compared to 314 kilograms produced among males, and 86% is sold.

In addition, due to the delays in obtaining the WV household survey data, two students at UAN conducted limited household surveys in two zones of Huambo Province, to understand smallholder production and marketing systems in depth, while gaining greater experience in field survey data collection. Kiala supervised the development of the research for their "Licenciatura" degrees, Donovan provided input, and the students are currently analyzing data and writing up the research. The CRSP funded their field research through funds to UAN, and we expect the draft reports in the next semester.

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 marketsheds 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 Sub-objective 2.3: undertake econometric analysis of the determinants of market participation by producing households, including sex of household head as an explanatory variable.

Approaches and Methods:
Objective 2.1: Multidisciplinary Action Research, Spacial and Temporal Analysis, and Institutional Capacity Building

During the first 18 months, the project will 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 will assess with partners the development of a formal Bean/Cowpea Task Force, if the stakeholders support and commit their time and efforts, but at the very least, an informal bean/cowpea task force will be brought together as a working group. The task force will have input into the design of the activities and receive regular feedback on findings. The task force will be relevant for all objectives.

Spatial and temporal analysis of existing national agricultural survey databases will be carried out and the production and marketing data will be presented tables and in the form of maps using GIS. The tables for the descriptive analysis will be specified jointly by PI from MSU and IIAM/CESE with the participation of the staff from SIMA. The PI/IIAM will be responsible in carrying out the statistical analysis. The GIS mapping will be led by the PI from MSU with on the job training of CESE staff. Report write-up will be led by the PI from MSU with participation of PI from IIAM. Production of the policy brief will be under the responsibility of the PI from IIAM

Institutional capacity building will take the form of on-job training of two staff from CESE and two from SIMA to gain skill in using statistical package STATA for descriptive analysis of survey data and in the use of GIS to present results in maps. The on-job training will be provided by MSU staff.

Objective 2.2: Multidisciplinary Action Research
This objective will be met using the previously described multidisciplinary action research approach with the task force--including focus group discussions with smallholders and field observations in the main agro-ecologies, as well as a rapid appraisal of markets during the major marketing season. Focus group discussions will also solicit detailed information about bean/cowpea production and access to input and output markets. The rapid appraisal will focus on marketing channels and margins. Through focus group discussions with producers and traders, relevant constraints and opportunities will be identified; and potential pilot interventions will be identified and prioritized to improve competitiveness of beans and cowpeas in the principal production agro-ecologies. Existing marketing channels and marketing margins will be documented.

The focus group discussion will be facilitated by staff from IIAM/CESE with backstopping from PI from MSU. The rapid appraisal of markets will be led by staff from SIMA with backstopping by the PI from MSU.

Institutional capacity building will take the form of in-service training on focus group discussion methods and rapid appraisal and will benefit staff from CESE, SIMA and IIAM Zonal Research Centers.

Objective 2.3: Participant Training and Organization of Data Set
During the first 18 months of the project, it was initially proposed that: a) a participant trainee (IIAM/CESE staff member) would be enrolled at MSU to pursue MS degree program in Agricultural Economics at MSU. During his/her degree program s/he would acquire skills to undertake sophisticated econometric analysis using appropriate and relevant statistical packages; and b) the participant trainee would organize existing household survey data and, if needed, conduct fieldwork to gather additional data to perform the econometric analysis (MS thesis).

Results, Achievements and Outputs of Research:
Objective 2.1: Multidisciplinary Action Research, Spacial and Temporal Analysis, and Institutional Capacity Building

Due to staffing changes at the market information service (SIMA), the analysis and draft report are delayed and only partially completed. There were 38 traders of vulgar beans (known locally as "feijao manteiga") 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 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.

Objective 2.2: Multidisciplinary Action Research
In Mozambique, field research was conducted using rapid appraisal and key informant interview. The draft report needs 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. As with Objective 1, having Donovan in country to work with Mozambique PI will be valuable to move forward in the coming semester. This objective, including the Task Force implementation, remains a key one for all the parties involved.

Objective 2.3: Participant Training and Organization of Data Set
The MS student had begun her studies at the University of Pretoria, has a designated advisor there, and a draft study and research plan. She will move forward on jointly developing the research proposal with him and CRSP collaborators. The 2008 TIA (household) data are only now available and combined with information from last year's rapid appraisal and the price data collected through the market information system, SIMA, she will has an excellent set of data for her research.

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.

Approaches and Methods:
Objective 3.1: Identification of Organic Fair Trade Bean Markets in the US

During the first 18 months of the project, key informant interviews and web searches will identify agents involved in international and domestic bean markets in the US. Researchers will contact US distributors/retailers of organic/fair trade commodities to identify interested buyers, determine required grades and standards, and negotiate purchase commitments.
Objective 3.2: Identification of Organic Methods for Producing Beans

During the first 18 months of the project, EAP researchers will identify organic production methods that meet international standards for organic production and test these methods via on-farm trials. Such aspects as IPM and soil fertility enhancements with organic improvements will be included.

Objective 3.3: Identification of Farmer Gropups to Produce Organic Beans

During the first 18 months of the project, EAP researchers will use identify interested farmer groups (CIALs) and collaborating NGO interested in growing organic beans and train them on organic bean production methods.

Objective 3.4: Identification of Private Sector Agents

During the first 18 months of the project, private sector participants will be identified who are interested in participating in the project.

Results, Achievements and Outputs of Research:
Objective 3.1: 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. However, given the delay in initiating the organic field trials (due to the delayed availability of funding) the 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 US 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 possible for TransFair USA to certify dry beans. TranFair 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.

Objective 3.2: Identification of Organic Methods for Producing Beans

During this period, practices most commonly used by small farmers on their crops and those recommended in the literature were identified. A workshop with farmers from the Yojoa Lake region was held 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 the organic practices was developed. The common practices include the preparation and use of organic fertilizers such as compost and bokashi, and natural pesticides from neem, madreado (Glyricidia sepium) and other plants, and manure ash, lime and other materials. Biological control of pests with already available products was identified as promising by farmers and some were already testing some of these products (Trichoderma, Beauveria). Also, the use of rhizobium and mycorrhizae inoculation was suggested.

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 Yojoa Lake and Yorito regions 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 as a good alternative because of the raising costs of fertilizers and pesticides and the similar productivity observed in organic plots.

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Objective 3.3: Identification of Farmer Groups to Produce Organic Beans

During this period 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 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 of the type of farmer group and its members. Small and poor farmers from the hillsides of the Yojoa Lake and Yorito, with very small plots to cultivate or landless farmers that have to rent land season by season, are interested in using organic practices to improve bean productivity 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 training activities offered by the project and in conducting the organic bean ECOFRIJOL trial.

Objective 3.4: Identification of Private Sector Agents

During February 2009, the PIs again met with the Michael Hawit and Ms. Kira Hasbun, who noted the recent volatility of Honduran bean prices, provided details on costs related to transporting, cleaning, and shipping/exporting beans to Houston, and mentioned a US-based distributor who might be interested in importing specialty beans (i.e., certified as organic, sustainably produced, fair trade). Mr. Hawit 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 US unless a waiver is obtained. In a meeting with Eduardo Carrasco, owner of one of Honduras' largest bean wholesalers/exporter (typically exporting 16 containers of 20 MT/month), we learned that during the past year he had exported few beans, due to the closure o the border. Subsequently, the PI's met with Arturo Galo (Director of SAG/DICTA), who reported that Honduras did not have an embargo on bean exports—rather, it was only issuing phytosanitary certification (required for exporting) to farmer cooperatives—not to private brokers/traders. Galo assured us that the Ministry of Agriculture (SAG) would allow the project to export beans, if a farmer association initiated a request to SAG to export and that DICTA would be willing to provide technical assistance to the project. In addition, the PIs met with Eduardo Chirinos (USAID) and Jose Antonio Ortizs (APHIS), who provided information on inspection requirements for exporting beans to the US. In a meeting with Ruben Castellanos, 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.

Explanation for Changes

Angola: UAN emphasized the need to have the MS student begin his studies in Brazil and researchers worked hard to ensure those studies. The transaction costs were high, however, and took time away from the research. The difficulties getting a visa for Angola for Donovan also delayed implementation. The research component of this project has had delays, but at the present time, there is work towards having the needed research output. The challenges of research in Angola relate to the lack of trained staff and the project has contributed to increased training, as seen by the higher numbers trained than anticipated.

Mozambique: Getting the MS student in Pretoria to start her studies needed a strong effort on the part of the researchers and the Pulse CRSP administration. For CESE, that training is high priority and its success well appreciated. The research component of the project has had difficulties, however, and we hope to overcome them with the presence of Donovan in Mozambique as a resident advisor with the MSU project at IIAM. The Value Chain training was expanded to incorporate a basic training on value chain concepts as well as intensive training on implementation of value chain analysis. The USAID-funded MSU project co-funded the two modules at IIAM. There has been a request for additional training as well. Since the SIMA team was already trained in rapid appraisal methods and able to guide new staff, the training was deemed not critical for IIAM at this time. The focus group training was conducted under the USAID MSU project in late 2008, so it is not needed here.

Honduras: During the period April 2008- September 2009, the project has worked with farmer groups from two types of organizations, ARSAGRO and CIALs. The first is a rather large organization of farmers located in the east central region of Honduras, which have been involved in production and commercialization of beans for many years, including some export to other countries o the Central American region and a few times to the US. ARSAGRO have had a lot of support from different projects and have good storage and processing facilities. Unfortunately, the interest of ARSAGRO has been limited to send participants to the training workshop offered by the project. In the other hand, farmers from CIALs are small groups of poor farmers located in less productive hillsides regions and with limited resources, and some have to rent land to produce beans and corn season after season because they are landless farmers. The CIALs groups have shown more interest in participating in the project activities; farmer from CIALs have already began to produce and use some organic products on bean production and have been involved in conducting the organic trials distributed by Zamorano. Due to the lack of resources of farmer from CIAL facilities for producing organic fertilizer need to be implemented by the project. Under the situation described before, to this moment it has been not possible to start a formal process for organic production with any of the two groups.

Networking and Linkages with Stakeholders

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 (DSA (Food Security Department) and INCER (Cereals Institute)) or in extension activities with smallholders (IDA (Extension Service). The working relationship between IIA (Angolan Research Institute) and UAN is strong and both are based in Huambo, facilitating the linkages. There are two other Pulse CRSP activities in Angola, both based with IIA. Continued discussions with the breeding program with 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).

Prior to traveling to Brazil for studies, Chaves conducted interviews with supermarkets and wholesalers in the Huambo area. He and Donovan also conducted a rapid appraisal field trip to local markets in late 2008. The small scale of marketing was considered to be a constraint in local markets as well as the mixing of varieties when selling. It is not uncommon to see women traders sorting through the beans to try to achieve greater uniformity and thus gain a higher prices for the beans. The value chain diagnosis was only preliminary and needs further work before it is ready for publication. A research collaborator is currently collecting price data in the main market of Huambo. IAM staff participated in the Value Chain training, and will be involved.

Mozambique:During the first 18 months of the project, a bean/cowpea taskforce including the principal stakeholders will be created and will have the following functions: 1) review the activities to be undertaken by the project; 2) participate in the evaluation pilot production and market interventions; and 3) promote the uptake of the recommendations arising from the study

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. The project is very much behind on this objective and recognizes the need to focus on it in the coming months, prior to the main bean marketing season in April-June period. The rapid appraisal is helpful in highlighting the demand differences among the various markets for beans and the need to specialize on the type of beans given the consumer. For instance, the Malawian consumers demand the darker beans, whereas the Maputo consumers demand white and speckled beans. The European market also has higher demand for the white beans.

Honduras: During the past 12 months, the PIs met with several stakeholders/HC institutions to provide an overview of the research project and solicit their suggestions for implementation, including Eduardo Chirinos (USAID), (APHIS), Michael Hawit and Kira Husbun (Rojitos, a bean processor/exporter), Arturo Galo (Director of SAG/DICTA). Jose Antonio Ortis (APHIS), Edwardo Carrasco (director of a large bean wholesaler/exporter) and Ruben Castellanos (Director of 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 Yorito and the Yojoa Lake conducted by the CIAL groups.

Leveraged Funds
Name of PI receiving leveraged funds**:** Cynthia Donovan
Description of leveraged Project: Angola household dataset completed with World Vision collaboration
Dollar Amount: $0
Funding Source: WV, Gates

Name of PI receiving leveraged funds: Cynthia Donovan
Description of leveraged Project: Mozambique training jointly by USAID/MSU Food Security Project & IIAM
Dollar Amount: $0
Funding Source: FS, IIAM

Name of PI receiving leveraged funds: Juan Carlos Rosas
Description of leveraged Project: Honduras-Organic Farming Workshop (FDN 1000)
Dollar Amount: $1,000

Name of PI receiving leveraged funds: Juan Carlos Rosas
Description of leveraged Project: Honuras-Practical Training (FDN 1000)
Dollar Amount: $1,000

Contribution to Gender Equity Goal

Angola: During the value chain training, there was active participation of 8 women and in data entry 4 women received training. The WV Prorenda Baseline survey and survey report will analyze gender components, and specifically targeted women in the sampling, interviewing 314 women (50% of sample).

Mozambique: The MS trainee is a woman, Ana Lidia Gungulo. During the Value Chain training, 13 women scientists and analysts attended the first Module, and 7 women continued through to the second applied module. As indicated earlier, the rapid appraisal of markets interviewed 63 women traders, to gain their perspective on markets and trading.

Honduras: In the organic farming workshop 2 o the 16 participants were women. In the practical training in organic farming, 2 of the 8 participants were women. In the workshop on organic practices used by farmers, 2 o the 8 participants were women.

Progress Report on Activities Funded Through Supplemental Funds

Not Applicable--no supplemental funds received

Capacity Building Activities: P1-MSU-2

Degree Training:

First and Other Given Names: Ana Lidia
Last Name: Gungulo
Citizenship: Mozambiquan
Gender: Female
Degree: M.S.
Discipline: Agricultural Economics
Host Country Institution to Benefit from Training: IIAM
Training Location: University of Pretoria, South Africa
Supervising CRSP PI: Donovan, Cynthia
Start Date: 2/09
Project Completion Date: 7/11
Training Status: Active
Type of CRSP Support (full, partial or indirect): Full (Category 1)

First and Other Given Names: Esteveo
Last Name: Chaves
Citizenship: Angolan
Gender: Male
Degree: M.S.
Discipline: Agricultural Economics
Host Country Institution to Benefit from Training: UAN
Training Location: University Federal Vicosa, Brazil
Supervising CRSP PI: Donovan, Cynthia
Start Date: 2009
Project Completion Date: 12/11
Training Status: Active
Type of CRSP Support (full, partial or indirect): Full (Category 1)

Short-term Training:

Type of Training: In-service training
Description of training activity: Provision of skills to the trainees on using value chain concepts to evaluate bean and cowpea supply and demand systems nationally and regionally
Status of this activity: Completed as planned
Reason if training activity not completed as planned: Due to scheduling conflicts, this activity was postponed until 12/08.
When did the activity occur?: 12/08
Location: UAM, Huambo
Who benefited from this activity?: A total of 40 participants attended the Value Chain training, rom both the University (UAN) and from the Agricultural Research Institute (IIMA).
Number of Beneficiaries: 40
  Male: 32>
  Female: 8
  Total: 40

Type of Training: In-service Training
Description of training activity: Provision of skills to the trainees on data entry and processing and econometric analysis of bean and cowpea production and marketing data
Status of this activity: Completed as planned
Reason if training activity not completed as planned: Training on econometric analysis postponed due to lack of researcher time in Angola, but completed in 3/09
When did the activity occur?: 3/09
Location: UAM, Huambo
Who benefited from this activity?: Research collaborators.
Number of Beneficiaries: 10
  Male: 6>
  Female: 4
  Total: 10

Type of Training: In-service Training
Description of training activity: Provision of skills to the trainees on participatory focus groups discussions to gather insights on beans and cowpeas based farming systems, major constraints and opportunities for bean/cowpea sub-sector development and new strategies for development of bean/cowpea markets towards increased bean and cowpea production and productivity
Status of this activity: Postponed
Reason if training activity not completed as planned: Due to scheduling conflicts, this activity has been postponed until 2009.
When did the activity occur?:
Location: IIAM, Maputo
Who benefited from this activity?: Info not provided
Number of Beneficiaries: 6
  Male: >
  Female:
  Total:

Type of Training: In-service Training
Description of training activity: Provision of skills to the trainees on participatory rapid rural appraisals to elicit key informants to provide insights on beans and cowpeas based farming systems, production constrains and potential demand for beans and cowpeas nationally and regionally
Status of this activity: Canceled
Reason if training activity not completed as planned: Training on other topics has been prioritized by IIAM and SIMA staff are already trained.
When did the activity occur?:
Location: Zonal Center of IIAM
Who benefited from this activity?: Info not provided
Number of Beneficiaries: 6

- Male: >
- Female:
- Total:

Type of Training: In-service Training
Description of training activity: Provision of skills to the trainees on using value chain concepts to evaluate bean and cowpea supply and demand systems nationally and regionally
Status of this activity: Completed as planned
Reason if training activity not completed as planned: Due to scheduling and time conflicts, the training was postponed, but completed in 3/09.
When did the activity occur?: 3/09
Location: IIAM, Maputo
Who benefited from this activity?: Staff of IIAM.
Number of Beneficiaries: 4

- Male: 35>
- Female: 20
- Total: 55

Type of Training: Practical Training
Description of training activity: Practical training for farmers who will grow organic beans and EAP staff interested in learning about organic bean production methods.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: September 2008
Location: Honduras
Who benefited from this activity?: farmer groups participating in organic bean production, and NGO technicians/EAP staff interested in learning how to grow organic beans
Number of Beneficiaries:

- Male: 13>
- Female: 2
- Total: 15

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.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: 9/08
Location: Zamorano, Honduras
Who benefited from this activity?: Project collaborators
Number of Beneficiaries: 16
Male: >
Female:
Total:

Type of Training: Practical training in organic farming
Description of training activity: The workshop emphasized practices to prepare and produce organic fertilizer and products to control pests and diseases.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: 4/08
Location: Zamorano, Honduras
Who benefited from this activity?: Project collaborators.
Number of Beneficiaries: 8
Male: >
Female:
Total:

Type of Training: Workshop on organic practices used by farmers
Description of training activity: The workshop compiled the practices commonly used by farmers to prepare and produce organic fertilizers and products to control diseases and pests.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: 3/09
Location: Yojoa Lake, Honduras
Who benefited from this activity?: Project collaborators
Number of Beneficiaries: 8
Male: >
Female:
Total:

Dry Grain Pulses CRSP

Report on the Achievement of "Semi-Annual Indicators of Progress"

(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

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

	Abbreviated name of institutions											
	MSU			Univ. Agos. Neto			IIAM			EAP		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***
	Tick mark the Yes or No column for identified benchmarks by institution											
Angola												
Objective 1. Collect/analyze secondary information to document trends, information gaps												
Draft literature review on agricultural production and markets in Angola, focused bean and cowpeas												
Objective 2. Interview subsector participants to develop value chain diagnosis, collect info. needed improve performance & identify constraints to subsector growth												
Diagnostic: Lic. Thesis proposal: Farmer marketing												
Diagnostic: Lic. Thesis proposal: Public markets: Sources and sales												
Diagnostic: proposal: Formal Private sector sources and destination												
Diagnostic: Lic. Thesis: Farmer marketing												
Diagnostic: Lic. Thesis: Public markets: Sources and sales												
Diagnostic: Formal Private sector sources and destination												
Draft Value chain diagnostic	1		X	1		X						
MS Thesis proposal	1		X	1		X						
Objective 3. identify, constraints, opportunities, and potential pilot interventions to improve competitiveness												
Participative survey with NGO in Planalto region												
Draft article on smallholder marketing												
Outreach with NGO on smallholder marketing re	1		X	1		X						

Dry Grain Pulses CRSP
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Benchmark Indicators by Objectives	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***
	Tick mark the Yes or No column for identified benchmarks by institution											
Mozambique												
Objective 1. Analyze spatial & temporal patterns of dry bean production & marketing, using national survey data (TIA), disaggregated by gender												
Tabular results of spatial analysis from TIA												
Summary report on price analysis (SIMA data)												
Synthesis Paper on spatial and temporal analysi	1		X				1		X			
Policy brief on production	1		X				1		X			
Objective 2. Map marketsheds for dry bean production areas. document market preferences & work with breeders to test varieties with desirable market characteristics to improve competitiveness												
Maps on production and marketing (TIA results)												
Draft rapid appraisal (Windshield Survey) bean/cowpea section for instrument												
Conduct focus group discussions on preferences												
Conduct rapid appraisal with SIMA participation												
Report on focus group discussions												
Report on rapid appraisal (Windshield Survey)												
Establishment of bean/cowpea task force												
Presentation of diagnostic results to stakeholders	1		X				1		X			
Joint meeting with IIAM breeders on market results and consumer preferences to identify potential interventions with production							1		X			
Working paper (for obj 1& 2)	1		X				1		X			
Policy brief (for obj 2)	1		X				1		X			
Objective 3. Undertake econometric analysis of the determinants of market participation by producing HHs, including HH head/gender as an explanatory variable												
Organize unified TIA dataset												
Draft M.Sc. thesis proposal	1		X				1		X			

Dry Grain Pulses CRSP
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Benchmark Indicators by Objectives	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***	**10/1/09**	**Y**	**N ***
	Tick mark the Yes or No column for identified benchmarks by institution											
Honduras												
Objective 1. Contact US retailers to identify markets for organic fair trade beans												
List of US retailers with potential for organic fair trade beans												
Identification of potential certification agency and the standards that are to be met for fair trade organic certification (preliminary assessment, confirmation assessment assessment)	1	X										
Objective 2. Validate via field trials agronomic recommendations for growing organic beans												
identify production technologies for field trials												
Establish initial field trials												
Report on initial trial results												
Establish second set of field trials												
Report on second set of field trials										1	X	
List of best practices for growing organic beans										1	X	
Objective 3 Train farmers to grow organic beans												
Identify farmer groups/NGOs interested in producing organic beans										1	X	
Train farmers on organic bean production methods										1	X	
Initiate production of organic beans for the US market										1		X
Objective 4. Establish market linkages with private market participants												
Establish list of firms available to transport, clean, and export organic beans; cost of these services (initial assessment, confirmation assessment)	1	X										

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

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

		Abbreviated name of institutions											
		MSU			Univ. Agos. Neto			IIAM			EAP		
		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives		10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
		Tick mark the Yes or No column for identified benchmarks by institution											
Objective 4: Institution Building													
Angola:	Identify trainee for MS training at U. Pretoria												
	In-service training STATA												
	In-service training on value chain analysis												
	Begin/continue MS degree training in SA				1	X							
	Begin thesis fieldwork in Angola				1		X						
Mozambique:	Identify trainee for MS training at MSU												
	Begin MS degree training at MSU												
	Conducts thesis fieldwork in Mozambique							1		X			
	In-service training STATA												
	In-service training GIS												
	In-service training on value chain analysis												
	Draft Focus group guide												
	In-service training focus group discussion methods												
	In-service training on Rapid Rural Appraisal												
Honduras:	Conduct first practical training for organic bean farmers												
	Conduct second practical training for organic bean farmers										1	X	

Name of the U.S. Lead PI submitting this Report to the MO **Richard H. Bernsten**

Richard H. Bersnten **10/1/2009**
Signature **Date**

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Expanding Pulse Supply & Demand in Africa and Latin America: Identifying Constraints & New Strategies
Lead U.S. PI and University: Bernsten, Boghton, and Donovan, Michigan State University
Host Country(s): Angola, Mozambique, and Honduras

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women	1	0	1	1
Number of men	1	1	2	1
Short-term Training: Number of individuals who have received short-term training				
Number of women	8	2	18	30
Number of men	20	13	34	82
Technologies and Policies				
Number of technologies and management practices under research	6	0	0	5
Number of technologies and management practices under field testing	0	0	6	3
Number of technologies and management practices made available for transfer	0	0	9	2
Number of policy studies undertaken	3	0	4	2
Beneficiaries:				
Number of rural households benefiting directly	0	0	0	0
Number of agricultural firms/enterprises benefiting	0	0	0	0
Number of producer and/or community-based organizations receiving technical assistance	3	0	13	12
Number of women organizations receiving technical assistance	0	0	3	1
Number of HC partner organizations/institutions benefiting	8	0	15	5
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	0	0	0	0

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

Principle Investigators

Jonathan Lynch, Pennsylvania State University, USA

Collaboratoring Scientists

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Celestina Jochua, IIAM, Mozambique
Soares Xerinda, IIAM, Mozambique
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Kathleen Brown, Penn State, USA

Abstract of Research Achievements and Impacts

At Zamorano, 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 QTL 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.

A bean breeder from Malawi, Virginia Chesale, has begun her graduate program at PSU. Nicaraguan agronomist Ana Vargas received training at PSU. Facilities and expertise for conducting studies in drought and low fertility tolerance have been upgraded at Zamorano. IIAM staff were trained in field techniques for social and economic network analysis/GIS.

Project Problem Statement and Justification

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.

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. Several of these traits can be evaluated in rapid screens with young plants, greatly facilitating breeding and selection.

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.

We also need a better understanding of 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 production in Africa and Latin America.

Planned Project Activities for April 1, 2008 - September 30, 2009

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

Approaches and Methods:
Drought and poor soil fertility are primary constraints to pulse production in developing countries. Several specific root traits that enhance bean productivity under drought and low fertility stress have been identified. The overall goal of under objective 1 is to improve bean production in Africa and Latin America through genetic improvement.

The activities under this objective include collection of germplasm, phenotyping root traits, screening root traits for low P/drought tolerance, introgression of root traits into elite lines in Africa and Latin America, and evaluation and development of low P/drought tolerant varieties for farmers using PBV and PVS. Bean germplasm will be collected from various breeding programs in Africa and Latin America: CIAT, SABRN, BILFA and BIC, regional landraces, improved cultivars, advanced lines. Bean germplasm will be systematically screened for key root traits including root hair length, root hair density, basal root whorl number (BRWN), basal root growth angle (BRGA), and adventitious rooting. Phenotypic screens will be conducted under controlled conditions and also as field root crown evaluations. The Latin America germplasm to be screened will also include landraces and improved lines from the Mesoamerican and Andean gene pools of *Phaseolus vulgaris* useful for Central American and the Caribbean, and Interspecific lines from *P. vulgaris* x *P. coccineus* crosses developed by the LAC project during the previous Bean/Cowpea CRSP.

Introgression of root traits conferring greater drought tolerance and P efficiency will be carried out by developing inbred backcross (IB) populations. These IB populations will be composed of breeding lines which combine key root traits with multiple disease resistance and preferred seed types in the target regions. The initial cross will be made between the recurrent parent (selected elite cultivars and/or advanced lines for CA/C and African target countries) and the donor parents (selected germplasm with the higher expression of key root traits), followed by two backcrosses to the recurrent parent and three generations of selfing by single seed descent to develop IB populations.

Field selection will be based on the average performance of advanced IB lines in replicated drought and low P trials, complemented with field and greenhouse evaluations of root traits. Selected lines will be tested individually or in multiline combinations. The identified locations for testing include Lichinga, Gurue, Angonia, Sussundenga and Chokwe in Mozambique, and Zamorano, Yojoa Lake, Yorito and El Paraíso in Honduras. Selection for some disease resistance will be conducted in the field. In addition, advanced lines will be evaluated in Malawi, Nicaragua and Haiti.

Participatory plant breeding (PPB) and PVS approaches will be used in the field trials for evaluation of the performance of the IB lines under drought/low P, agronomic adaptation and commercial seed types. Participants in the value chain of common beans (production, processing, commercialization and export) in the target countries will be invited to participate in these evaluations.

Results, Achievements and Outputs of Research:

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 have been studied previously in Honduras and Puerto Rico, and the results submitted for publication recently (Henry et al. 2009).

During this period, 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 assembly a group of near isogenic lines for testing under farmer conditions.

A field experiment including nine L88 lines differing in shallow and deep root plasticity will be conducted under drought and low fertility conditions to continue studying the relations of these root traits and the tolerance of bean to these abiotic factors. This study is part of the research of two graduate students from the Lynch lab group. The plot to be used for this study started to be prepared and analyzed, and the seed of the L88 lines was produced in the recent months.

Two promising lines derived from our previous PSU/Zamorano collaborative project under the Bean/Cowpea CRSP are 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 were 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).

Several drought and/or low fertility tolerant lines developed previously were included in the advanced lines small red and black bean nurseries (VIDAC) and trials (ECAR) distributed for testing in Central America and the Caribbean to members of the Regional Bean Research Network. In addition, some tolerant lines were included in the set of 50 lines sent to Julie G. Lauren, Cornell University, for testing in Kenya, and in the set of 34 lines sent to Tim Porch, USDA/TARS, Puerto Rico, for testing in Angola. Preliminary results from Angola indicated that several of our 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. An additional line is being considered for release in Honduras during 2009 by other CIAL in another region.

Facilities and expertise for conducting studies in drought and low fertility tolerance in beans have been upgraded at Zamorano. The soil cylinders methodology for studying root traits involved in drought and low fertility tolerance in common beans has been implemented. Root studies are being conducted using the WinRhizo program and other root phenotyping techniques, which were learned after training received at PSU and during the stays of Melissa Ho and Amelia Henry, former PSU graduate students that conducted part of their PhD research in Honduras, in previous years. In addition, during this year Ana Gabriela Vargas, research technician from Zamorano received training for three months at PSU learning root phenotyping techniques currently used by Lynch´s group. Four undergraduate students from Zamorano have conducted their research topics for graduation using these techniques during 2008 and 2009.

IIAM/Mozambique

Activity 1. Collection of common bean germplasm

The objective of this activity is to collect common bean materials to be evaluated in different trials in Mozambique and for selection of 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 collected included several lines from CIAT, local germplasm and the Southern Africa Bean Network. Part of the germplasm was increased and/or evaluated in 2008 and 2009. The germplasm will be stored in Chokwe and Sussundenga Research Station.

Activity 2. 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). The space between plants in the row was 20 cm and between lines was 60 cm. Each genotype was planted in 2 rows of 5 meters. 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. A 1 to 9 rating scale (Table 1) was used to rank the traits of adventitious, basal and primary roots.

Preliminary results show variation in traits of these root classes (Table 1). 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).

Table 2. Summary of the basal root traits of 60 genotypes from CIAT evaluated in Chokwe in 2008. The data are averages of 4 plants per genotype.

Genotype	Basal Whorl #	1) Architecture	Basal Root #	1) Basal Root Length
VTTT 928/9-1	2.75	2	7	8
MORE 92018	2.75	6.25	8.5	7.5
BF 13572-10	2.5	3.25	6.75	7
VTTT 925/3-2-2-1	2.5	3.5	7	9
BF 13573-7	2.5	3.5	6.5	8
VTTT 924/15-2	2.5	3.75	7	7.5
VTTT 918/15-1	2.5	4	7.25	8.25
VTTT 923/9-1-2	2.25	1.75	6.75	7.25
VTTT 924/19-8-1	2.25	2.75	6.75	6.25

VTTT 925/19-4	2.25	3.25	6.25	8.75
BF 13572-3	2.25	3.25	5.5	6.5
VTT 925/2-7-1	2	2	6	8
VTTT 925/7-6	2	2.25	7.5	8.25
BF 13573-6	2	2.25	6	8
BF 13607-8	2	2.75	6.25	6.75
VTTT 925/1-2-1	2	3	7	7.75
CIM-RM00-POP 326	2	3.25	6.5	5
VTTT 926/9-6	2	3.25	6.25	7.5
CAL 143[CONTROL]	2	3.25	6	8
BF 13572-6	2	3.25	5.75	6.75
RA 13166-7-1-2	2	3.25	5.5	8.75
VTTT 918/15-4-5	2	3.25	5.25	6.75
BF 13607-12	2	3.5	6.5	7.75
BF 13572-11	2	3.5	5.75	7.5
VTTT 918/15-2	2	3.5	5.5	6.25
VTTT 925/2-7-1	2	3.5	5	6
VTTT 924/18-6	2	3.75	7	8.5
CIM-RM00-323LN03	2	3.75	6.5	5.25
MN 13509-8-5	2	3.75	6.5	8.5
MN 13389-6	2	3.75	6.25	8.5
RA 13019-3-1-4	2	3.75	6	9
VTTT 916/14-4-3	2	3.75	5.5	7
BF 13607-6	2	3.75	5.25	7.75
MN 13451-6-9	2	3.75	5	8.5
BF 13573-5	2	4	6.25	7.5
BF 13607-9	2	4	6.25	6.25
MR 13508-2	2	4	6	7.25
VAX 6	2	4	6	8.25
CIM-RM00-290LN03	2	4.25	6.5	6.75
CIM-RM00-321LN02	2	4.5	6.75	6.25
VTTT 924/2-4-2-1	2	4.5	5.75	6
VTTT 925/1-4	2	4.5	5.75	6.5
CIM-RM00-321LN01	2	4.75	6.5	7
MN 13389-2	2	4.75	6.25	7.75
BF 13572-5	2	4.75	6	6.25
VTTT 925/12-4	2	4.75	5	8.25
AND 1064	2	5	6.75	8.75
MN 13509-8-6	2	5	6.5	7.75
MR 13508-6	2	6.25	5.25	7.25
VTTT 920/24-3	1.75	2.25	5.25	9
MN 13590-8-3	1.75	2.5	4.75	7
MN 13509-8-1	1.75	2.75	5	9
VTTT 925/2-5-2-2	1.75	3.75	6.25	7
ARA 4	1.75	4	5	7

MR 13456-12-3	1.75	4	4.5	7.5
MR 13508-7	1.75	5.25	4.5	8.5
MN 1874-11-2	1.75	5.5	5.5	8.25
FEB 192	1.5	4.5	5	8.25
MR 13557-16-7	1	3	4.25	7.75

1) – Values from rating scale Table 1

Activity 3. 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 trial was installed in a RCBD with 30 genotypes (Table 3) with 4 replications. The root traits were evaluated at 45 days after germination (podding stage). The space between plants in the row was 20 cm and between lines was 70 cm. Each genotype was planted in 2 rows of 5 meters. Four plants were selected at random in each replication for root evaluation making a total of 16 plants per genotype. 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. A 1 to 9 rating scale (Table 1) was used to rank the traits of adventitious, basal and primary roots. Other measurements including plant phenology and shoot biomass were collected. The evaluation of root traits was done in 2008 in Chokwe and Umbeluzi; and in 2009 the trials ware repeated in Chokwe and Sussundenga.

Table 1. Rating scale used to evaluate root traits.

1) Adventitious root length	1 = 1 cm to 9 = 15-20cm
2)Adventitious root number	Actual number per plant
3) Adventitious branching	1 = no lateral branching to 9 = multiple branches with up to 4 orders of branching
4) Root whorl number	Actual number per plant
5) Basal root length	1 = 1 cm to 9 = 15-20cm
6) Basal root number	Actual number per plant
7) Basal root branching	1 = no lateral branching to 9 = multiple branches with up to 4 orders of branching
8) Basal root depth (root architecture)	1 = Horizontal to 9 = vertical
9) Primary root length	1 = no primary root left to 9 = 20-30cm (depth of excavation)
10) Primary root branching	1 = no lateral branching to 9 = multiple branches with up to 4 orders of branching
11) Nodulation	1 = Excellent (>80 nodules) to 9 = absent (< 10)
12) Root rot	1 = no visible symptoms to 9 = 75% or more of hypocotyl and root with severe lesions

Where:

1. Adventitious root length: 1 = ≤ 1cm; 2 = 2-4 cm; 3 = 4-5cm; 4 = 6-7 cm; 5 = 8-9 cm; 6 = 10-11 cm; 7 = 12-13cm; 8 = 14-15 cm; 9 = 15-20 cm.

3. Adventitious branching: 1 = no lateral branching; 3 = 1 order of ramification; 5 = 2 orders of ramification; 7 = 3 orders of ramification; 9 = multiple branches with up to 4 orders of branching.

5. Basal root length: 1 = ≤ 1cm; 2 = 2-4 cm; 3 = 4-5 cm; 4 = 6-7 cm; 5 = 8-9 cm; 6 = 10-11 cm; 7 = 12-13 cm; 8 = 14-15 cm; 9 = 15-20 cm.
7. Basal root branching: 1 = no lateral branching; 3 = 1 order of ramification; 5 = 2 orders of ramification; 7 = 3 orders of ramification; 9 = multiple branches with up to 4 orders of branching.
8. Basal root deep: 1 = horizontal; 5 = intermediate; 9 = Vertical
9. Primary root length: 1 = ≤ 3 cm; 2 = 4-6 cm; 3 = 7-9 cm; 4 = 10-12 cm; 5= 13-15 cm; 6 = 16-18 cm; 7 = 19-21 cm; 8 = 22-24 cm; 9 = 25-30 cm
11. Nodulation: 1 = Excellent; > 80 pink/red nodules; 3 = Good: 41-80 nodules; 5 = Intermediate: 21-40 nodules; 7 = Poor: 10-20 nodules; 9 = less than 10 nodules (CIAT, 1987).
12. Root rot: 1 = no visible symptoms; 3 = 10% hypocotyl and root with light lesions; 5 = 25% hypocotyl and root with lesions ; 7 = 50% hypocotyl and root with lesions ; 9 = 75% or more of hypocotyl and root with severe lesions (CIAT, 1987).

This part presents results from one of the trials conducted in Chokwe in 2008 that was grown under water stress (the irrigation interval was 28 days, while normal irrigation was 15 days). 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) (Table 2). 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 (Table 2). The results show a positive relationship between number of root whorls and number of basal roots (Figure 1).

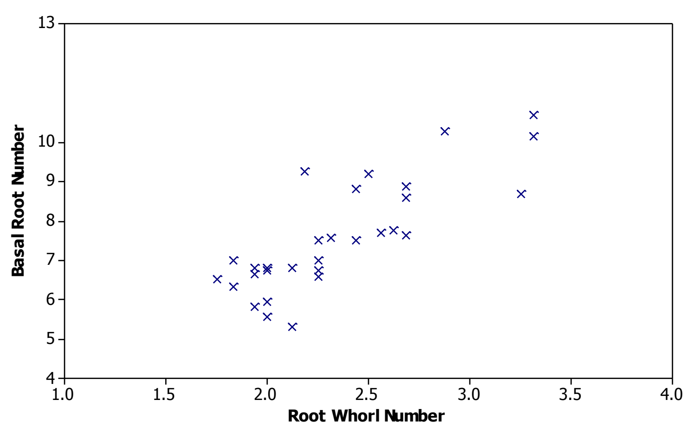

Figure 1. Basal root whorl number vs basal root number measured in 45-day-old -plants in the field.

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) (Table 2). 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. Most of the genotypes did not have nodules (parameter for estimation of BNF) and the incidence of root rot was also low. Shoot biomass analyses were not included in the present report. Figure 2 shows variation in basal root number and architecture root traits.

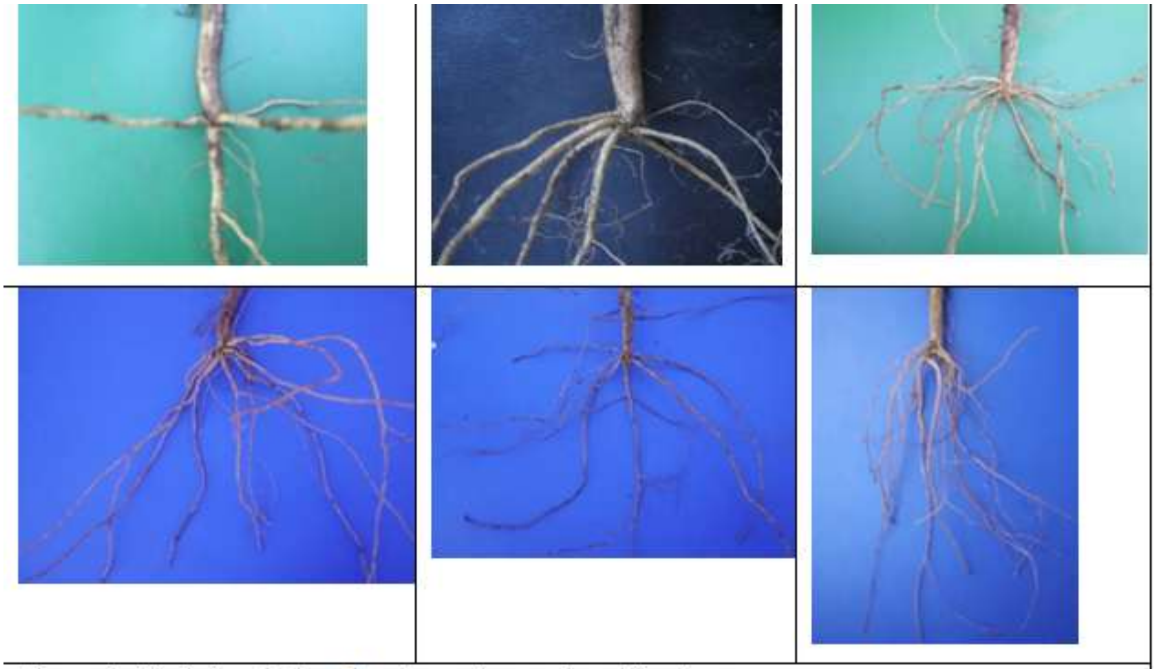

Figure 2. Variation in basal root number and architecture

Table 3. Summary of the root traits measured in 30 genotypes. The data are average of 4 replications per genotype.

Genotype	Adventitious roots			No. whorls	Basal roots		Root architecture	Primary root [1)]	
	Number	Lengh[1)]	Branching[1)]		Number	Lengh[1)]		Lengh	Branchi
Llic-04-1-3	10.81	4.31	2.50	3.31	10.69	7.50	4.94	4.50	3.75
AFR 298	16.94	3.31	2.13	2.88	10.25	7.81	6.50	5.06	3.75
DOUTOR	7.94	2.81	1.69	3.31	10.13	7.13	5.56	3.94	3.25
ICA PIJAO	11.19	4.25	2.13	2.19	9.25	7.38	4.63	4.94	3.31
AFR 708	13.69	4.75	2.25	2.50	9.19	6.94	4.63	4.25	3.25
CAL 143	11.06	2.88	1.94	2.69	8.88	5.94	4.19	4.63	3.63
SEQ 1003	9.81	3.19	1.94	2.44	8.81	7.69	5.63	4.88	3.63
CAL 96	16.06	4.13	2.38	3.25	8.69	7.06	4.31	5.69	3.63
G 4523 (I P)	10.71	2.79	1.67	2.69	8.58	7.83	5.44	5.60	4.08
D. CALIMA	14.56	3.13	2.00	2.63	7.75	7.56	5.75	4.75	3.31
PVA 773	11.69	3.88	1.88	2.56	7.69	7.69	5.63	5.25	2.81
G 19833	21.94	5.00	2.88	2.69	7.63	7.56	4.19	5.00	3.75
BAT 477	12.88	3.94	2.75	2.31	7.56	6.44	5.25	5.25	3.25
BONUS	13.00	4.06	2.44	2.25	7.50	6.56	5.00	5.00	3.50
SAB 258	9.13	3.31	1.94	2.44	7.50	6.38	5.31	4.50	4.00
A 774	16.33	4.00	2.33	1.83	7.00	6.42	3.33	5.75	3.75
RAB 655	16.13	3.63	2.44	2.25	7.00	7.31	4.88	4.19	3.88
DOR 500	7.44	3.56	2.00	1.94	6.81	7.13	3.69	5.19	3.88
G 2333	19.00	4.25	2.25	2.13	6.81	6.00	6.00	4.13	3.25
SEA 15	9.63	2.44	1.50	2.00	6.81	6.38	5.38	5.63	3.56
SEA 5	13.50	3.19	2.00	2.00	6.75	5.81	5.19	4.75	3.56
VAX 1	11.69	2.94	1.94	2.25	6.75	6.94	7.00	5.00	4.25
Carioca	14.56	4.13	2.50	1.94	6.63	7.94	6.88	5.81	4.50
G 21212	12.56	3.06	2.44	2.25	6.56	7.38	5.50	5.63	4.25
BAT 477N.N	9.00	4.38	2.19	1.75	6.50	7.69	3.00	4.81	3.25
SXB 412	11.92	4.08	3.00	1.83	6.33	6.58	3.42	4.83	3.58
SER 16	8.75	3.06	1.88	2.00	5.94	6.63	5.19	4.50	4.00
T.CANELA	7.50	2.06	1.56	1.94	5.81	7.25	5.88	4.88	4.00
DOR 364	8.06	3.06	1.94	2.00	5.56	7.94	6.31	6.00	3.88
SXB 418	10.00	4.31	2.13	2.13	5.31	7.19	5.88	5.69	3.75

[1) –] Values from rating scale Table 1

<u>Activity 4. Development of common bean genotypes adapted to low P soils</u>

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.

Activity 5. 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. The evaluated root classes and the rating scale are shown in table 1. 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 rate 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 trial and for use in breeding as parents.

Activity 5.1. Identification of common bean genotypes tolerant to drought

To identify genotypes tolerant to drought a trial with 21 genotypes with 4 replications was installed in 2009 in Chokwe. The genotypes were planted in 2 blocks: one with irrigation during all crop cycle and the other with irrigation that was interrupted at the flowering stage. The data to be collected include plant phenology, yield performance under normal irrigation and water stress. This trial still at the maturity stage and the data is being collected.

Activity 6. Seed increase of promising genotypes and germplasm maintenance

The goal of the current project is to develop varieties adapted to Mozambique with traits acceptable by farmers, and delivery seed to farmers. Thus, while testing the genotypes we are increased seed of selected promising genotypes that can be available for next phase of the project, National Bean Program, NGOs and other partners for testing in on-farm.

PSU/USA

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 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% (Fig. 6). This trait has never before been considered in bean breeding programs, but these results suggest that it is worth further evaluation.

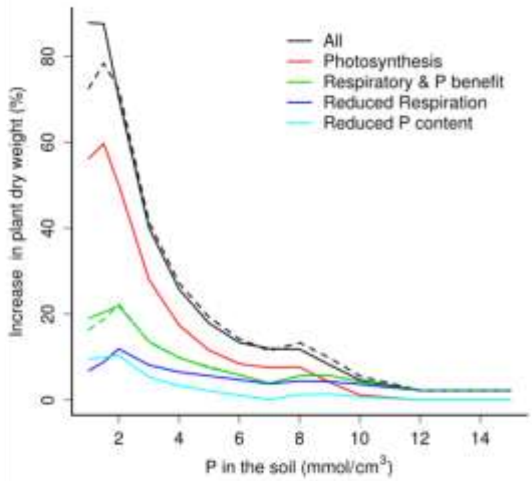

Fig. 6. Root cortical aerenchyma increases plant biomass at flowering at low P availability. Results from *SimRoot*.

<u>Objective 2</u>: Develop integrated crop management systems for stress tolerant bean genotypes.

Approaches and Methods:

A) Evaluation of the effect of P efficient bean genotypes on soil erosion:

To conduct this study we will install erosion lysimeters at IIAM station in Lichinga in Mozambique. Using methods we have developed and used successfully in Costa Rica and Ecuador, these 2 by 1.6 m plots allow the measurement of soil and P lost from erosion from specific genotypes.

B) Evaluation of the utility of local rock P with P efficient bean genotypes:

In this activity we will first obtain ground local rock phosphates from Monapo and Montepuez districts and evaluate the their efficacy for bean genotypes with contrasting root traits in greenhouse and field conditions at Sussundenga and Lichinga. Results will test the hypotheses that more P efficient bean genotypes will have better utilization of local rock P than traditional genotypes, and that local rock phosphate can be a useful source of both P and Ca in red acid soils of Central and Northern Mozambique.

C) Evaluation of synergy of water conserving soil management with drought tolerant genotypes:

Various methods of soil management such as mulching, crop residue management, crop rotations, microcachement systems, and minimum tillage may conserve residual moisture during the dry season and periodic drought. Root traits may have synergy with these methods by for example permitting better exploitation of water deep in the soil profile. These issues have never been investigated.

In this activity we will establish soil moisture plots to compare traditional and drought-tolerant genotypes under traditional versus moisture-conserving soil management to text the hypothesis that combined packages of novel genotypes and integrated soil management have greater potential impact than either approach in isolation. Plant materials to be evaluated will include those developed for drought tolerance by CIAT-Malawi.

D) Evaluation of the effect of root traits in maize/bean intercrops:

The effects of BRGA, BRWN, and root hair length on root competition in maize intercrops will be the MS thesis research of one of the IIAM students at Penn State. Closely related bean genotypes contrasting for root traits (RILs of L-88) will be grown in sole crop or intercropped with maize, with and without irrigation and at high and low P fertility, in field studies at the Rock Springs research station at Penn

State. Root phenotypes will be confirmed through destructive sampling of root crowns as well as nondestructive root imaging with minirhizotrons. Soil cores at R5-R7 will permit analysis of root length by depth. Plant P acquisition and water status will be assessed over time. Results will test the hypothesis that root traits that benefit bean growth under drought and low P may or may not affect yields of maize intercrops depending on spatial niche segregation. Parallel studies with more genotypes and less intensive physiological sampling will be conducted at the IIAM Sussundenga research station in Mozambique.

Results, Achievements and Outputs of Research:
IIAM/Mozambique
This year we started with activities in Lichinga where we installed lysimeters for an experiment on "The effects of phosphorus-efficient common bean genotypes on erosion", and in Monapo where we identified rock phosphate reserves, excavated and transported about 600 kg of Rock Phosphate (RP) that are being ground at the Nampula Agriculture Research Station. We also conducted a pot experiment on use of RP compared to single super-phosphate (SSP) by efficient and inefficient common bean genotypes. We have established moisture plots (experiment in the field) to screen for materials that are drought tolerant. We also identified low P fields where, with local collaborators and partners, we planned to establish experiments with RP and lime in Gurue and Lichinga in the next growing season.

Benchmark Objectives for Agro-ecology			
Agroecology	10/1/2008	4/1/2009	10/1/2009
install erosion lysimeters Lichinga	x		
conduct erosion studies Lichinga		x	
analyze erosion results Lichinga			x
obtain ground local rock phosphate (RP)	x		
conduct greenhouse studies w RP		x	
establish soil moisture plots			x

The benchmark objectives for the agroecology component are presented in Table 1. These objectives include
1) Install erosion lysimeters, conduct erosion studies in Lichinga, and analyze the results;
2) Obtain and grind local rock phosphate (RP);
3) Conduct greenhouse studies using local rock phosphate and establish moisture plots;
4) Establish moisture plots in Chókwe

Activity 1) 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", with 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 (Figures 3, 4). 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


Figure 3. Lysimeters installed, in land with 6% slope, at Lichinga Agriculture Research Station.

Fig. 4a. P-efficient Common bean genotypes L88-57

Fig. 4b. P-Inefficient Common bean genotype L88-43

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 were concluded recently and we do not have statistical analyses concluded yet.

Activity 2) Location, Extraction and Grinding of Rock Phosphate in Monapo-Nampula

In February 2009 we went to Nampula Province in Monapo District which has the largest Rock Phosphate (RP, phosphorite) reserves known in Mozambique at shallow depth (Fig. 5). Phosphate rock from Monapo contains about 18% P. The RP is located from the depth of 3 to 4 m, which is considered very shallow since generally, RP is located at a depth of more than 1000 m. In this case it will be relatively cheaper and easier to explore the RP even with small-scale mining. We transported 600 kg of RP to the Nampula Research Station. From that material we have more than 150 kg of RP ground at the station using a small manual grinder. We now have enough local rock phosphate fertilizer to use in on-farm and on-station trials to be conducted in the next planting season, starting in January/February 2010 in Gurue and Lichinga.

Fig 5a. Rock Phosphate at Nacololo mineral reserve in Monapo District, Nampula-Mozambique.

Fig. 5b. Manual grinder that is used to grind rock phosphate.

Activity 3) Pot experiment in Chókwe and follow up work

One 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 (bean genotype) with three levels (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% P_2O_5) 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. The growing environment was a screen house to help protect against insect damage. There are still no conclusive results, but the 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). There was a difference in the effect of RP as compared to SSP. This suggest that it is necessary to apply the RP before planting to have some incubation time before the crop is planted, and it also may be necessary to apply more RP compared to its equivalent commercial SSP fertilizer. A continuation of this work are several on-farm and on-station field experiments to be conducted in Gurue and Lichinga. The experiments will include liming treatments and RP application, which is planned for November 2009, starting in Gurue.

Activity 4) Establish moisture plots in Chókwe

Moisture plots were established in the field in Chókwe Research Station. This is joint work with the breeding component. We used 21 genotypes among SEQ genotypes known as drought tolerant to serve as control, local materials (genotypes) and Bilfa lines. The treatments were replicated 4 times, and the field was subdivided in two parts to allow interruption of irrigation at flowering in one part and continue the irrigation of the other part through the end of crop cycle. We will measure the growth and yield components (biomass, number of pods, and grain weight) at maturity. The experiment is still in progress.

PSU/USA

Intercropping is common practice by small scale, subsistence farmers, while mono cultures have become the practice in large scale, high input agriculture. Currently, the most common inter cropping system combines maize and bean. Historically, in the Americas, maize and bean were often grown in combination with squash. This system is commonly referred to as the 'three sisters'.

While the benefit of these intercropping systems has been studied before, the focus has always been on pest-management, above ground complementarity and nitrogen fixation. However, competition or complementarity in nutrient acquisition strategies has, to our knowledge, never been researched, despite the fact that these systems are usually grown on soils low in fertility. Especially low phosphorus and nitrogen availability are severe growth constraints reducing yields to 10% or less of yield potential.

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

To test our hypothesis we conducted a two-year field experiment in which we grew mono cultures, maize-bean and maize-bean-squash intercropping systems under phosphorus and nitrogen limiting and non-limiting conditions. We intensively sampled the system with multiple harvests, taking soil cores, root crowns and biomass. We also performed a dual tracer study using rubidium and strontium, both a mobile and immobile tracer, to study relative uptake by the individual plants at two depth. For the analyses of the soil cores, we have developed a genetic technique to differentiate between the roots of the different species. Our tracer study indicated that uptake by the three species may not only differ due to root architectural differences, but also due to kinetic differences. We confirmed these results in a hydroponic study.

The intercropping systems resulted in same or higher yields, depending on year and stress involved (Figure 6). The cores showed that the root distribution with depth differs strongly for each crop. The data suggests some plasticity in responds to nutrient treatment and neighbors, however, further analysis is need to see if these changes can be explained by allometric changes in the plant. The differences between species is much larger than differences between nutrient treatments and cropping systems within a species.

Squash is a deep rooting species, while maize and bean are more shallow. Consistent with this observation, phosphorus deficiency effected squash yields more than maize and bean yields. The tracer study seems to confirm that squash takes up relatively more nutrients from deeper resources, however, further calculations are needed to correct for differences in uptake kinetics. Bean was the most 'indifferent' species with yields/hectare least affected by nutrient or cropping system. Preliminary results suggest that bean is more adaptive than the other species to environmental differences and is thereby able to maintain more stable growth and yield. Maize yields are higher in the intercropping systems, especially under high fertility. This is expected, as under high fertility, light is a primary growth constraint, and in the intercropping system, maize, with its large upright shoot, is able to capture more light.

Our preliminary data analysis supports our hypothesis that *niche differentiation* between these species allows intercropping systems to utilize phosphorus and nitrogen resources more efficiently increasing growth in low fertility soils.

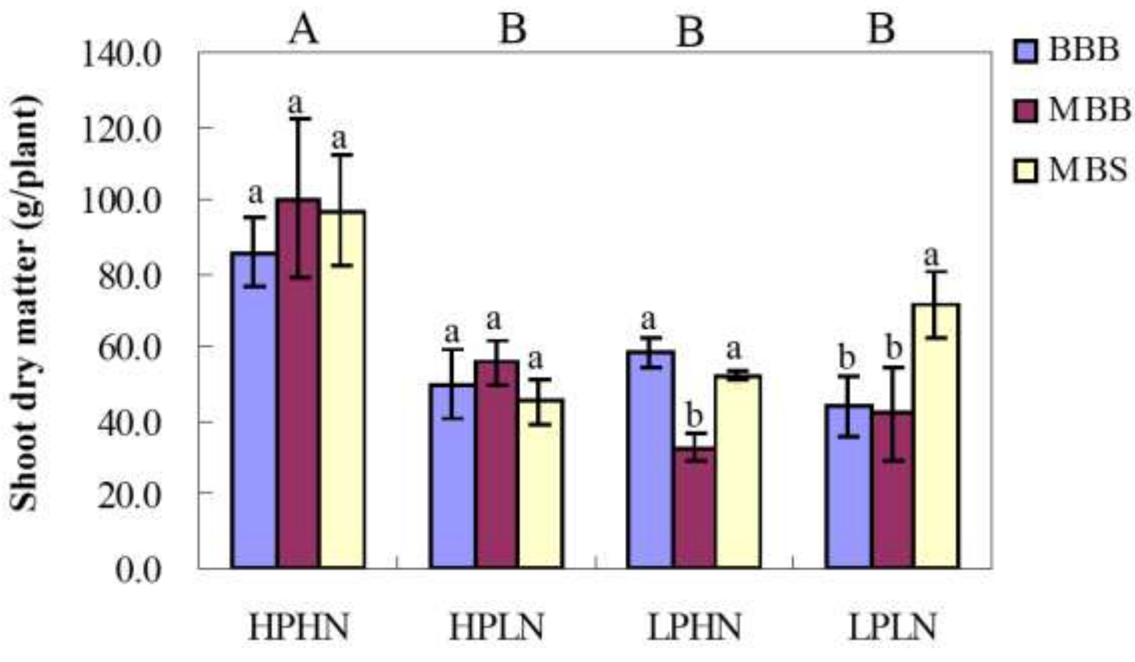

Figure 6. Shoot dry matter of common bean 80 days after planting. HP=high phosphorus, LP=low phosphorus, HN=high nitrogen, LN=low nitrogen, BBB= bean monoculture, MBB=maize bean intercrop, MBS=maize, bean, squash polyculture. Nutrient treatments significantly influenced biomass production. Bean biomass was higher in MBS in low N and low P plots. But intercropping maize and bean, reduced bean biomass when phosphorus was only limiting.

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

Approaches and Methods:
Farm households in the four study areas in Mozambique will participate in identification of a) barriers to widespread adoption, b) constraints to achieving potential income and nutrition impacts, and c) intra-household impacts of introduction of new bean technologies. Questions related to the implications of human disease for production, marketing and health status will be included. To achieve Objective 3, a quantitative survey of farm households will be conducted in villages proximate to the four project study areas (Sussundenga, Lichinga, Gurue, and Angonia).

The Mozambique Vulnerable Soil Vulnerable Household (VSVH) Survey will be conducted in a face-to-face format. Male and female surveys will be conducted, with one adult male (primary decision-maker) and one adult female (a spouse of primary decision-maker) surveyed in each household. It is recognized that not all households will include both spouses; in these cases, two adult decision-makers will be interviewed or only one adult will be interviewed, if two are not available. The location of each surveyed household will be geo-identified using GPS.

The survey instrument will be developed, translated and cleared through the Human Subjects approval process at Pennsylvania State University in the first 6 months of the project. The face-to-face survey will then be pretested at the Sussundenga site; the face-to-face surveys will be conducted at the four Mozambique sites in the period October 1, 2008-September 30, 2009 period.

Results, Achievements and Outputs of Research:
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.

Figure 6. Use of mapping to identify networks to design quasi-experimental interventions for testing of low-P seed dissemination and distribution alternatives under Phase II.

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. As shown in Figure 7, 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.

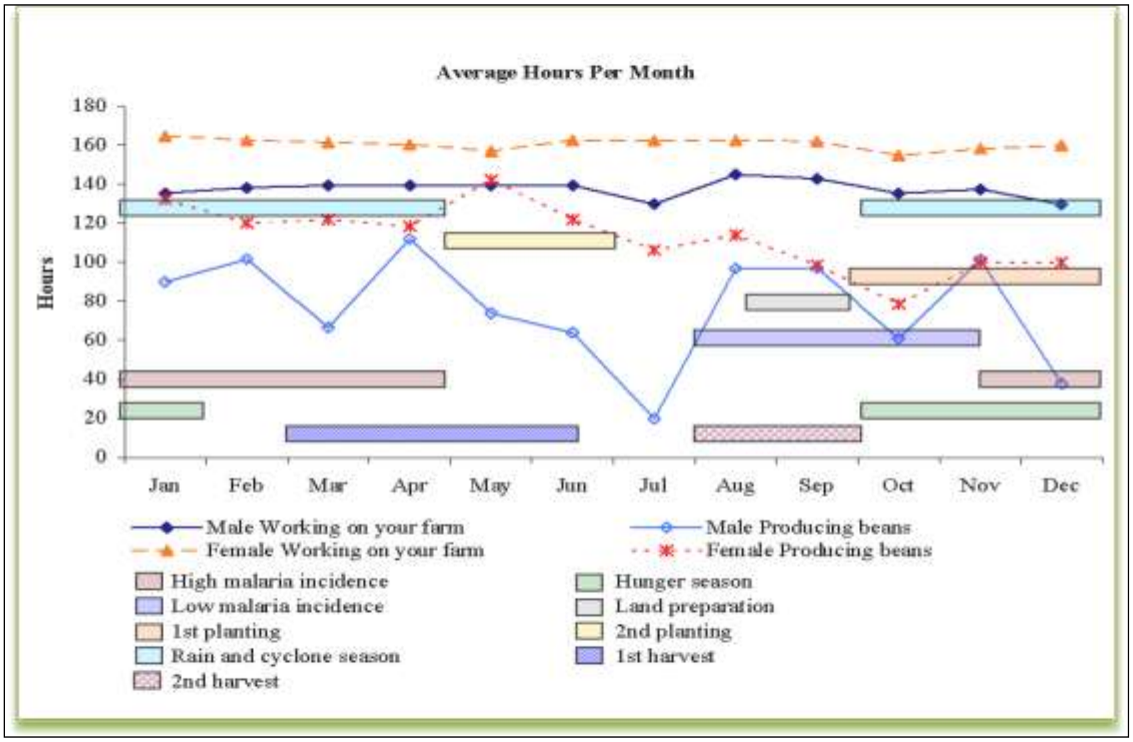

Figure 7. Labor allocation (farm and to bean production) and timing of agricultural production, hunger and malaria season, Mozambique.

The work plan for the next period 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 below*), 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.

Objective 4: Capacity Building.

Our immediate goal under this objective was to recruit two IIAM scientists for MS degree training at Penn State. On the basis of interviews conducted by JP Lynch and M Miguel in early 2008, 5 IIAM scientists were identified as potential candidates for MS training at Penn State, based on English proficiency and professional duties in IIAM. Funds from other projects were used to pay for TOEFL tests for these 5 candidates. Of the 5, one had to postpone his test due to travel, and the other 4 failed to reach the minimum TOEFL requirement for entry to the Penn State graduate school. We identified a candidate from the Malawi Ministry of Agriculture, a bean breeder named Virginia Chesale, who began her studies in the Spring of 2009. In the summer of 2009, with guidance from the MO, we trained another IIAM candidate in English in South Africa, so that he might begin his MS studies Fall 2009, but after two cycles of instruction, this candidate also failed to pass the TOEFL. We now propose to bring an IIAM candidate to PSU for intensive English instruction in Spring 2010, so that MS studies might begin Summer or Fall 2010. Short-term training was accomplished by training Ana Vargas, a Nicaraguan agronomist working with Dr. Rosas at Zamorano, for three months at PSU in the Summer of 2009. Dr. Rosas trained three undergraduate students at Zamorano in undergraduate research projects under the project. Training in field methods for network analysis/GIS was conducted among IIAM staff involved in the socioeconomic survey effort. Luis Sevilla, a El Salvadoran PhD student earning PhD degrees in Agricultural, Environmental and Regional Economics & Demography (fields: international development, production economics, demography) completed his field research in collaboration with this project.

Explanation for Changes

As discussed above, our training goals have been delayed by the inability of IIAM staff, all capable of conversing in English, to meet the minimum English requirements (TOEFL) of the PSU graduate school. Scores of candidates, even after intensive English instruction in South Africa, average around 50% of the minimum required for entry. Clearly, English language training is an important component of the professional development of IIAM researchers.

Networking and Linkages 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. Mission staff appreciated being updated, and appreciated the integrated science-social science approach taken by the project. 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

P.I.s: R Smith, J Findeis, JL Lynch, A Read, M Thomas
Title: Investigating the Social Influences Underlying Agricultural and Malaria Practices in Mozambique in Order to Diffuse Innovations in Beans and Malaria Vector Control
Amount: $50,000
Source: Clinical and Translational Research Institute

P.I.s: J Findeis, R. Smith, A. Sharma, B. Demeke, R. Radhakrishna
Title: Ag 2 Africa: Development of an International-US Learning Laboratory
Amount: $150,000
Source: International Science and Education (IES-USDA)

P.I.s: JP Lynch
Title: Roots of the second green revolution
Amount: $1,426,000 plus ca. $500,000 in capital investments
Source: Howard G Buffett Foundation

P.I.s: JP Lynch, M Miguel
Title: Participation of African Scientists in 17th Penn State Plant biology Symposium
Amount: $9,000
Source: McKnight Foundation Collaborative Crop Research Program (CCRP))

P.I.s: JP Lynch, P Backman (PSU)
Title: SANREM Collaborative Research Support Program (CRSP)
Amount: $179,000 for PSU
Source: USAID

P.I.s: JP Lynch, KM Brown, J Findeis collaborating with S. China Agr. Univ. and Agricultural Research Institute of Mozambique (IIAM)
Title: Increasing Phosphorus Efficiency and Production of Grain Legumes in China and Africa
Amount: $800,000
Source: McKnight Foundation

P.I.s: JP Lynch, KM Brown
Title: Characterization of root traits contributing to enhanced phosphorus acquisition from low fertility soil
Amount: $30,000
Source: International Atomic Energy Agency

P.I.s: JP Lynch and KM Brown (PSU), S Kaeppler (U Wisconsin)
Title: Aerenchyma- a novel mechanism to enhance soil water acquisition by reducing root metabolic costs
Amount: $349,562
Source: AFRI/National Research Initiative

P.I.s: JP Lynch and others at other institutions
Title: Genetic control of root architecture
Amount: $823,557 (PSU portion)
Source: National Science Foundation Plant Genome Program

P.I.s: JP Lynch and colleagues at other institutions
Title: Genetic control of root architecture
Amount: $900,000
Agency: Generation Challenge Program

List of 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

Professional Recognition, Awards and Accomplishments

Jill Findeis was named University Distinguished Professor at Penn State.

Capacity Building Activities: P1-PSU-1

<u>Degree Training:</u>

Student #1

First and Other Given Names: IIAM Scientist 1

Last Name: TBD

Citizenship: Mozambique

Gender: Male

Degree: M.S.

Discipline: Agronomy

Host Country Institution to Benefit from Training:

Training Location: Penn State

Supervising CRSP PI: Lynch, Jonathan

Start Date: 10/08

Project Completion Date: 10/10

Training Status:

Type of CRSP Support (full, partial or indirect): Full (Category 1)

Student #2

First and Other Given Names: IIAM Scientist 2
Last Name: TBD
Citizenship: Mozambique
Gender: Male
Degree: M.S.
Discipline: Plant Nutrition
Host Country Institution to Benefit from Training: IIAM
Training Location: Penn State
Supervising CRSP PI: Lynch, Jonathan
Start Date: 10/08
Project Completion Date: 10/10
Training Status:
Type of CRSP Support (full, partial or indirect): Full (Category 1)

<u>Short-term Training</u>:

Type of Training: In service
Description of training activity: in service training of INTA agronomists in root biology
Status of this activity:
Reason if training activity not completed as planned:
When did the activity occur?:
Location: Penn State
Who benefited from this activity?: INTA agronomists
Number of Beneficiaries: 2

Male:
Female:
Total:

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

Project Title: Improving bean production in drought-prone, low fertility soils of Africa and Latin America - an integrated approach

	Abbreviated name of institutions								
	IIAM			EAP			PSU		
	Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)								
Objective 1									
Aggregate germplasm									
Phenotyping root traits	x	x		x	x				
Screen for drought/low P tolerance	x	x							
Field evaluation/trials of identified genotypes	x	x							
Introgress root traits for drought/low P tolerance	x	x							
Objective 2: agroecology									
install erosion lysimeters Lichinga									
conduct erosion studies Lichinga									
analyze erosion results Lichinga									
obtain ground local rock phosphate (RP)									
conduct greenhouse studies w RP									
establish soil moisture plots	x	x							
intercropping study conducted									
Objective 3: socioeconomics									
develop survey instrument							x	x	
human subjects approval of survey							x	x	
interviewer training completed	x	x							
filed test survey instrument	x	x							
quantitative survey conducted	x	x							
Objective 4: capacity building									
recruit IIAM MS students	x								
MS student practicum							x		x
MS student coursework							x		x
MS student research begun							x		x
INTA training				x	x				
internet access Chokwe		x	x						
analytical capacity at Sussundenga	x	x							
web resource root methods							x	x	
root phenotyping methods				x	x		x	x	
Name of the PI reporting on benchmarks by institution	Miguel			Rosas			Lynch		

Name of the U.S. Lead PI submitting this Report to the MO: Jonathan Lynch

Signature **Date** ######

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Graduate training of a Mozambique trainee did not start because none of IIAM candidates that took TOELF manged to get enough score for admission to a US university so far. Currently, we are witing for another candidate to take TOEFL.

The establishment of Internet Access at Chokwe is stil in progress.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Improving bean production in drought-prone, low fertility soils of Africa and Latin America - an integrated approach
Lead U.S. PI and University: Jonathan Lynch, Pennsylvania State University
Host Country(s): Mozambique, Honduras

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women	0		0	0
Number of men	0		2	0
Short-term Training: Number of individuals who have received short-term training				
Number of women	0		1	1
Number of men	0		1	1
Technologies and Policies				
Number of technologies and management practices under research	3		6	6
Number of technologies and management practices under field testing	0		6	6
Number of technologies and management practices made available for transfer	0		4	4
Number of policy studies undertaken	1		1	1
Beneficiaries:				
Number of rural households benefiting directly	0		256	256
Number of agricultural firms/enterprises benefiting	0		10	10
Number of producer and/or community-based organizations receiving technical assistance	0		10	10
Number of women organizations receiving technical assistance	0		2	2
Number of HC partner organizations/institutions benefiting	1		3	3
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	0		0	0

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

Principle Investigators

Philip A. Roberts, University of California-Riverside, USA

Collaboratoring Scientists

Ndiaga Cisse, ISRA, Senegal
Issa Drabo, INERA, Burkina Faso
António Chicapa Dovala, IIA, Angola
Jeff Ehlers, University of California-Riverside, USA

Abstract of Research Achievements and Impacts

Progress was made in three areas under "Develop improved, pest resistant and drought tolerant cowpea varieties for target regions in sub-Saharan Africa and the US". Final testing and release of cowpea varieties: In California, new 'blackeye' cowpea CB50 was released in 2008 and 8,000 kg Certified Seed produced in 2008 was sold out for 2009 planting. The 2009 crop is being sold by several warehouses as a premium export class. Elite novel dry grain 'all-white' cowpea line evaluations in four on-station trials for grain quality, yield, disease and insect resistance were positive and a release will be attempted next year. In Burkina Faso, 5 tests of two new varieties confirmed improved yields (700-800 kg/ha) and strong farmer interest. In Senegal, 30 on-farm tests were made and Foundation Seed produced to complete release of line ISRA-2065 with thrips and aphid resistance. Advanced yield trials were conducted in the 2008 and 2009 seasons in Burkina Faso (4), Senegal (6) and California (7) on a total of 180 lines for release selection based on grain quality, yield, and disease and insect resistance. Crosses for developing new breeding lines were made in Burkina Faso (7), Senegal (12) and California (21) to combine high yield, grain quality, and abiotic and biotic stress resistance traits. Most crosses were advanced to F3-F4 stage in 2009. Under the seed production and delivery systems objective, the following was achieved: In Burkina Faso, Breeder Seed of 10 improved varieties (>100 kg/entry) was grown in Pobe-Mengao, Foundation Seed of 4 varieties was produced at Saria and Pobe-Mengao, and 2.5 MT of Foundation Seed of 4 varieties from off-season production was sold to Certified Seed producers. 40 lead farmers were trained as Certified Seed producers. In Senegal, 2 ha each of Melakh and Yacine Foundation Seed was produced at Bambey to supply EWA NGO seed producer network. In Thilmakha 1 ha each of Melakh and Yacine Certified Seed was produced by farmers in 2009. Certified Seed was also produced in the Mekhe and Merina areas and women and men farmer groups trained in seed production. From Foundation Seed provided to Producers Professional Training Center, Sangalkam 1 MT of Melakh and Yacine seed was produced in 2008 and a second generation in 2009, plus Certified Seed produced by 10 farmer organizations. A student from Angola started degree training in cowpea germplasm and breeding and will aid in Angola seed production and distribution system assessment.

Project Problem Statement and Justification

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." Genomics and modern breeding methods will be used to improve cowpea for yield limiting constraints. By leveraging genomic resources developed under a complementary cowpea project, we will implement a comprehensive application of modern breeding protocols for cowpea. 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 probably a market for cowpea seed as well.

Recently, 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. We propose to help support increased production of Breeder Seed and work 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.

Training and Capacity Building: The research under these topical areas will provide an excellent framework for training current and new African scientists and capacity building for Host Country

Institutions (*Theme D* "increase the capacity, effectiveness and sustainability of agriculture research institutions which serve the cowpea sector in developing countries).

Planned Project Activities for April 1, 2008 - September 30, 2009

Objective 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.

Approaches and Methods: Three main paths of work will be followed to achieve our research objective. We will complete final testing and release protocols of lines developed under the previous Bean/Cowpea CRSP of other germplasm in the development 'pipeline', and initiate new short- and long-term breeding strategies to develop high-yielding improved varieties.

Final Testing and Release of Varieties
Several advanced breeding lines have been developed under the previous Bean/Cowpea CRSP at UCR and in Burkina Faso and Senegal that are nearing release (Table 1). Limited experiment station and/or on-farm tests are needed to complete the final evaluation of these lines.

Table 1. Varietal candidate lines

Candidate Line	Developing Institution	Releasing Institution	Type	Steps Needed in Workplan Period
03Sh-50	UCR	UCR	Blackeye	Completion of Release, PVP Documentation
07-11-572	UCR	UCR	All-white	Experiment station tests. Breeder and Foundation seed increase
03-11-747	UCR	UCR	'Dry Green'	Experiment station tests. Breeder and Foundation seed increase
IT98K-205-8	IITA	INERA	White	Seed production and on-farm evaluations
Melakh	ISRA	INERA	White	Seed production and on-farm evaluations
KVx421-2J	INERA	INERA	White	Seed production and on-farm evaluations
ISRA2065	ISRA	ISRA	White	Final on-farm evaluation, Breeder and Foundation seed increase

In Burkina Faso and Senegal, final on-farm evaluations of four lines (Table 1) will be conducted, and the lines released by the end of workplan period. In Senegal, candidate ISRA 2065 will be compared to 'Melakh' in on-farm trials grown at five sites in the 'Peanut Basin' area of the country. Each on-farm trial will consist of plots ¼ ha in size. Also, 60 advanced lines will be evaluated in on-station trials at 3 locations (Bambey, Nioro, Louga). The trials will have 4 replications with each plots being four rows and 5 m length.

In Burkina Faso, the 3 varietal candidate lines will be grown in on-farm trials by 5 farmer groups at Pisela Village and at 10 other sites in Central and Northern Burkina Faso. Sites will be considered as replications and each plot will be 300 m^2. In addition, six other new candidate varieties that have been developed at INERA will be evaluated in on-farm trials at the same 10 sites in Central and Northern Burkina Faso.

At UCR, breeder and foundation seed of 03Sh-50 was produced in 2007 in anticipation that this variety would be released in 2008. We will continue to work with at least two farmers and one cleaning warehouse (Cal Bean and Grain, Pixley, CA) by monitoring these fields from planting through sales of the product. The farmers will grow two 15-ha production-scale fields of 03Sh-50 and the standard cultivar CB46. The grain produced will be cleaned at Cal Bean and Grain and this warehouse will supply commercial 'clean-out' information. During the first six months, we will collate existing information from on-station and on-farm trials conducted between 2003 and 2007 with this variety, request formation of a UCR Variety Release Committee, and file for Plant Variety Protection and Variety Registration through the Crop Science Society of America. For 07-11-572 and 03-11-747 (or a related 'sister line'), a 'fast-track' release protocol will be followed to accommodate the needs of potential licensees for these varieties to be made available as quickly as possible. We will be able to do this because these varieties represent new grain types that do not have existing standard varieties with which they can be compared. In anticipation of release of these lines, Breeder and Foundation Seed of these lines will be produced by the end of the workplan period.

A set of five advanced blackeye lines have already been identified as potential blackeye cowpea varieties for the US. These will be included in advanced trials that will be conducted in trials conducted at two locations (Shafter and Kearney) during the workplan period. Each trial will have at least four replications with plots consisting of 4 rows, with rows 8m long. One or more of these varieties may be advanced to candidacy for release by the end of the workplan period.

We will initiate a new two-tiered breeding strategy to meet the immediate and longer term needs of farmers. The **Short-Term Strategy** will use improved and local varieties having both grain quality and agronomic features appreciated by farmers such as appearance, taste, cooking qualities, yield stability, appropriate plant type and maturity. Obvious defects in local and improved varieties will be improved by breeding in resistance to diseases and pests plus other traits, using a rapid recurrent backcrossing approach that will improve productivity and be accepted by farmers. During the first six months, selected varieties to be improved by this approach are given in Table 2.

Table 2. Lines to be improved by introgression of specific traits using backcrossing.

Recurrent Parent Line	**Institution**	**Trait being introgressed**	**Trait donor (non-recurrent) parent**
Yacine	ISRA	Macrophomena	IT93K-503-1
Yacine	ISRA	Flower thrips resistance	58-77
Yacine	ISRA	Striga	SuVita 2
Mouride	ISRA	Large grain	Montiero derived line
Melakh	ISRA	Striga resistance	IT97K-499-39
Melakh	ISRA	Green grain	UCR 03-11-747
KVx396-4-5-2D	INERA	Striga resistance, Large grain	IT81D-994
KVx396-4-5-2D	INERA	Green grain	UCR 03-11-747
IT98K-205-8	INERA	Large seed	Montiero derived line
CB5	UCR	Fusarium wilt	CB27
CB46	UCR	Green grain	UCR 03-11-747
CB46	UCR	Root-knot nematodes	IT84S-2049

During the workplan period crosses between the recurrent and non-recurrent parents will be made, plus the first and second backcrosses, followed by inbreeding the second backcross progenies to develop BC_2F_2 families. Early in the second workplan period, these progenies will be evaluated for trait expression, and a third backcross made onto selected individuals. Molecular markers for some of the target resistance traits emanating from the EST-derived SNP-marker genotyping effort under the GCP-TL1 cowpea project will be used to select progenies carrying required alleles at each BC generation before flowering. This will allow quick identification of individuals without phenotyping for another round of backcrossing.

The **Longer Term Strategy** is to pyramid resistance and grain quality factors in varieties desired by farmers using crosses between elite parents having complementary parental lines. To develop high performing, drought tolerant varieties we will use a 'two-stream' recurrent selection approach. One stream will include the six possible biparental crosses between highly drought tolerant lines SuVita 2, 58-57, TN88-63, IT93K-503-1. The F_1's will be made at UCR, then advanced to the F_2 generation and subjected to seedling screening for drought tolerance. A set of 100 drought-tolerant F_2 individuals will be identified and advanced to the F_3 for each population. By the end of the workplan period, the 100 F_3 lines of each population will be developed. They would then be selected again for drought tolerance at the seedling stage, and 50 F_4 lines selected at UCR. Two of the six populations of 50 F_4 lines would be distributed to each program (UCR, ISRA, and INERA) for drought tolerance phenotyping. A smaller subset of 10 lines would be selected from this evaluation, and reevaluated for drought tolerance at the F_5 generation. Individuals from the most drought tolerant lines will be used for crossing to the improved lines developed under the backcrossing program described earlier and in Table 2. Also in the workplan period, breeders in Senegal and Burkina Faso will choose a set of popular local cowpea varieties for targeted genetic improvement through MAS or MARS. These will be hybridized to sources of known thrips resistance and heat/drought tolerance. Using greenhouse and off-season nurseries, the F_1 and F_2 generations will be advanced as quickly as possible. Individuals selected with markers will be evaluated for trait expression to validate the usefulness of the markers in different genetic backgrounds.

Results, Achievements and Outputs of Research:
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*:* In 2008 we conducted a large lygus resistance trial under unprotected (no insecticide) conditions at Kearney, with 30 entries including CB27, CB46, and CB50. The trial was harvested by hand-picking pods 90 days after sowing from a 5 foot section from the middle of the two middle rows of each 4-row plot. 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. Data from the October harvest including seed damage assays have not been finalized.

All-white and dry-green grain classes: Tests in 2008 and 2009 at two locations of 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. However, in the same 2008 and 2009 field trials the grain yields of 'dry green blackeye' advanced breeding line 03-11-747 and its sister lines were relatively low, with observations of weaker root system development than normal in one location. For this 'dry green' market class further testing of new breeding lines developed from previous crosses will be done to identify more promising materials before release is considered. Now the high-throughput marker genotyping capability is developed, a promising planned approach to expedite selection will be employed next year by using marker-assisted backcross breeding to introgress the 'green genes' into a CB46 or CB50 genetic background, thus retaining the high yield potential and other component traits of CB46 (Table 2).

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. In each village, 3 farmers conducted the evaluation trial. Average yields in 2008 obtained were 700kg/ha for IT98K-205-8 and 800kg/ha for Melakh. The 2009 trials data are not yet completed. The two varieties were preferred because of Striga resistance and their earliness. Farmers started 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. It has been tested extensively in the peanut basin of Senegal and additional on-farm assessments were made during 2008. 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. Demonstration trials were conducted in the South zone of the peanut basin (Kaolack Nioe and Kaffrine) zone in 2009. Larger plot sizes of 1000 m^2 were used for each of the 2 varieties (Mélakh and ISRA-2065) tested. These demonstration trials were conducted in a total of 30 farms. These trials constitute the final activity for an official release.

Advanced yield trials:

In Burkina Faso (INERA): In Burkina Faso, two advanced yield trials were conducted at Saria and Pobe Mengao in both 2008 and 2009. A set of 23 improved insect tolerant lines were compared to a popular released variety (KVx 396-4-5-2D). The KVx 396-4-5-2D variety will be used in the recurrent backcrossing program. Each trial had a randomized block design with 3 replicates. The 2008 trial data allowed selection of the best performing lines and these have been harvested at the two sites in 2009 and performance data are being analyzed. The best performing lines will be re-tested in the 2010 season at multiple sites in anticipation of decisions on release of one or more of the lines.

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 experimental design was a 10 x 10 lattice with 2 replications. Two-row plots 5 m long were used. 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. A randomized block design with 4 replications was used. Individual plots were 4 rows, 5 m long. The two center rows are being used for yield and agronomic characterization of each line, and harvest data are being collected at time of reporting. 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 both of these trials randomized complete block designs with 4 replications and plots size of 4 rows, 5m long were used.

In California: Evaluation of three 'new' advanced blackeye breeding lines for grain yield and quality, and agronomic characteristics was conducted at two locations: At the Shafter and Kearney (Parlier) UC Research and Extension Centers, 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 experimental design both years was a Latin Square with 6 replications. In the 2008 trials with five lines analysis was completed in November 2008, the three best of the five lines were selected for testing in 2009. We conducted Fusarium wilt and root-knot nematode resistance screens of these lines in greenhouse and field plot tests to characterize their resistance profiles. These 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 in the 2008 trials (data not yet analyzed for the 2009 season). 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. Seed-coat splitting was also significantly lower on the three new breeding lines compared to CB46 in 2008; this is being assessed again in the grain harvested from the 2009 field trials. In 2008, percent 'split' seed-coat averaged 8.2, 5.7 and 5.6% for P-87, P-191, and P-203, respectively, compared to an average of 14.8% for CB46, in line with results from previous years.

Crosses for developing new breeding lines:

In Burkina Faso (INERA): Dr. Drabo made all the planned crosses, and these are summarized in Table 3. 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 preference in the sub-region. The range of crosses should allow selection of new larger seeded varieties carrying important insect, disease, Striga and nematode resistance traits, drawing on previous findings from the Bean/Cowpea CRSP project (Sawadogo et al., 2009). 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.

In Senegal (ISRA): In Senegal, all the planned crosses were made by Dr. Cisse at ISRA. The crosses are summarized in Table 4. 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 are in 2009 yield trials. The Mouride x Monteiro lines will 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.

In California: The planned crosses were made at UC Riverside during the summer of 2008 for use in the recurrent back-crossing program (Table 5). Some of these were based on previous introgression crosses with the trait donors, whose best looking late backcross progeny were crossed with the recurrent CB5 and CB46 backgrounds. Small replicated plot field tests of the back-cross populations were made at on–station evaluation sites during the 2008 season (completed in October 2008) to assess seed size and quality, and several promising lines were selected. In 2009 the selected lines were included in replicated trials at the Shafter and Kearney locations and plots have been harvested for yield and grain quality determinations but not yet analyzed. A significant challenge is to select improved lines with acceptable grain size, especially in the CB46 x IT84S-2049 cross because the nematode resistance donor is a small-seeded African line. We anticipate that our ability to make foreground and background selection decisions with the SNP-based marker genotyping will aid in breaking this and other negative linkages.

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 during the reporting period. To develop high performing, drought tolerant varieties we are using a 'two-stream' recurrent selection approach. 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 (Table 6). 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. Genotyping through the platform will be conducted in late 2009 and early 2010 so selected progenies can be grown out during next year.

<u>Objective 2</u>: Strengthen cowpea seed production and delivery systems in Angola, Burkina Faso and Senegal to ensure delivery of improved varieties.

Approaches and Methods: Cowpea seed production and delivery systems in Burkina Faso and Senegal will be strengthened to ensure delivery of improved varieties. Adoption of improved varieties is constrained by inadequate supply of Breeder and Foundation Seed, which in turn limits the Certified Seed that can be produced. Insufficient resources limit growing, harvesting and storing Breeder Seed increases, in turn limiting Foundation Seed and Certified Seed for farmers is due to the lack of Foundation seed coupled with the relatively low interest in cowpea by public and governmental organizations and private seed companies.

We will increase directly amounts of Breeder and Foundation Seed available to Certified Seed producers, help identify new Certified Seed producers, and strengthen and expand proven activities in Senegal and Burkina Faso through leveraged funding from NGOs and USAID Mission funding, if possible. We will work with the national extension services in Senegal (ANCAR), Burkina Faso, and Angola (SENSE) to reach the farmers' organizations in different communities. We will also seek to strengthen the small private seed producers, some of them already working on cowpea.

A strategy adopted by the newly created GCP/ICRISAT 'Legumes for Livelihoods' project that is on-going in Niger, Nigeria, Mali, Tanzania, and Mozambique for cowpea is to improve farmers' access to seed and enhance widespread adoption of improved cowpea varieties through the development and promotion of community seed production and promotion of local markets for seed. Their well-considered view is that no single agency can produce and provide the required quantities of high quality planting seed. Seed of improved varieties can be disseminated through rural retail networks based on government schools. In Senegal, Burkina Faso, and Angola, schools can act as a seed supply center in each village, with teachers trained on procedures for quality seed production. Several progressive farmers will be selected per village and given guidance in seed production and supplied with quality Foundation Seed for multiplication. They will become the source of improved seed for the entire village. From these efforts, local entrepreneurs may arise to form local seed companies. Strong linkages will be developed with PASS (Program for Africa's Seed Systems), WASNET (West African Seed Network) and other programs to derive synergy in promoting local seed enterprises.

In Burkina Faso, Breeder Seed will be produced in the off-season for five varieties (IT98K-205-8, Melakh, KVX421-2J, KVX414-22-2, Gorom Local) on 200 m^2 per variety. The seed will be produced at Bazega under irrigation. Foundation Seed production will be made to ensure an adequate capacity on each of the three INERA stations (Saria, Pobe, and Kamboinse). This activity will generate about 4 tonnes of Foundation Seed on 5 ha planting. This will address the estimated 20 % shortage of Foundation seed, kick-starting an expansion of the self-sustaining system seed production system. Training of farmers as Certified Seed producers will be done in three locations (ZandomaProvince and SenmatengaProvince in the north, and NayalaProvince in the center). At each location, 25 seed producers, a mix of women and men, will be trained. Foundation Seed will be provided and farmers will be trained in seed production, harvest and post-harvest handling, recognizing that this process differs from the production of cowpea for consumption.

In Senegal, availability of Foundation Seed has been identified as a bottleneck for adequate supply of seed to farmers. Foundation seed is used to produce the Certified Seed that is distributed to farmers for production planting. To overcome this, N. Cisse will produce ½ ha of Melakh and ½ ha of Yacine to complement the Foundation Seed production by the ISRA seed unit at Bambey. This effort will help to identify the demand level for Foundation Seed and provide seed for establishing new Certified Seed growers in cowpea production areas where there is currently no formal Certified Seed production effort. To achieve new Certified Seed grower establishment, we will work with the national Extension Service

(ANCAR) and farmer organizations at 3 locations (Thilmakha region, Merina district, Mekhe). At each location, Foundation Seed will be provided and farmers will be trained in seed production, harvest and post-harvest handling, recognizing that this process differs from the production of cowpea for consumption. Organizations who contact ISRA for Certified Seed will be directed to the new Certified Seed producers, to establish a supply and demand relationship that should become self-sustaining.

In Angola, we will conduct an initial assessment of the infrastructure available upon which to develop a viable seed production and distribution system, recognizing that no system exists currently. We will link with government and NGO institutions, including World Vision, Africare, CRS and ADRA-Angolana, to determine opportunities for initiating the cowpea seed system. We will provide guidelines and descriptions for Angolan nationals in multiplication of high quality seed of selected varieties for farmers. In parallel to this effort, the cowpea field evaluations will be conducted under Objective 1, with the aim of identifying candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal and/or Burkina Faso) and IITA varieties. One or more of these candidates will become the first varieties to be formally produced for farmers under the new seed system. We will plan to use the data from the primary season trials, planned for completion in March 2009, to make the variety selection and produce the first generation (G1) of Breeder seed by the end of the workplan period.

Results, Achievements and Outputs of Research:

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.

In Angola: Our initial assessment of the infrastructure available upon which to develop a viable seed production and distribution system has been based on communication within the project, recognizing that no robust system exists currently. This effort is in conjunction with Dr. Beaver who visited Angola in summer 2009 for similar assessments of the bean breeding and seed distribution setup. We were unable to visit Angola during the reporting period, but are hopeful that our interactions with the new trainee Angola trainee Antonio David focusing on cowpea in the MS program at UPR will help develop new approaches with target cowpea varieties.

CAPACITY BUILDING

As reported under Section XII, supplemental funds approved in September 2008 through the CRSP Technical Committee and Director for Capacity Building were used in Senegal and Burkina as planned, and in Angola funds for the vehicle purchase are in the process of being invoiced. Approvals were granted in September 2009 of additional funds for the three Host Country partner Institutions in support of the cowpea breeding and genetic improvement programs. These pass-through funds will be contracted between UCR and the HC institutions at in the next two month, so expenditures of these funds can be made before the new cowpea growing season.

Under Training: MS Training (Breeding) - Angola (Univ. Puerto Rico). Mr. Antonio David, a student from Angola was identified for training in the MS Plant Breeding program through the University of Puerto Rico (UPR). After some delay, he started in the program at UCR in August 2009 for the Fall Semester. We are coordinating with Dr. James Beaver, who is providing local mentorship. Antonio David will work on Angola-based cowpea gemplasm characterization for the research component of the degree.

Degree Training:

MS Student 1:

First and Other Given Names: Antonio
Last Name: David
Citizenship Angola
Gender: Male
Degree Program for training: MS
Program Areas or Discipline: Plant Breeding/Genetics/Plant Pathology
Host Country Institution to Benefit from Training: Angola
University to provide training: University of Puerto Rico
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? Yes
Supervising CRSP PI: PA Roberts and HC PI
Start Date: August, 2009
Projected Completion Date September 2010
Type of CRSP Support (full, partial or indirect) Full
If providing Indirect Support, identify source(s) of leveraged funds:
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $40,000
Indirect cost: None
U.S. or HC Institution to receive CRSP funding for training activity: UC-Riverside.

We have been working with several trainee applicants for the PhD program at UC Riverside, but have yet to have one accepted in and matching with the program. Currently 2 candidates are in the application process, with a start date in the PhD program of Winter Quarter 2010 (January 2010). Of these two, Madame Penda Sarr is an applicant from Senegal where she is working with HC PI Dr. Cisse and ISRA scientists with interest in Plant Pathology and cowpea breeding. She is coming to UCR in December for English training. The second candidate is Mr. Arsenio Daniel Ndeve, from Mozambique, who recently completed a MS degree in Denmark and is working with cowpea breeder Rogerio Chiulele, at Universidade Eduardo Mondlane. He is an excellent candidate for training in cowpea breeding and pathology, building on the vigorous cowpea breeding program being established by R. Chiulele with assistance from IAMM and their research stations at Umbelezi and especially Chokwe, where the station manager is Celestina Jochua, HC PI for Jonathon Lynch's Pulse CRSP project in Mozambique.

Explanation for Changes

Under Objective - Training:

Difficulty has been encountered in communication with the HC PI for Angola. As a result, we have been unable to make an appropriate assessment of the seed system needs for cowpea in Angola. We will endeavor to complete this activity of Objective 3 during the coming year of the project period. We have, however, initiated the MS degree training of the Angola student (Antonio David) at University of Puerto Rico, and plan to engage him in developing this assessment of the Angola cowpea seed system.

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Networking and Linkages with Stakeholders

We are working closely with national and international cowpea breeders and other scientists, including Drs. Ousmane Boukar, Christian Fatokun, and Sata Muranaka, Senior Scientists and Cowpea Breeders at IITA, Dr. Mohammed Ishiyaku of the IAR in Nigeria, Rogerio Chiulele at Eduardo Mondlane University in Maputo, Mozambique, Michael Timko at University of Virginia, and Larry Murdock at Purdue Univ. We are working closely with the California Dry Bean Advisory Board and its Blackeye Council on research priorities of the industry. We are working with Inland Empire Foods, an important legume processor based in Riverside, on developing Akara (or 'Bean Tots') for inclusion into the California school program and with another major US manufacturer on utilization of several products that our varieties are well suited to. We have provided Dr. Julie Lauren of the Dry Pulse CRSP project with advice about and seed of 35 cowpea varieties for her project in Kenya. We are also working with Dr. Jim Beaver at the University of Puerto Rico on training a CRSP student from Angola. 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 1, we are leading the cowpea improvement Objective and interact with a large international network of tropical legumes researchers.

In Burkina Faso, we are working with AFRICARE, a NGO financed by USAID to ensure food security. Our collaborative work aims to develop new Striga resistant varieties adapted to intercropping. A collaboration with LVIA, a NGO financed by the EU and Italy, aims to train farmers for cowpea certified seed production and conservation. With Association FERT, a French NGO whose aim is to improve cowpea production in the northern part of the country, we have initiated on-farm tests of improved varieties and we 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, collaboration was established with the extension service 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. Support for the amount of 2500 USD was received from the Network of farmers organization (RESOPP) which EWA has helped establish. A Memorandum of Understanding was signed in 2008 between RESOPP-EWA and ISRA for the production of Melakh and Yacine Foundation Seed; the program is established to last five years. In June 2009, The Kirkhouse Trust started supporting activities on marker assisted backcrossing for Striga resistance, by providing $20,000 annually for 3 years.

Dr. Bahiru Duguma, the Pulse CRSP oversight officer, accompanied Drs. Roberts, Ehlers and Drabo on a research field-site visit to Burkina Faso in September 2009. We visited key cowpea research and production areas in Kamboinse, Koudougou, and Pobe-Mengao. This was a valuable sharing experinece about cowpea breeding research, seed systems work, and the vision and expectations of the USAID program supporting the CRSP.

Leveraged Funds

Name of PI receiving leveraged funds: Phillip Roberts
Description of leveraged Project: Functional Genetic Analysis of Drought Tolerance Genes in Cowpea Through Virus Induced Gene Silencin
Dollar Amount: $30,000
Funding Source: USDA

Name of PI receiving leveraged funds: Phillip Roberts
Description of leveraged Project: : Improving Cowpea Productivity for Marginal Environments in sub-Saharan Africa
Dollar Amount: $1,952,008
Funding Source: CGIAR-GCP

Name of PI receiving leveraged funds: Jeff Ehlers
Description of leveraged Project: : Improving Drought Phenotyping in Cowpea
Dollar Amount: $243,811
Funding Source: CGIAR-GCP

Name of PI receiving leveraged funds: Jeff Ehlers
Description of leveraged Project: Evaluation of UCR SNP Cowpea Genotyping Platform for Fingerprinting Wild Cowpea
Dollar Amount: $30,000
Funding Source: USDA
Name of PI receiving leveraged funds: Phillip Roberts
Description of leveraged Project: California Blackeye varietal improvement
Dollar Amount: $19,960
Funding Source: CalDBAB

List of Scholarly Activities and 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 as director of the ISRA/CNRA Bambey Research Station in 2009.

Following are descriptive statements concerning leveraged funding awards:
California Dry Bean Advisory Board and its Blackeye Varietal Council (funds currently and typically set at $18,000 – 20,000 per year) funded for cowpea breeding in
California. This is a continuing, longterm research arrangement in support of the UC Riverside cowpea breeding program.

The CGIAR Generation Challenge Program (GCP) Tropical Legumes I Project funded for 3 years (May 2007-April 2010) with expectation for extension of funded research (4-year extension for Phase 2 of project being applied for). The cowpea component of this project is lead by UC Riverside (Ehlers, Roberts, and Close) and includes collaborative funded cowpea breeding and research with the cowpea breeding programs in Burkina Faso (with PI I. Drabo), Cameroon (PI O. Boukar) and Senegal (PI N. Cisse), and IITA (PI, C. Fatokun and O. Boukar). This project funded at nearly $1.9M is developing cowpea genomic resources, including cDNAs, BACs, ESTs and SNP genotyping for genetic and physical mapping, and development of high-throughput marker genotyping for major traits. Traits targeted are insect resistance, especially flower Thrips, nematode and disease resistance, and drought and heat tolerance. The more upstream genomics and marker work funded under this project provides an excellent leveraging for CRSP activities described here to be used for more application (downstream) breeding.

A second GCP project funded to UC Riverside (Ehlers, Roberts, and Close) for $450,000 (January 2008 to December 2010), focuses on development of phenotyping protocols for cowpea drought tolerance, with work in the West Africa partner countries, California and Texas. This provides direct leveraging opportunities for the drought tolerance efforts.

A Southwest Consortium on Plant Genetics and Water Resources project (funded via USDA-CSREES) for $30,000 per year for two years was recently approved for 2010 and 2011 to develop a virus-induced gene silencing (VIGS) system for gene functional analysis in cowpea. Target test traits are drought tolerance candidate genes, although the system when established will be valuable for analysis of other important trait determinants.

The Pulse CRSP funds will also be leveraged with opportunity funds within the Host Countries via NGOs and national sources through presentation of the CRSP effort and the associated opportunities for participatory funding.

At INERA, for our cowpea work we are getting: - $30 000 from GCP/TL1 project (Improving tropical legume productivity for marginal environments in sub-Saharan Africa) and $22420 from GCP commissioned project for cowpea drought resistance.

At ISRA, support for the amount of 2500 USD was received from the Network of farmers organization (RESOPP) which EWA has help established. A Memorandum of Understanding was signed between RESOPP-EWA and ISRA for the production of 50 kg each of Melakh and Yacine foundation seeds. The program is established to last five years. The Kirkhouse Trust has started supporting from June 2009 activities on marker assisted backcrossing for Striga resistance. 20,000 USD will be provided annually for 3 years.

Contribution to Gender Equity Goal

Among the target beneficiaries of the project work, the activities in Burkina Faso and Senegal resulted in eight producer/community based organizations being recipients of technical assistance during the report period, which are comprised of women and men. More specifically, four women organizations received technical assistance in Senegal and Burkina Faso, as planned. The technical assistance was focused on seed system processes under Objective 2, for growing, harvest handling and storing cowpea planting seed (Certified Seed producers).

Progress Report on Activities Funded Through Supplemental Funds

During the reporting period, supplemental funds were approved through the CRSP Technical Committee and Director for Capacity Building in the three Host Country partner Institutions. The approvals were made in support of the cowpea breeding and genetic improvement programs as follows:

1. ISRA, Senegal: $30,000 to the Institut Senegalais de Recherches Agricole (ISRA), Bambey Research Station, in support of the purchase of a vehicle that will enhance the capacity of ISRA's cowpea breeding program to serve the needs of stakeholders of cowpea value chains in Senegal.

2. INERA, Burkina Faso: $11,000 to the Institut de l'Environnement et du Recherches Agricoles (INERA) in support of vehicle repair, the purchase of a weather station and training that will enhance the capacity of INERA's cowpea breeding program to serve the needs of stakeholders of cowpea value chains in Burkina Faso.

3. IIA, Angola: $33,600 to the Instituto de Investigacao Agronomica (IIA), Huambo Research Station, in support of the purchase of a vehicle and laboratory equipment that will enhance IIA's research capacity to serve the stakeholders of bean and cowpea value chains in Angola.

The contract for these supplemental awards were not processed during the reporting period, and will be reported on for progress during the October 1, 2008 to September 30, 2009 year under the current workplan period.

Tables/Figures Cited in the Report

Table 1. Varietal candidate lines

Candidate Line	Developing Institution	Releasing Institution	Type	Steps Needed in Workplan Period
03Sh-50	UCR	UCR	Blackeye	Completion of Release, PVP Documentation
07-11-572	UCR	UCR	All-white	Experiment station tests. Breeder and Foundation seed increase
03-11-747	UCR	UCR	‘Dry Green’	Experiment station tests. Breeder and Foundation seed increase
IT98K-205-8	IITA	INERA	White	Seed production and on-farm evaluations
Melakh	ISRA	INERA	White	Seed production and on-farm evaluations
KVx421-2J	INERA	INERA	Brown	Seed production and on-farm evaluations
ISRA2065	ISRA	ISRA	White	Final on-farm evaluation, Breeder and Foundation seed increase

Table 2. Lines to be improved by introgression of specific traits using backcrossing.

Recurrent Parent Line	Institution	Trait being introgressed	Trait donor (non-recurrent) parent
Yacine	ISRA	Macrophomena	IT93K-503-1
Yacine	ISRA	Flower thrips resistance	58-77
Yacine	ISRA	Striga	SuVita 2
Mouride	ISRA	Large grain	Montiero derived line
Melakh	ISRA	Striga resistance	IT97K-499-39
Melakh	ISRA	Green grain	UCR 03-11-747
KVx396-4-5-2D	INERA	Striga resistance, Large grain	IT81D-994
KVx396-4-5-2D	INERA	Green grain	UCR 03-11-747
IT98K-205-8	INERA	Large seed	Montiero derived line
CB5	UCR	Fusarium wilt	CB27
CB46	UCR	Green grain	UCR 03-11-747
CB46	UCR	Root-knot nematodes	IT84S-2049

Table 3: 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

Table 4. 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

Table 5. 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

Table 6. Crosses made and advanced to F3-F4 generation that will provide progenies for selection of drought and pest tolerant cultivars.

Cross	Type	Current Status (October 2009)
SuVita2/Mouride	Elite Drought Tol. x Elite Drought Tol.	F3 – F4 in field at CVARS now
IT93K-503-1/IT84S-2246	Elite Drought Tol. x Elite Drought Tol.	F4 at CVARS
Mouride /IT84S-2246	Elite Drought Tol. x Elite Drought Tol.	F4 at CVARS
IT97K-499-39/IT93K-503-1	Elite Drought Tol. x Elite Drought Tol.	F3 – F4 in CVARS now
IT97K-503-1/IT97K-556-6	Elite Drought Tol. x Elite Drought Tol.	F3 – F4 in field at CVARS now
Mouride/Apagbaala	Elite Drought x Elite Heat Tolerant	F3 – F4 in field at CVARS now
KVx61-1/Mouride	Elite x Elite Drought Tolerant	F3 – F4 in field at CVARS now
IT93K-503-1/UCR 779	Elite Drought Tolerant x Drought Tolerant and aphid resistant landrace	F3 – F4 in field at CVARS now
Apagbaala/IT82E-18	Elite Heat Tolerant x Elite	F3 – F4 in field at CVARS now
IT97K-819-45/Ein El Ghazal	Elite x Elite Drought Tolerant	F3 – F4 in field at CVARS now
Ein El Ghazal/KVx544-6-151	Elite Drought Tolerant x Elite	F3 – F4 in field at CVARS now
IT98K-558-1/Mouride	Elite x Elite Drought Tolerant	F3 – F4 in field at CVARS now
Apagbaala/IT98K-558-1	Elite Heat Tolerant x Elite	F3 – F4 in field at CVARS now
IT95K-1479/Mouride	Elite x Elite Drought Tolerant	F3 – F4 in field at CVARS now

CVARS – Coachella Valley Agricultural Research Station, Thermal, California desert location off-season nursery.

Literature Cited

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Muchero, W., J.D. Ehlers, and P.A. Roberts. 2009c. QTL analysis for resistance to foliar damage caused by *Thrips tabaci* and *Frankliniella schultzei* (Thysanoptera: Thripidae) feeding in cowpea (*Vigna unguiculata* L. Walp.). *Molecular Breeding* (Online first, July 2009 DOI 10.1007/s11032-009-9307-6).

Muchero, W., N.N. Diop, P.R. Bhat, R.D. Fenton, S. Wanamaker, M. Pottorff, S. Hearne, N. Cisse, C. Fatokun, J.D. Ehlers, P.A. Roberts, and T.J. Close. 2009d. A consensus genetic map of cowpea [*Vigna unguiculata* (L) Walp.] and synteny based on EST-derived SNPs. *Proceedings of the National Academy of Sciences*, USA 106:18159-18164.
Sawadogo, A., B. Thio, S. Kiemde, I. Drabo, C. Dabire, J. Ouedraogo, T. R. Mullens, J.D. Ehlers, and P.A. Roberts. 2009. Distribution and prevalence of parasitic nematodes of cowpea (*Vigna unguiculata*) in Burkina Faso. *Journal of Nematology* 41 (1): (In press).

Capacity Building Activities: P1-UCR-1

First and Other Given Names: TBD
Last Name: TBD
Citizenship: African
Gender: Female
Degree: Ph.D.
Discipline: Plant Breeding/Genetics/Plant Pathology
Host Country Institution to Benefit from Training:
Training Location: University of Ghana, Legon and UCR
Supervising CRSP PI: Roberts, Phillip
Start Date: 10/08
Project Completion Date: 10/12
Training Status:
Type of CRSP Support (full, partial or indirect): Partial (Category 2b)

First and Other Given Names: Antonio
Last Name: David
Citizenship: Angola
Gender: Male
Degree: M.S.
Discipline: Plant Breeding
Host Country Institution to Benefit from Training: Angola
Training Location: UPR
Supervising CRSP PI: Roberts, Phillip
Start Date: 08/09
Project Completion Date: 06/11
Training Status: Active
Type of CRSP Support (full, partial or indirect): Full (Category 1)

First and Other Given Names: Marti
Last Name: Portorff
Citizenship: US
Gender: Female
Degree: Ph.D.
Discipline: Plant Genetics/Pathology
Host Country Institution to Benefit from Training:
Training Location: UC-Riverside
Supervising CRSP PI: Roberts, Phillip
Start Date: 10/08
Project Completion Date: 09/12
Training Status: Active
Type of CRSP Support (full, partial or indirect): Partial (Category 2b)

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

Project Title: **Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the US.**

	Abbreviated name of institutions											
	UCR			ISRA			INERA			IIA		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*	10/1/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1 Breeding												
Varietal identification and release	x	x		x	x							
Germplasm assembly and seed increase												
Germplasm Screening												
Varietal candidate screening - Angola										x	x	
Germplasm Development												
Cross Improved varieties												
Make BC1F1 and BC2F1												
Inbreed BC2F1 to BC2F2	x	x										
Make F1 elite x elite												
Advance F1 To F2,												
Develop F3 lines	x	x		x	x		x	x				
Objective 2 -Improve Seed Systems												
Breeder's Seed Production												
Foundation Seed Production												
Certified Seed Producer Training							x	x				
Assess seed system needs - Angola	x		x							x		x
Objective 3 - Training												
MS Training (Breeding) - Angola (Univ. PR) started												
PhD Training (Breeding - HPR) - started												
Training in MAS with SNP-based markers	x	x										
Breeding Guide	x	x										

Name of the PI reporting on benchmarks by institution	**P. Roberts**	**N. Cisse**	**I. Drabo**	**A. Chicapa**

Name of the U.S. Lead PI submitting this Report to the MO	**Philip A. Roberts**

Signature **Date** ######

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the US.
Lead U.S. PI and University: Philip A. Roberts, University of California, Riverside
Host Country(s): Angola, Burkina Faso, Senegal

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women	0	0	1	1
Number of men	0	0	1	0
Short-term Training: Number of individuals who have received short-term training				
Number of women	0	0	3	3
Number of men	0	0	4	2
Technologies and Policies				
Number of technologies and management practices under research	1	2	13	18
Number of technologies and management practices under field testing	5	5	5	7
Number of technologies and management practices made available for transfer			5	4
Number of policy studies undertaken	0	0	0	0
Beneficiaries:				
Number of rural households benefiting directly	0	0	>2,000	>3,000
Number of agricultural firms/enterprises benefiting	0	0	8	9
Number of producer and/or community-based organizations receiving technical assistance	8	7	10	13
Number of women organizations receiving technical assistance	4	4	6	6
Number of HC partner organizations/institutions benefiting	3	4	3	3
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	0	0	>11,600	>19,000

Number of public-private sector partnerships formed as a result of USAID assistance 0

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

Principle Investigators

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

Collaboratoring Scientists

Ibrahim Baoua, INRAN, Niger
Mohammad Ishiyaku, IAR, Nigeria
David Onstad, UIUC, U.S.
Larry Murdock, Purdue, U.S.
Joseph Huesing, Monsanto, U.S.
Julia Bello, UIUC, U.S.
Mamadou N'Diaye, IER, Mali
Clèmentine Dabirè, INERA, Burkina Faso
Jeremy McNeil, UWO, Canada
Brad Coates, University of Iowa/USDA, U.S.
William Muir, Purdue, U.S.
Niang Malick Ba, INERA, Burkina Faso
Manuelle Tamo, IITA, Benin
Madhu Viswanathan , UIUC, U.S.

Abstract of Research Achievements and Impacts

Our 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 (described in the next section). Our program is focused on (1) developing and disseminating the most practical solutions for control of these pest insects, (2) building institutional infrastructure to sustain these strategies, as well as (3) exploring and enabling cost-effective educational programs to increase the impact of these approaches in the target countries where we are working in: Nigeria, Niger, Burkina Faso, Mali, and Benin. Our group 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; an approach we have termed "Integrated Pest Management Omics" (IPM-Omics)(Pittendrigh *et al*. 2008; Gassmann *et al*., 2009). We have developed the necessary molecular tools to understand population dynamics and movement patterns of the legume pod borer (*Maruca vitrata*) in West Africa and have applied these tools 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 allow us to effectively determine 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 our project. In order to optimize the impact of our project, we have also developed and are exploring a diversity of extension approaches for deployment of the educational component of cowpea pest control strategies. We have used farmer field schools, in collaboration with other groups, *e.g.* Peace Corps, 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). We will continue to explore the long-term potential of these pest control and educational strategies to impact cowpea farmers.

Project Problem Statement and Justification

Arguably, the greatest biotic constraints on cowpea (*Vigna unguiculata* [L.] Walp.) production 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. As addressed below, 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. We have outlined below why the most logical long-term option for control of pests of cowpea will be the use of biological control agents.

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 a few of the pest species of cowpea, and should actively be 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, we need immediate, tangible, and cost-effective solutions that can be placed in the hands of 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). Our HC 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 our 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).

Our project has aimed: (i) 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; (ii) to develop the necessary expertise to extend these IPM-omics strategies to all other insect pests of cowpea; and (iii) 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 the next stage of our project. We are well positioned to develop a comprehensive IPM-omics tool set for the major pests of cowpea.

Planned Project Activities for April 1, 2008 - September 30, 2009

Objective 1: *Light Trapping of Maruca and Microsatellite Markers*
This activity will build both (i) institutional infrastructures to monitor *Maruca* (ii) as well as a better understanding of the problems of this pest within the host counties. Although our efforts are not specifically focused on *Bt* cowpea, this work will lay the basis for the development of an IRM plan for *Bt* cowpea, as well as potentially providing the basis for other IPM-based pest control strategies.

Approaches and Methods: Light trapping will occur throughout the 18 months at the existing locations: (i) in Niger the current locations is Maradi; (ii) in Nigeria the existing location is Zaria; and, (iii) in Burkina Faso the existing locations are Farako-ba, Kamboinsé, and Fada N'Gourma. The site at

Pobe in Burkina Faso will not be used due to high fuel costs associated with the generator. Instead we will build a new light trap at Dori, where the light trap can be plugged into a main electricity source. In Niger we will also added a location at Kornaka and move the light trap at Niamey to Gaya. In Nigeria additional traps will be stationed at Kadawa and Minjbir. Adults will be monitored and collected from the light traps on a daily basis. Adults will be sent to UIUC through a courier service for microsatellite analysis. The aforementioned work will be the responsibility of the host country P.I.'s.

The microsatellite analysis will be performed by Dr. Weilin Sun, in Dr. Pittendrigh's laboratory, over the last 1 year of the 18-month budget period (and for one more year of the 2.5 year grant based on the availability of funds).

Results, Achievements and Outputs of Research:
Light Trapping of Maruca and Molecular Markers
Our original goals, of light trapping at all the given locations and the development of microsatellites to investigate these populations, have all been met. However, a series of discoveries, opportunities, and technological changes have allowed us to accomplish outcomes in this project beyond our original expectations. Our accomplishments (both intended and beyond our original goals) are given below.

This activity has allowed us to (i) build institutional infrastructures to monitor *Maruca vitrata* using light traps (as planned), (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* (Onstad *et al*., in progress).

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). We have termed our approach for combining genomics and integrated pest management as "Integrated Pest Management-Omics" (IPM-Omics) (Pittendrigh *et al.*, 2008; Gassmann *et al*., 2009). Our initial experiments, with light trapping and scouting data, has 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. We have been recently funded by the Dry Grain Pulses CRSP for a "Technology Dissemination Project" to deploy biological control agents for the control of cowpea pests.

Molecular Tools Development -- We have developed a series of genomics tools 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]. We have used a new large-scale sequencing technology (454 sequencing), combined with novel bioinformatics approaches to rapidly discover microsatellites that can be used to study *M. vitrata* populations (*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. A manuscript using this approach is now being prepared for submission to a peer-reviewed journal (the target journal will be Insect Molecular Biology).

(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) 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 (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 (in

the next phase of this project) 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.

Resultant Publications and Manuscripts in Progress (Both directly from CRSP support and related to IMP-omics strategies that we will use in the next stage of this project)

Ba, N.M., Margam V. M., Dabire-Binso C. L., Sanon A., McNeil J., Murdock, L.L. and Pittendrigh B. R. 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(3): 109-113. (from CRSP support)

Gassmann, A.J., D. W. Onstad and B. R. Pittendrigh. 2009. Evolutionary Analysis of Herbivorous Insects in Natural and Agricultural Environments. Pest Manag. Sci. 65(11): 1174 – 1181. (Note: IPM-omics strategies developed based on concepts from CRSP project).

Pittendrigh, B.R., L. Sun, P. Gaffney, and J. Huesing. 2008. "Negative Cross Resistance", in Insect Resistance Management. Ed. David Onstad. p. 108-124. (Note: IPM-omics strategies outlined based on concepts from CRSP project).

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). Expected to be submitted December 2009.

Douglas, M.R. Margam, V. M., Coates, B., Ba, N.M., Dabire-Binso, C., Baoua, I., Tamò, M. M. F. Ishiyaku, Douglas, M.E., and Pittendrigh B. R. 2009. Development and use of microsatellite markers using for understanding population dynamics and movement patterns of *Maruca vitrata* Fabricius (lepidoptera: pyraloidea: crambidae) in West Africa. In preparation for Insect Molecular Biology. (from CRSP support). Expected to be submitted January 2010.

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. Thesis finished at Purdue University. Co-major advisor: Barry Pittendrigh.

Onstad, D. W., N. M. Ba, C. Dabire, M. Tamand B. R. Pittendrigh. Modeling Evolution of Resistance by *Maruca vitrata* to transgenic insecticidal cowpea in Africa. In progress for submission to Journal of Economic Entomology. (Not directly funded by CRSP but a by-product of our current research efforts).

Objective 2: This activity will provide the basis for a better understanding of the problems of pest insects of cowpeas within the host countries. It will also allow for cross training in pest insect biology across the three host countries. Although our efforts are not specifically focused on *Bt* cowpea, this work will lay the basis for the development of an IRM plan 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.

Approaches and Methods:

The data sharing from our preliminary work and the experimental design for the field studies on the insect pests of cultivated cowpeas will be completed in the first six month budget period. Based on these experimental plans we will study 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. In Burkina Faso, Dr. Dabire will have one graduate student in working on the pests of cultivated cowpea. All experimental designs will be checked with our statistician (Dr. William Muir of Purdue University) to ensure proper experimental design and analysis of the datasets. Planting for these experiments will occur in the summer of 2008. Data collection will occur upwards of into November/December of 2008. The data will be tabulated, shared with the group, and analyzed. Another round of planting will occur in the summer of 2009, however, the experiments will be completed beyond the 18-month budget period.

Results, Achievements and Outputs of Research:
Insect Pests on Cultivated Cowpeas

We have performed the above experiments over the past two field-seasons (summer 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), and we recorded all details of the 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 of Purdue University) and we have analyzed the datasets. We have been able to ascertain which pest insects represent the greatest problems (and at what time interval) in northern Nigeria, Niger, and Burkina Faso. We have a preliminary manuscript in progress on this topic, however, this type of research can only be published with three field seasons of data. Thus, we will continue to perform these experiments in the summer of 2009 and then finalize the resultant manuscript after this data has been collected.

However, 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 of these varieties.

We have made large-scale collections of insects from these experiments 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.

<u>**Manuscript in Progress**</u>

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].

<u>**Objective 3**</u>**:** This activity will provide the basis for a better understanding of the problems of pest insects of cowpeas within the host counties both during the growing season and when cowpea is not in season. Although our 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.

Approaches and Methods: A standardized scouting plan will be established within the first six months of the project. Scouting of pests of cowpea on alternative host plants will occur both during and outside of the cowpea-growing season. The frequency and distances of the scouting trips will be dependent on the costs of transportation (*e.g.,* fuel prices). However, no fewer than one scouting trip will occur per country per six-month budget period. Every effort will be made to maximize the amount of scouting data in relationship to the resources available.

Surveys of wild alternative hosts around and near cowpea fields will be designed in the first six months of the project. The experiments will be performed in each country during the cowpea-growing season. Briefly, farmers' fields will be surveyed for the numbers of insects on cowpeas in relationship to any nearby wild alternative hosts (or the lack of alternative hosts will be documented). In the case of *Maruca*, this will provide the basis for the estimated wild refuge potential for an IRM plan for *Bt* cowpea.

Results, Achievements and Outputs of Research:

<u>**Survey Wild Alternative host plants (in and off season) of *M. vitrata***</u>

In keeping with these objectives, we have performed a series of scouting trips in Niger, Nigeria, Benin, and Burkina Faso prior to and throughout the last 18-months. 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 our work has shown 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 we are now in a position to determine where best to release these parasitoids in order to maximize their potential impact on *M. vitrata* populations.

We will continue these scouting efforts in the upcoming year (FY10) 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 our project (e.g., in FY11 and FY12) 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; we also have bio-control agents 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 in our Pulse CRSP Technology Dissemination Project.

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.

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.

Objective 6:

Degree Trainees (Ph.D., M.S., and B.S./B.Sc. students)

In keeping with our original plans, Dr. Pittendrigh has a female Nigerian graduate student (Agunbiade Tolulope) in the Ph.D. program in the Department of Entomology at UIUC. This student is now using molecular tools to address issues of movement of *M. vitrata* populations in West Africa. This student is funded by UIUC and hence her support is part cost-sharing provided by UIUC.

Additionally, Dr. Pittendrigh has recently had a Doctoral student complete his doctoral thesis (Mr. Venu Margam) on the genomics and population dynamics of *M. vitrata* (his degree will be granted in December of 2009). Mr. Margam's work dealing with *M. vitrata* will be continued by Agunbiade Tolulope.

Dr. Dabire has been training an M.S. student through the University of Ouagadougou. This student is directly funded by the CRSP.

Six more graduate and undergraduate students, through IITA in Benin, are also working on our project as part of their degree programs. Their projects are focused on pests of cowpea or the development of biological control strategies for the pests of cowpeas or both.

The details of these aforementioned students are given below:

First and Other Given Names: Agunbiade Tolulope
Last Name: Adebimpe
Citizenship: Nigerian
Gender: Female
Degree Program for training: Ph.D. at UIUC
Program Areas or Discipline: Entomology
Indirect CRSP support

First and Other Given Names: Traore
Last Name: Fousseni
Citizenship: Burkina Faso
Gender: Male
Degree Program for training: M.S. at University of Ouagadougou
Program Areas or Discipline: Entomology
Direct CRSP support

First and Other Given Names: Elie
Last Name: Dannon
Citizenship: Benin
Gender: Male
Degree Program for training: Ph.D. (working with IITA) Agricultural University, Wageningen, The Netherlands
Program Areas or Discipline: Biology and ecology of bio-control agents for control of pests of cowpeas.
Starting date: June 2008
Indirect CRSP support

First and Other Given Names: Laura
Last Name: Loko
Citizenship: Benin
Gender: Female
Degree Program for training: M.S. (working with IITA) Universite d'Abomey Calavi
Program Areas or Discipline: Effects of essential oils on *M. vitrata*
Starting date: March 2009
Indirect CRSP support

First and Other Given Names: Hermann
Last Name: Somakpon
Citizenship: Benin
Gender: Male
Degree Program for training: M.S. (working with IITA) Universite d'Abomey Calavi
Program Areas or Discipline: Biology and ecology of bio-control agents for control of pests of cowpeas.
Starting date: November 2008
Indirect CRSP support

First and Other Given Names: Kouami
Last Name: Gnammi
Citizenship: Benin
Gender: Male
Degree Program for training: M.S. (working with IITA) Universite d'Abomey Calavi
Program Areas or Discipline: Biology and ecology of bio-control agents for control of pests of cowpeas.
Starting date: November 2008
Indirect CRSP support

First and Other Given Names: Venu
Last Name: Margam
Citizenship: Indian
Gender: Male
Degree Program for training: Ph.D. at Purdue University
Program Areas or Discipline: Genomics of *M. vitrata*
Starting date: October 2004
Indirect CRSP support

First and Other Given Names: Louisiane
Last Name: Bachabi
Citizenship: Benin
Gender: Female
Degree Program for training: B.Sc. at Universite d'Abomey Calavi
Program Areas or Discipline: Insect pests of cowpea
Starting date: October 2008
Indirect CRSP support

First and Other Given Names: Monipo
Last Name: Kolany
Citizenship: Togo
Gender: Female
Degree Program for training: B.Sc. at Universite d'Abomey Calavi
Program Areas or Discipline: Insect pests of cowpea
Starting date: April 2009
Indirect CRSP support

Farmer Field Schools

We have held farmer field schools (FFSs) 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, the farmers are also enabled in understanding how to develop assessments of new technologies and literacy training also occurs in many of our FFSs with Peace Corps volunteers. 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, (8) how to minimize the use of traditional pesticide sprays in areas where farmers typically spray their cowpea crops, and (9) in the summers of 2010-2012 will also include the release of biological control agents in these areas where the farmer field schools have occurred.

Data from these FFSs have also allowed us to (1) identify (in an economically efficient manner) which pest problems are the greatest concern in various regions of each country and (2) enable farmers the ability to identify early on in the field season which pest problems may be occurring, such that they can take logical measures to minimize the pest populations. This latter point will ultimately help farmers who use pesticides to use this technology in a more responsible and economically viable manner.

Our long-term goal has been 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 we release biological control agents into these areas, we will have the FFSs continue to monitor the pest populations and also for 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. Of course, we will be doing tightly controlled experiments at 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 our program on a larger number of individuals, we have taken the following measures. First, as part of these FFSs, we also have also held one-day sessions where other farmers, production groups, and people from other villages can come to interact with the FFSs to see the impacts of the various pest control strategies (and other technological improvements) on cowpea production. Second, in order to increase the impact of our project, improved seed varieties have also been given out to other farmer organizations for them to assess, multiple, and encourage the use of these seeds in their programs. 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, such that beyond the scope of the current project future Peace Corps volunteers can continue to integrate improved technologies into their village-level programs.

As part of the FFSs we have also been focused on determining the needs and roles of women in various aspects of cowpea production. 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 we are working on the current CRSP project.

We are also collaborating with Dr. Madhu Viswanathan of UIUC on our 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 University of Illinois, (3) an author on numerous books and publications on extension/education strategies for oral/low literate learners in developing nations, and (4) for his efforts of developing novel educational and assessment tools for low literate learners in developing nations. He was also recently awarded the "Bharat Gaurav Award" by the India International Friendship Society (please note other recipients of the award include the late Mother Teresa and a former Vice President of India). He is currently assisting us in developing the necessary assessment tools for our extension materials that will be tested in the field in 2010.

<u>Publication</u>

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 (it has been reviewed, minor edits were made based on reviewer suggestions, and we are waiting for a final decision from the editor).

Dr. Ba's (from INERA) visit to Dr. Pittendrigh's Laboratory (at UIUC)

This CRSP training activity allowed Dr. Ba to visit UIUC to develop molecular biology skills in order to use the IPM-omics tools, that we developed at UIUC, in his home institution in Burkina Faso. Dr. Ba also developed skills to better understand and create the necessary modeling tools to develop IRM plans for deployment of resistant varieties of cowpeas in West Africa. Dr. Ba also learned new computer and technical skills for the development and deployment of electronic based (e.g., MP3 files) extension strategies. This stay in the laboratory resulted in two manuscripts being submitted (Ba *et al*., 2009; Sannon *et al*., in press) and accepted at two peer-reviewed journals. It also allowed Drs. Pittendrigh and Ba the time and proximity necessary to write other manuscripts with Mr. Venu Margam (a Ph.D. student under Dr. Pittendrigh's direction). Dr. Ba also was able to visit with scientists at Cornell University (e.g., Dr. Anthony Shelton) with the expertise in the area of resistance management in insects to host plant resistance traits. Dr. Ba also met with Dr. J. Huesing of Monsanto Corporation, allowing Dr. Ba the opportunity to interact with another group with expertise in resistance and resistance management.

Project Planning Workshop (FY08)

A project-planning workshop was help in FY08 in Ouagadougou (Burkina Faso) (June 22-24) with Drs. Pittendrigh, Dabire, Ba, Baoua, Ishiyaku, McNeil, and Tamó and present in order to (1) plan for the next 2.5 years of our project, (2) cross-train each other in the group about various aspects of insect, plant and molecular biology as associated with our project. Also in attendance was Pete McClain of T4Global. T4Global is an NGO focused on using cutting edge extension technologies for development projects.

Mr. McClain attended our meeting at no cost to our CRSP project as his trip expenses were provided by other organizations. He trained our host country collaborators on how to generate MP3 audio files (and best practices for content) for use with solar powered MP3 players for use in villages to allow farmers to replay messages about extension strategies. We have developed (and are continuing to develop) content for solar powered MP3 and video players and will test their impact in field experiments in FY10 (pending human subjects' regulatory approval associated with our experimental design). As a result of our planning meeting discussions, our group has also developed video materials for extension work with effective control strategies for one pest of cowpeas, we are currently doing the voice overlays in several West African languages, and we expect to release the videos in the coming months to test their effectiveness in extension work. This planning workshop was highly critical for us to both (1) plan for our overall project and (2) provided an opportunity to generate novel approaches to dealing with both pest problems and how to get important information on pest control into the hands of farmers.

Training of Host Country Collaborator in Rearing of Biological Control Agents of Pests of Cowpeas

Our project received supplemental funding from the Pulses CRSP in FY09 for cross-training of host country scientists, and Dr. Tamò of IITA, in the best practices for rearing and release of biological control agents for the 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.

Drs. Tamò, Ba, Dabire, and Baoua are continuously sharing updates and necessary materials on advancements regarding the rearing and release of biological control agents for the control of pests of cowpeas. These training sessions have occurred during other CRSP-related trips (*e.g*., during our recent field visit in Niger with Dr. Widders in 2009), with e-mail, and by Skype and telephone calls. 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.

IITA, INERA, and INRAN will be the primary benefiting institutions. This will allow all three institutions the capacity to better develop and deploy biological control programs for pests of cowpeas. We the total number of scientists and technicians have benefit from this training is around 16 individuals, including scientist (and technician) who are both part of our CRSP project as well as scientists at other national programs in Ghana and Togo. At INRAN (in Niger) six (6) technicians (3 females) have and will continue to be trained in the areas of pests of cowpea, rearing of these pests, and rearing and release of biological control agents against these species. However, in the long-term we expect the deployment of a biological control program for the pests of cowpeas to have benefits for millions of people that rely on cowpea production in Burkina Faso, Niger, northern Nigeria, and other cowpea producing countries in West Africa.

Explanation for Changes

There were no significant deviations from our core objectives on this project.

Networking and Linkages with Stakeholders

Interactions with NGOs and Other Organizations Focused on Farmer Field Schools and Extension

We have worked with national agricultural extension programs, and Peace Corps volunteers in some areas to further expand (i) where we can feasibly hold FFSs, (ii) provide an on the ground person to interact with the farmers on a regular basis for their FFSs activities, and (iii) 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. Additionally, by involving the Peace Corps in our extension activities we hope to find provide for a mechanism by which many of our activities can be passed on to new Peace Corps volunteers beyond the scope of our current project.

Government Organizations

We (Dr. Tamo is taking the leadership role on this issue) are working with other national agricultural programs in Togo and Ghana in regards to release of biological control agents for the pests of cowpeas.

Interactions with USAID Missions

Dr. Pittendrigh has visited both the USAID missions in Mali and Nigeria (Summer of 2008). Dr. Tamò is working with collaborators in Ghana to ultimately request funds from a USAID mission office in regards to a biological control program of insect pests of cowpeas in Ghana. The contact with the mission will occur after a concept note has been completed and the CRSP office has been consulted regarding the proper protocol for contacting the mission. The concept note will be submitted to the USAID mission, by the Ghanaian government. Thus, IITA and our CRSP project will not be involved in the direct request for funding support. However, if funded, part of our CRSP program (at IITA) would certainly benefit, as would the country of Ghana. Again, the Pulses CRSP office will be informed of any involvement that we will have in this process prior to it occurrence. In FY2010 and onwards, Dr. Pittendrigh will pursue interactions with Dr. Widders for the CRSP office to seek proper challenges to inquire about supplemental funding from the missions for the biological control release project that has been funded by the CRSP for 2009-2012.

Public-Private Sector Partnerships (with U.S. Firms)

As part of this project we have formed two public-private sector partnerships.
The first partnership was with Dow AgroSciences to perform experimental work 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 one publication:

1. 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*.

Although this project, with Dow AgroSciences, does not relate directly to our Pulses CRSP objectives, our currently funded CRSP project provided the foundation for this linkage with industry. Our resultant publication suggests that Spinosad may be very effective in controlling storage pests of cowpeas. We are well aware of the current PICS hermetic sealing project for control of cowpeas (funded by the Bill and Melinda Gates Foundation grant) as many participants on our CRSP project are also part of the PICS project (Dr. Pittendrigh was one of the original four Purdue University co-P.I.'s that originally wrote the grant). However, we are also well aware of the literature dealing with the fact that insects can develop resistance to low-oxygen levels. Thus, Dr. Pittendrigh is currently working on efforts to address how best to manage this "low oxygen resistance" (*e.g.*, use of Green Chemistry pesticides in combination with hermetic sealing) in cowpea bruchid populations; as the current PICS project may be a giant selection program for bruchids that can survive in low oxygen conditions.

Our second partnership is with Monsanto Company. Our work has primarily been with Dr. Joseph Huesing regarding issues of transgenic *Bt* cowpea. Again, our CRSP project is not focused on *Bt* cowpea, however, our datasets of importance to those individuals interested in issues associated with the development and deployment of *Bt* cowpea in West Africa.

Leveraged Funds

Name of PI receiving leveraged funds: Barry Pittendrigh
Description of leveraged Project: Molecular resistance mechanisms in a pest of cowpea
Dollar Amount: $399,000
Funding Source: USDA-BRAG

Name of PI receiving leveraged funds: Barry Pittendrigh
Description of leveraged Project: C.W. Kearns, C.L. Metcalf and W.P.Flint Endowment
Dollar Amount: $53,050
Funding Source: Endowment

Name of PI receiving leveraged funds: Barry Pittendrigh
Description of leveraged Project: Extension Material Development for cowpea
Dollar Amount: $19,800
Funding Source: Gates Foundation/Purdue University subcontract

Name of PI receiving leveraged funds: Barry Pittendrigh
Description of leveraged Project: Technician and graduate student support
Dollar Amount: $38,124
Funding Source: Startup

Name of PI receiving leveraged funds: Barry Pittendrigh
Description of leveraged Project: Molecular biology of a pest of cowpea/no cost extension on project
Dollar Amount: $24,000
Funding Source: USDACSREES

Name of PI receiving leveraged funds: Julia Bello
Description of leveraged Project: Funds for a project on woman and FFSs in West Africa
Dollar Amount: $4,000
Funding Source: CIBER

Name of PI receiving leveraged funds: Julia Bello
Description of leveraged Project: Funds for video/audio development for extension materials
Dollar Amount: $1,000
Funding Source: UIUC Extension funds

List of Scholarly Activities and Accomplishments

During this funding cycle, Dr. Pittendrigh was invested in the C.W. Kearns, C.L. Metcalf, and W.P. Flint Endowed Chair in Insect Toxicology at the University of Illinois at Urbana-Champaign.

Once of our key collaborators, 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.

Contribution to Gender Equity Goal

Women and Farmer Field Schools

1) Our FFSs programs have made every effort to obtain equal numbers of men and women in our programs.

2) As part of the FFSs we have also been focused on determining 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 we are working on the current CRSP project. Thus, we are interested in determining how we can best increase our impact on women through our FFSs.

Female Scientists

1) Our host country PI in Burkina Faso is a female scientist.
2) A female Nigerian graduate student has begun her PhD program at UIUC under Dr. Pittendrigh's direction.
3) Dr. Manuelle Tamò at IITA has established a network of scientists (many of whom are female) at other institutions that are interested in the pests of cowpeas. These institutions include:

Benin: Universite d’Abomey Calavi, 3 collaborators (1 female)
Togo: Universite du Benin (Togo), 1 collaborator (1 female)
Ghana: Plant Protection and Regulatory Services, 1 collaborator (1 female)

4) Dr. Manuelle Tamò at IITA has a significant number of female students and technicians working on his component of our project.

5) Dr. Ibrahim Baoua at INERA also has a significant number of female students and technicians working on his component of our project.

Progress Report on Activities Funded Through Supplemental Funds

1) Farmer Field Schools in Mali and use of MP3 players

As per our proposed efforts, FFSs were held in Mali in FY09 and we are currently planning for MP3 testing in FY10 with locally created contents for these devices.

2) Training of Host Country Collaborator in Rearing of Biological Control Agents of Pests of Cowpeas

Our project received supplemental funding from the Pulses CRSP in FY09 for cross-training of host country scientists, and Dr. Tamò of IITA, in the best practices for rearing and release of biological control agents for the pests of cowpea. This training has been instrumental in establishing the initial information for the development of a biological control program for the pests of cowpeas.

Drs. Tamò, Ba, Dabire, and Baoua are continuously sharing updates and necessary materials on advancements regarding the rearing and release of biological control agents for the control of cowpea pest. These training sessions have occurred during other CRSP-related trips (*e.g.,* during our recent field visit in Niger with Dr. Widders in 2009), over e-mail, and by Skype and telephone calls. 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 *M. vitrata* 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.

IITA, INERA, and INRAN will be the primary benefiting institutions. This will allow all three institutions the capacity to better develop and deploy biological control programs for pests of cowpeas. The total number of scientists and technicians that have benefited from this training is around 16 individuals, including scientist (and technician) who are both part of our CRSP project as well as scientists at other national programs in Ghana and Togo. However, in the long-term we expect the deployment of a biological control program for the pests of cowpeas to have benefits for millions of people that rely on cowpea production in Burkina Faso, Niger, northern Nigeria, and other cowpea producing countries in West Africa.

Literature Cited

Literature cited is given within the text and the end of the text for each section.

Capacity Building Activities: P1-UIUC-1

Degree Training:

First and Other Given Names: Traore
Last Name: Fousseni
Citizenship: Burkina Faso
Gender: Male
Degree: M.S.
Discipline: Entomology
Host Country Institution to Benefit from Training: INERA
Training Location: University of Ouagadougou
Supervising CRSP PI: DabirÈ, ClÈmentine
Start Date: 09/08
Project Completion Date: 08/10
Training Status: Active
Type of CRSP Support (full, partial or indirect): Full (Category 1)

First and Other Given Names: Agunbiade Tolulope
Last Name: Adebimpe
Citizenship: Nigerian
Gender: Female
Degree: Ph.D.
Discipline: Entomology
Host Country Institution to Benefit from Training: Nigeria
Training Location: UIUC
Supervising CRSP PI: Pittendrigh, Barry
Start Date: 08/09
Project Completion Date: 09/13
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Elie
Last Name: Dannon
Citizenship: Benin
Gender: Male
Degree: Ph.D.
Discipline: Entomology/Biological Control
Host Country Institution to Benefit from Training: IITA/Benin
Training Location: Agricultural University, Wageningen, The Netherlands
Supervising CRSP PI: Tamo, Manuelle
Start Date: 06/08
Project Completion Date: 06/12
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Laura
Last Name: Loko
Citizenship: Benin
Gender: Female
Degree: M.S.
Discipline: Biology/Biological Control
Host Country Institution to Benefit from Training: IITA/Benin
Training Location: Universite d'Abomey Calavi
Supervising CRSP PI: Tamo, Manuelle
Start Date: 03/09
Project Completion Date: 05/13
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Hermann
Last Name: Somakpon
Citizenship: Benin
Gender: Male
Degree: M.S.
Discipline: Biology/Biological Control/Entomology
Host Country Institution to Benefit from Training: IITA/Benin
Training Location: Universite d'Abomey Calavi
Supervising CRSP PI: Tamo, Manuelle
Start Date: 11/08
Project Completion Date: 12/12
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Kouami
Last Name: Gnammi
Citizenship: Benin
Gender: Male
Degree: M.S.
Discipline: Biology/Biological Control/Entomology
Host Country Institution to Benefit from Training: IITA/Benin
Training Location: Universite d'Abomey Calavi
Supervising CRSP PI: Tamo, Manuelle
Start Date: 11/08
Project Completion Date: 12/12
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Venu
Last Name: Margam
Citizenship: Indian
Gender: Male
Degree: Ph.D.
Discipline: Entomology
Host Country Institution to Benefit from Training: Burkina Faso --- Mr. Margam trained Dr. Ba in molecular biology approaches during Dr. Ba's stay in the USA
Training Location: Purdue University
Supervising CRSP PI: Pittendrigh, Barry
Start Date: 10/04
Project Completion Date: 12/09
Training Status: Active
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Louisiane
Last Name: Bachabi
Citizenship: Benin
Gender: Female
Degree: B.S.
Discipline: Biology/Biological Control/Entomology
Host Country Institution to Benefit from Training: IITA/Benin
Training Location: Universite d'Abomey Calavi
Supervising CRSP PI: Tamo, Manuelle
Start Date: 10/08
Project Completion Date: 05/09
Training Status: Completed
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

First and Other Given Names: Monipo
Last Name: Kolany
Citizenship: Togo
Gender: Male
Degree: B.S.
Discipline: Biology/Biological Control/Entomology
Host Country Institution to Benefit from Training: IITA/Benin/Togo
Training Location: at Universite d'Abomey Calavi
Supervising CRSP PI: Tamo, Manuelle
Start Date: 04/09
Project Completion Date: 10/09
Training Status: Completed
Type of CRSP Support (full, partial or indirect): Indirect (Category 2c)

<u>Short-term Training</u>:

Type of Training: Dr. Ba (INERA) will visit 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.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: FY09
Location: UIUC
Who benefited from this activity?: INERA and our overall network of African researchers. We also expect that the skills that 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 Beneficiaries: 61

  Male: 1>
  Female: 1
  Total: 2

Type of Training: Bio-control agent rearing and release
Description of training activity: Drs. Tamò, Ba, Dabire, and Baoua are continuously sharing updates and necessary materials on advancements regarding the rearing and release of biological control agents for the control of pests of cowpeas. These training sessions have occurred during other CRSP-related trips (e.g., our initial planning meeting in 2008 and our recent field visit in Niger with Dr. Widders in 2009), over e-mail, and by Skype and telephone calls. Dr. Tamó 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 M. vitrata 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.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: Throughout FY08-FY09
Location: Benin, Burkina Faso, and Niger
Who benefited from this activity?: IITA, INERA, and INRAN will be the primary benefiting institutions. This will allow all three institutions the capacity to better develop and deploy biological control programs for pests of cowpeas. We expect a total number of scientists and technicians that will benefit from this training to be about 16 individuals, including scientist (and technician) who are both part of our CRSP project as well as scientists at other national programs in Ghana and Togo. However, in the long-term we expect the deployment of a biological control program for the pests of cowpeas to have benefits for millions of people that rely on cowpea production in Burkina Faso, Niger, northern Nigeria, and other cowpea producing countries in West Africa.
Number of Beneficiaries: 16

  Male: >
  Female:
  Total:

Type of Training: Farmer Field Schools
Description of training activity: Farmer field schools are to be held in Niger, Nigeria, Mali, and Burkina Faso. These programs will be run in conjunction with NGOs, extension services, farmer organizations, women's organizations, and Peace Corps volunteers. These programs will involve enabling farmers (1) to better understand the pests of cowpeas, (2) to learn about and test new improved varieties of cowpeas, and (3) to learn about and test better management practices for producing cowpeas. Additionally, our FFSs will also involve some literacy training (as it relates to participating in FFSs activities) and enabling farmers to better understand how to use scientific approaches to assess new concepts and approaches for cowpea production. In many of our FFSs, farmers will also be taught about the concepts of biological control agents, thus, setting the stage for use of FFSs programs to assist our biological control agent release program in FY10-12.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: 1/2 day training sessions over 3 month period
Location: Niger, northern Nigeria, Mali, and Burkina Faso
Who benefited from this activity?: Farmers, farmer organizations, women's organizations, Peace Corps, NGOs
Number of Beneficiaries: 200
Male: 300>
Female: 300
Total: 600

Type of Training: Training of Technicians at INRAN in pests of cowpea and their control
Description of training activity: Six (6) technicians (3 male and 3 female) were trained in various aspects of the biology and biological control of pests of cowpea. This is an ongoing training activity to build capacity at INRAN for future efforts for control of these pests.
Status of this activity: Completed as planned
Reason if training activity not completed as planned:
When did the activity occur?: FY09
Location: Maradi, Niger
Who benefited from this activity?: This will benefit INRAN.
Number of Beneficiaries: 6
Male: >
Female:
Total:

Dry Grain Pulses CRSP

Report on the Achievement of "Semi-Annual Indicators of Progress"

(For the Period: April1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

Project Title: *Biological Foundations for Management of Management of Field Insect Pests of Cowpea in Africa*

	Abbreviated name of institutions																	
	UIUC			INERA			INRAN			IAR			IITA			IER		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*
(Tick mark the Yes or No column for identified benchmarks by institution)																		
Objective 1 - Ligh trapping / molecular marker work with Maruca / manuscript submissions																		
Run Existing light traps				X	X		X	X		X	X							
Maruca samples to UIUC	X	X		X	X		X	X		X	X		X	X				
Microsatellite work	X	X		X	X													
Development/use novel markers	X	X		X	X													
SNP markers	X	X		X	X													
Pittendrigh visits collaborators	X	X		X	X		X	X		X	X		X	X				
Collaborator teleconferences	X	X		X	X		X	X		X	X		X	X		X	X	
IRM Maruca model in development	X	X		X	X								X	X				
Manuscripts submitted/journals	X	X		X	X		X	X		X	X		X	X				
Objective 2 - Insect pests on cultivated cowpeas																		
Share previous data				X	X		X	X		X	X		X	X				
Planting				X	X		X	X		X	X							
Data Recording				X	X		X	X		X	X							
Data Sharing	X	X		X	X		X	X		X	X							
Manuscript in Progress	X	X		X	X		X	X		X	X							
Objective 3 - Survey of wild alternative host plants (in and off season)																		
Scouting for Wild Alt Host Plts				X	X		X	X		X	X			X*				
Survery fields for insect pests				X	X		X	X		X	X			X*				
Scouting Manuscript Prepared	X	X		X	X		X	X		X	X							

Dry Grain Pulses CRSP

Report on the Achievement of "Semi-Annual Indicators of Progress"

(For the Period: April1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

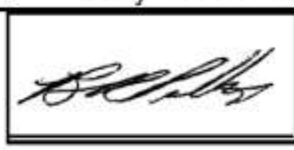
Project Title: *Biological Foundations for Management of Management of Field Insect Pests of Cowpea in Africa*

	Abbreviated name of institutions																	
	UIUC			INERA			INRAN			IAR			IITA			IER		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*	9/30/09	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 4 Farmer field school / general training / other information exchanges and visits																		
Farmer field schools				X	X		X	X		X	X					X	X	
IPM control techniques/training				X	X		X	X		X	X		X	X				
Biocontrol agents avilable for HCs				X	X		X	X		X	X		X	X				
Nigerian Gradaute student at UIUC	X	X																
Grad Student in BF				X	X													
Student training in Niger							X	X										
Student Training at IITA													X	X				
IPM control study/training				X	X		X	X		X	X		X	X				
Site vist with Dr. Widders (in Africa)	X	X		X	X		x	x		X	X		X	X				
MP3 devices delivered	X	X		X	X		X	X		X	X		X	X		X	X	
MP3 / Video messages initiated	X	X		X	X		X	X		X	X		X	X		X	X	
MP3 Concept manuscript submitted	X	X		X	X		X	X		X	X		X	X				

Name of the PI reporting on benchmarks by institution	Pittendrigh	Dabire	Baoua	Ishiyaku	Tamo	N'Diaye

Name of the U.S. Lead PI submitting this Report to the MO

Barry Robert Pittendrigh, University of Illinois at Urbana-Champaign



Septemer 29, 2009

Signature Date

* *IITA also performed surveys to determine the impact of their experimental release of biological control agents in Benin.* Although this was planned for 2010 (this was not a target for 2009), they achieved this work ahead of schedule.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Biological Foundations for Management of Management of Field Insect Pests of Cowpea in Africa
Lead U.S. PI and University: Barry Robert Pittendrigh, University of Illinois at Urbana-Champaign
Host Country(s): Burkina Faso, Niger, Nigeria, Mali, Niger,
and Benin (with impact on the aforementioned host countries as well as Ghana and Togo)

Output Indicators	2009 Target	2009 Actual
	(October 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	3
Number of men	1	5
Short-term Training: Number of individuals who received short-term training		
Number of women	>100	>300
Number of men	>100	>300
Technologies and Policies		
Number of technologies and management practices under research	4	7
Number of technologies and management practices under field testing	4	7
Number of technologies and management practices made available for transfer	4	5
Number of policy studies undertaken	N/A	N/A
Beneficiaries:		
Number of rural households benefiting directly	>150	>600
Number of agricultural firms/enterprises benefiting	N/A	1
Number of producer and/or community-based organizations receiving technical assistance	10	15
Number of women organizations receiving technical assistance	5	7
Number of HC partner organizations/institutions benefiting	5	14
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	N/A	>5,000
Number of public-private sector partnerships formed as a result of USAID assistance	1	2

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

Principle Investigators

James Beaver, University of Puerto Rico, Puerto Rico

Collaborating Scientists

Juan Carlos Rosas, EAP, Honduras
António Chicapa Dovala, IIA, Angola
Timothy Porch, USDA-ARS, U.S.
Emmanuel Prophete, CRDA, Haiti

Abstract of Research Achievements and Impacts

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 Problem Statement and Justification

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.

Planned Project Activities for April 1, 2008 - September 30, 2009

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

Approaches and Methods: Plant breeders will focus on the combination of disease (BGYMV, BCMNV, rust, common bacterial blight, anthracnose and angular leaf spot) resistance with enhanced resistance to pests (bruchid, leafhopper) and greater tolerance to abiotic stress (drought, low soil fertility, high temperature). Elite bean breeding lines with multiple disease resistance have already been crossed with sources of resistance to pests or tolerance to abiotic stress. Bean lines will be screened for the selected traits each generation in environments that are most likely to provide the desired abiotic or biotic stress. This can be most easily achieved through collaboration among Dry Grain Pulse CRSP scientists and the regional bean research network in Central America and the Caribbean. Regional performance trials for black, small red, red mottled and light red kidney bean lines will be conducted in collaboration with national bean research programs in Latin America and the Caribbean.

Basic seed stocks of bean varieties developed and released by the project will be multiplied and small lots of seed will be distributed to farmers in Latin America and the Caribbean for testing in on-farm trials. Performance of the varieties in the on-farm trials also provides bean breeders with valuable feedback concerning the direction of their research. The project will also produce basic seed stocks of the most promising bean breeding lines and make seed available to the national bean research programs and NGO's involved in the multiplication and dissemination of improved seed.

The project will initiate collaborative research with Mr.Antonio Chicapa Dovala, Head of the Legume Program of the Instituto de Investigacão Agronómica in Angola. Promising bean breeding lines from Central America, the Caribbean and the U.S., primarily of medium-sized market classes, will be provided to the Angolan bean research program for evaluation for local adaptation and consumer acceptance.

Results, Achievements and Outputs of Research:

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 past year, F_1 populations were developed and F_2 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 F_2 and F_3 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.

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

Nome	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

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.

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 University of Puerto Rico, the University of Nebraska, the USDA-ARS Tropical Agriculture Research Station and IDIAF have developed a 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. Supplemental funds were provided by the Management Office to purchase a thresher that will facilitate seed multiplication during the upcoming year.

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

Approaches and Methods: Inadequate soil nitrogen is a frequent yield constraint for common beans in the Tropics. The use of nitrogen fertilizers increase production costs and, in some intensive bean production systems, can contribute to groundwater contamination. Researchers have pointed out the need to develop integrated soil nutrient management practices for beans that would combine biological nitrogen fixation with limited use of fertilizers, sustainable crop management practices, and the development of crop varieties better adapted to low fertility soils. Bean varieties with greater efficiency in the utilization of nitrogen should have enhanced biological nitrogen fixation capacity, root traits such as greater root hair density that contribute to tolerance to low soil P, and healthy root systems that can take advantage of available soil nitrogen and other nutrients.

Recurrent selection (RS) has proven to be useful in the selection of quantitatively inherited traits such as web blight resistance and tolerance to low soil P. We propose to conduct one cycle of recurrent selection to develop Mesoamerican and Andean breeding lines with greater adaptation to low soil N. A second cycle of RS would be conducted if the project is extended beyond the initial 30 months of funding. Preliminary screening conducted in Honduras and Puerto Rico has identified disease resistant bean breeding lines that could be used to form the base population for recurrent selection. A few elite small red bean breeding lines from Zamorano were found to have good biological nitrogen fixation when evaluated in field trials in Minnesota (Peter Graham, personal communication). The root rot resistant black bean line PR0443-151 from Puerto Rico and CIAT bean breeding lines A 774 and VAX 3 have performed well in a low N soil in Puerto Rico. During the past five years, the Zamorano bean breeding program and Dr. Jonathan Lynch have collaborated in the development of small red and black bean breeding lines with greater tolerance to low P soils and drought. Some of these lines also have better yield under low N soils due to increased nodulation by resident rhizobia. Zamorano has experience conducting strain selection and inoculation studies, maintains a collection of bean rhizobia and has the expertise needed to conduct the multifaceted research related to biological nitrogen fixation. Black bean lines developed at the University of Puerto Rico with enhanced levels of root rot resistance, will serve as a source of root rot resistance. In the proposed project, breeding lines will be evaluated in the F_3 and F_4 generations in replicated field trials. The field trials will receive low levels (20 kg/ha) of N fertilizer. The bean lines will be inoculated with recommended bean *Rhizobium* strains to create conditions favorable for biological nitrogen fixation. Dr. Tim Porch will evaluate the F_4 generation for root rot resistance in a field maintained specifically for root rot screening and selection. The most promising F_5 lines will be screened using molecular markers for disease resistance and traits associated with tolerance to low P soils. The most promising lines from each cycle of recurrent selection will be included as entries in regional performance trials in Central America and the Caribbean.

Results, Achievements and Outputs of Research: 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 3^{rd} 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 F_2 nursery based on agronomic characteristics and commercial seed type. In June 2008, approximately 500 F_3 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 F_4 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 $F_{3:4}$ 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.

Approaches and Methods: Marker-assisted selection has proven to be a very useful tool for bean breeders. Unfortunately, molecular markers are not available for some important genes and the use of other molecular markers is often limited to either the Andean or Middle American gene pools. The development of new molecular markers for valuable traits or markers with greater versatility would benefit the entire bean research community.

Resistance to charcoal rot caused by *Macrophomina phaseolina* has been reported to be associated with drought tolerance and it has been recommended that breeding for terminal drought tolerance should include breeding for resistance to charcoal rot. The charcoal rot resistance in the breeding line BAT 477 was found to be controlled by two dominant complementary genes. The RAPD $B386_{900}$ has been reported to be linked in coupling with one of the resistance genes (*Mp-1*) whereas $B459_{1600}$ was reported to be linked in repulsion with the other resistance gene (*Mp-2*). The utility of these markers has not been confirmed because the presence of the markers has not been surveyed in susceptible lines and in other sources of resistance to charcoal rot. The Dry Grain Pulse CRSP project will evaluate the usefulness of the putative molecular markers. If proven to be useful, Dr. Tim Porch will convert these RAPD markers to SCAR markers. If the putative RAPD markers are proven to be ineffective, recombinant inbred lines will be developed from crosses between BAT 477 and susceptible bean lines to attempt to identify new molecular markers for the charcoal rot resistance genes using bulk segregant analysis (BSA).

Although marker-assisted selection is routinely used by some breeding programs, it is currently used by only a few programs in Latin America and the Caribbean. The molecular marker lab at Zamorano will assist other bean research programs in the region in the use of this new technology by providing informal training and assistance in screening elite bean breeding lines and in the application of any new molecular markers developed by this project.

Results, Achievements and Outputs of Research: 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 $B386_{900}$ (coupling) was not amplified in BAT 477 nor in other resistant genotypes, while $B459_{1600}$ (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 $B386_{900}$ and $B459_{1600}$ 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.

Approaches and Methods: The Lima bean (*Phaseolus lunatus* L.) is a heat and drought tolerant dry grain pulse crop that is produced and consumed throughout the Caribbean. Most landrace varieties are indeterminate, short day plants that produce pods during the dry season when there is often a scarcity of common beans. Because Lima beans grow well in fence rows or on walls, the crop is well suited for urban agriculture. Lima bean landraces have been cultivated in the Caribbean during the past 500 years and may have acquired unique traits of economic value. At present, the USDA and CIAT bean germplasm collections contain very few accessions from the region. The germplasm collections currently have 2 accessions from Haiti, ≤ 3 accessions from Puerto Rico and no accessions from the Dominican Republic. We plan to collect and characterize the agronomic traits of at least 30 Lima bean landrace varieties from Puerto Rico and Haiti. Passport data will be collected so that the germplasm can be included in the CIAT and USDA germplasm collections. Seed of superior Lima bean accessions will be increased for further evaluation and possible release in the country of origin.

Cowpeas [*Vigna unguiculata* (L.) Walp] are produced on a limited scale in the Caribbean. Ing. Emmanuel Prophete has expressed interest in evaluating promising cowpea breeding lines from the University of California, Riverside and IITA. The Dry Grain Pulse CRSP project will serve as a facilitator in obtaining cowpea breeding lines for testing in Haiti. The project will also attempt to identify research programs in Central America that might be interested in evaluating cowpea breeding lines. Zamorano will conduct preliminary evaluations of cowpea lines and will provide seed of the best adapted lines to other programs and organizations interested in this crop. Potential areas of adoption of new cowpea lines are the semi-arid regions in northern Nicaragua and southern Honduras where the crop is used as an alternative to common beans during the 'postrera' season. We also plan to collaborate with the University of California, Riverside Dry Grain Pulse CRSP in Angola in the evaluation of beans, cowpeas and other grain legumes, such as Lima beans or pigeonpeas.

Results, Achievements and Outputs of Research: 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%) (Table 3). These results suggest that these cowpea lines have potential either as a forage or as a cover crop.

Table 2. Performance of cowpea lines planted at Isabela, Puerto Rico in February 2009 and harvested approximately 60 days after planting.

Line	Seed type	Dry matter yield (T/ha)	% protein in the biomass
UCR 739	Red-brown	7.9	18.7
UCR 2532	Grey-brown	8.2	16.4
CC 27	Cream	6.0	14.6
CC 36	Cream black eye	6.2	15.1
IT95K-1093-5	Brown cream	5.3	18.3
Lenteja	Cream small	7.5	14.1
Gorda	Cream black eye	7.1	14.7
Mean		6.9	16.0
LSD(0.05)		1.5	2.9
CV(%)		16.3	13.7

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.

Explanation for Changes

Monica Mmbui and Antonio David delayed initiation of graduate studies at the University of Puerto Rico, Mayaguez Campus until August 2009. It was not possible to obtain their J-1 visas to begin studies in January 2009.

During the past year, there was severe damage to crops in Haiti caused by flooding. Therefore, it was not possible to make a collection of Lima bean landraces in Haiti. Ing. Prophete plans to make the collection of the Lima beans during the upcoming year.

During the trip to Angola in November 2008, Ascochyta blight was identified as an important bean disease. Some breeding for Ascochyta blight resistance has been conducted in Ecuador. We plan to request breeding lines that have been reported to have moderate levels of resistance.

Dr. Consuelo Esteves and Dr. Mildred Zapata will join the project as collaborators. Their expertise in plant pathology and biological nitrogen fixation will strengthen the capacity of the project to achieve objectives.

Networking Activities 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

Name of PI receiving leveraged funds: Juan Carlos Rosas
Description of leveraged Project: Development and testing of drought/low fertility tolerant lines in Nicaragua and Honduras
Dollar Amount: $240,000
Funding Source: Red SITCA

Name of PI receiving leveraged funds: James Beaver
Description of leveraged Project: Research assistantship for Ronald Dorcinvil to study soil nutrition problems on the Mycogen Research
Dollar Amount: $15,000
Funding Source: Mycogen

List of Scholarly Activities and 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 e 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.

Contribution to Gender Equity Goal

The development and dissemination of bean cultivars that produce greater or more reliable bean yields should contribute to economic growth and improve the lives of the families of bean producers in Central America, Haiti and Angola.. The project also supports the participation of women in formal and informal training activities.

Progress Report on Activities Funded Through Supplemental Funds

The project received supplemental funds to conduct workshops in Honduras and Angola describing recent advances in bean and cowpea research. Approximately 20 researchers from Central America and the Caribbean and 20 researchers from Angola attended the workshops. Project personnel prepared PowerPoint presentations in Spanish and in Portuguese that were distributed to the participants in the workshop. Greater knowledge of research techniques should permit bean breeding programs to be more effective in the development of improved cultivars.

Equipment to improve the plant pathology laboratory in Huambo, Angola has been purchased. Materials have also been purchased to repair greenhouses in Huambo. Consuelo Estevez will visit Angola in December 2009 to review progress in the establishment of the plant pathology. Quotations have been obtained to purchase threshers for Haiti and Angola.

A significant amount of basic seed stock of bean cultivars was produced in Honduras and Haiti. This effort helped to disseminate seed of improved bean cultivars to farmers in Central America and the Caribbean.

Publications of project personnel during FY09

Beaver, J.S. and J.M. Osorno. 2009. Achievements and limitations of contemporary common bean breeding using conventional and molecular approaches. Euphytica 168:145-175.

Beaver, J.S., M. Zapata, M. Alameda, T. Porch, J.C. Rosas, G. Godoy de Lutz y E. Prophete. 2009. Mejoramiento genético del frijol en el Caribe. Cartel presentado en la Segundo Congreso Internacional y Feria Nacional del Frijol realizado en Zacatecas, Mexico - 4 a 7 de agosto de 2009.

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.

Capacity Building Activities: P1-UPR-1

Objective 6: Degree Training:

Trainee # 1

Name: Ronald Dorcinvil
Citizenship: Haitian
Gender: Male
Degree Program for Training: M.S.
Program Areas or Discipline: Soil Science
Host Country Institution to Benefit from Training: Haitian Ministry of Agriculture
University to provide training: University of Puerto Rico
Supervising CRSP PI: David Sotomayor and James Beaver
Start Date: August 2006
Completion Date: May 2009
Type of CRSP Support (full, partial or indirect): Partial
If providing Indirect Support, identify source(s)s of leveraged funds :

- During the summer of 2008, Mr. Dorcinvil participated in an internship at North Dakota State University. He worked for the NDSU bean breeding program under the supervision of Dr. Juan Manuel Osorno.
- During the 2008/2009 academic year, Mr. Dorcinvil received a research assistantship from a project financed by Mycogen. He was responsible for conducting field research to improve soil nutrient management of corn nurseries planted on the Mycogen Research Station near Salinas, Puerto Rico.
- In August, Mr. Dorcinvil initiated studies at North Dakota State University to pursue a PhD degree in plant breeding and genetics.
- The Pulse CRSP project provided funds for field labor and materials for Mr. Dorcinvil's thesis research. His thesis research was related to the screening of bean lines for adaptation to low soil fertility.

Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $1,000
Indirect cost: $200
U.S. or HC Institution to receive CRSP funding for training activity: University of Puerto Rico.

Trainee # 2

Name: Monica Mmbui Martins
Citizenship: Angolan
Gender: Female
Degree Program for Training: M.S.
Program Areas or Discipline: Plant Breeding and Genetics
Host Country Institution to Benefit from Training: Angola
University to provide training: University of Puerto Rico
Supervising CRSP PI: Tim Porch
Start Date: August 2009
Projected Completion Date: August 2011
Type of CRSP Support (full, partial or indirect): Full
If providing Indirect Support, identify source(s) of leveraged funds
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $20,000/year
Indirect cost: None
U.S. or HC Institution to receive CRSP funding for training activity: The University of Puerto Rico
Comments: Ms. Mbui initiated graduate studies at the UPR, Mayaguez Campus in August 2009.

Trainee # 3

Name: Antonio Nkulo Ndengoloka David
Citizenship: Angolan
Gender: Male
Degree Program for Training: M.S.
Program Areas or Discipline: Plant Breeding and Genetics
Host Country Institution to Benefit from Training: Angola
University to provide training: University of Puerto Rico
Supervising CRSP PI: James Beaver
Start Date: August 2009
Projected Completion Date: August 2012
Type of CRSP Support (full, partial or indirect): Full
If providing Indirect Support, identify source(s) of leveraged funds
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $20,000 ((PI-UCR-1 project)
Indirect cost: None
U.S. or HC Institution to receive CRSP funding for training activity: The University of Puerto Rico
Comments: Mr. David initiated graduate studies at the UPR, Mayaguez Campus in August 2009.

Trainee # 4

First and Other Given Names: Paola
Last Name: Alvarado
Citizenship: Honduran
Gender: Female
Degree Program for training: B.S.
Program Areas or Discipline: Plant Science
Host Country Institution to Benefit from Training: TBD
University to provide training: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Start Date: January 2009
Projected Completion Date: December 2009
Type of CRSP Support (full, partial or indirect): Partial
If providing Indirect Support, identify source(s)s of leveraged funds:
Family support
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $2,000.00
Indirect cost: 0
U.S. or HC Institution to receive CRSP funding for training activity: Zamorano

Trainee # 5

First and Other Given Names: Ruth
Last Name: Valladares
Citizenship: Salvadoran
Gender: Female
Degree Program for training: B.S.
Program Areas or Discipline: Plant Science
Host Country Institution to Benefit from Training: TBD
University to provide training: Zamorano
Supervising CRSP PI: Juan Carlos Rosas
Start Date: January 2009
Projected Completion Date: December 2009
Type of CRSP Support (full, partial or indirect): Partial
If providing Indirect Support, identify source(s)s of leveraged funds:
Family support
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $2,000.00
Indirect cost: 0
U.S. or HC Institution to receive CRSP funding for training activity: Zamorano

Short-term Training:
Training activity # 1

Type of training: Informal training of bean research personnel in Angola
Description of training activity:
Participants: Tim Porch, Consuelo Estevez and James Beaver traveled to Angola to provide short-term training to IIA bean research personnel in Angola on research techniques used to screen bean lines for resistance to biotic and abiotic constraints. The first portion of the workshop was presented in November 2008 and the remainder of the topics of the workshop was presented in August 2009. The presentations in Portuguese were recorded on CDs and distributed to participants of the workshop.
Location: Huambo, Angola
Duration: One week
Scheduling of training activity: November 2008 and August 2009.
Participants/Beneficiaries of Training Activity: IIA pulse crop researchers and staff
Anticipated numbers of Beneficiaries (male and female): 15 people
Amount Budgeted in Workplan:
Direct cost: $10,000
Indirect cost: $1,500
If leveraged funding is to be used to support this training activity, indicate the source and amount:
- None.

Comments: Presentations and other materials for the workshop were prepared by project personnel. The presentations in Portuguese were recorded on CDs and distributed to participants of the workshop.

Training activity # 2

Type of training: Bean breeding workshop for Central American and Caribbean bean researchers.
Description of training activity: The 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 in Spanish were recorded on CDs and distributed to participants of the workshop.
Location: Zamorano

Duration: 5 days
Scheduling of training activity: August 2009
Participants/Beneficiaries of Training Activity: 20
Anticipated numbers of Beneficiaries (male and female): 15
Amount Budgeted in Workplan:
Direct cost: $26,975
Indirect cost: $3,025
If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount:FDN$ 1,000
Comments: Supplemental funds were provided by the Dry Pulse CRSP Management Office to support the workshop. A total of $30,000 was approved for the workshop, including funds ($3,725) to permit University of California, Riverside (PI-UCR-1 project) personnel to discuss cowpea research techniques at the workshop.

Training activity # 3

Type of training: Informal training of a Guatemalan bean researcher.
Description of training activity: Karla Ponciano, technician of the Biotechnology Lab, ICTA, Guatemala, received a short term training dealing with isolation, characterization of *Pheoisariopsis griseola* and screening of ALS resistant germplasm.
Location: Zamorano
Duration: 3 weeks
Scheduling of training activity: Nov-Dec, 2008
Participants/Beneficiaries of Training Activity: 1
Anticipated numbers of Beneficiaries (male and female): 1 female
Amount Budgeted in Workplan:
Direct cost: $1,000
Indirect cost: $150
If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: N/A
Comments: Ms. Ponciano will help ICTA bean researchers on *P. griseola* race characterization and germplasm screening for resistance to ALS.

Dry Grain Pulses CRSP

Report on the Achievement of "Semi-Annual Indicators of Progress"

(For the Period: April 1, 2009 -- September 30, 2009)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2009

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

Provide abbreviated name of institutions in columns below

	UPR			USDA			EAP			IIA			Haiti		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *	10/1/09	Y	N *
(Tick mark the Yes or No column for identified benchmarks by institution)															
Objective 1: Development, release and dissemination of improved bean cultivars.															
Germplasm acquired for key abiotic and biotic stress factors of Angola															
Germplasm tested in Angola				X	X										
Breeding populations developed															
Breeding populations tested	X	X					X	X					X	X	
Advanced trials conducted	X	X					X	X		X	X		X	X	
Promising lines validated on farm	X	X					X	X					X	X	
Cultivar released	X	X					X	X							
Objective 2: Selection of beans for adaptation to low N soils.															
Complete field and greenhouse evaluations to identify most promising sources of BNF germplasm	X	X					X	X							
Complete crosses for the first cycle of recurrent selection for enhanced BNF	X	X					X	X							
Harvest F2 seed for the first cycle of recurrent selection	X	X					X	X							
Objective 3: Develop molecular markers for disease resistance genes.															
Sources of ashy stem blight resistance acquired				X	X										
Existing RAPD markers tested				X	X										
Effectiveness of RAPD markers in acquired germplasm determined				X	X										
RAPD products cloned and sequenced				X		X									
SCAR markers designed and initially tested				X		X									
Objective 4: Evaluation of other pulse crops for Central America and the Caribbean															
Complete collection of P. lunatus															
Complete first year of field testing of cowpeas in PR, Haiti, and Central America	X	X													
Characterize the phenological, morphological, and agronomic traits of P. lunatus (Haiti, PR)	X	X											X		X
Objective 5: Increase the capacity, effectiveness and sustainability of agricultural research institutions that serve the bean and cowpea sectors in Central America, Haiti and Angola.															
M.S. training of Ronald Dorcinvil completed	X	X													
M.S. training of Monica mmbui initiated	X	X													
M.S. training of Antonio David initiated	X	X													
Informal training in Angola in bean research techniques				X	X										
Informal training in Honduras in bean research techniques															
Workshop in Central America in bean research techniques and the discussion of a new strategy for the development and dissemination of bean cultivars							X	X							
Name of the PI reporting on benchmarks by institution	James Beaver			Tim Porch			Juan Carlos Rosas			Antonio Chicapa			Emmanuel Prophete		

Name of the U.S. Lead PI submitting this Report to the MO: James Beaver

James Beaver (signature) — Signature

Oct 20, 2009 — Date

* *Please provide an explanation for not achieving the benchmark indicators on a separate sheet.*

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 -- September 30, 2009)

PERFORMANCE INDICATORS/TARGETS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Development, Testing and Dissemination of Genetically Improved Bean Cultivars for Central America, the Caribbean and Southern Africa.
Lead U.S. PI and University: James S. Beaver, University of Puerto Rico
Host Country(s): Central America, Haiti, Angola

Output Indicators	2008 Target	2008 Actual	2009 Target	2009 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)	
Degree Training: Number of individuals who have received degree training				
Number of women			2	2
Number of men			1	1
Short-term Training: Number of individuals who have received short-term training				
Number of women			2	8
Number of men			10	32
Technologies and Policies				
Number of technologies and management practices under research			50	100
Number of technologies and management practices under field testing			5	10
Number of technologies and management practices made available for transfer			2	5
Number of policy studies undertaken			0	0
Beneficiaries:				
Number of rural households benefiting directly			1,000	5,000
Number of agricultural firms/enterprises benefiting			2	2
Number of producer and/or community-based organizations receiving technical assistance			5	10
Number of women organizations receiving technical assistance			1	2
Number of HC partner organizations/institutions benefiting			5	6
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices			5,000	10,000

Note: Each breeding line and variety is considered as an individual technology.

ACRONYMS

CIAT	Centro International de Agricultura Tropical (International Center for Tropical Agriculture), Colombia
EAP	Escuela Agricola Panamericana- Zamorano, Honduras
HC	Host Country
IAR	Institute for Agricultural Research, Nigeria
IEHA	Presidential Initiative to End Hunger in Africa
IIA	Instituto de Investigação Agronómica, Angola
IIAM	Instituto de Investigacao Agraria de Mocambique, Mozambique
INERA	Institut de l'Environment et des Recherches Agricole, Burkina Faso
INIAP	Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INRAN	l'Institut National de la Recherche Agronomique du Níger, Niger
ISAR	Institute des Sciences Agronomique du Rwanda, Rwanda
ISU	Iowa State University
KARI	Kenyan Agriculture Research Institute, Kenya
KIST	Kigali Institute of Science and Technology, Rwanda
MO	Management Office
MSU	Michigan State University
NCRRI	National Crops Resources Research Institute, Uganda
PSU	The Pennsylvania State University
UCR	University of California- Riverside
UIUC	University of Illinois at Urbana Champaign
UPR	Universidad de Puerto Rico- Mayaguez
USAID	United States Agency for International Development
UWO	University of Western Ontario
VEDCO	Volunteer Efforts for Development Concerns, Uganda