FY 2010 TECHNICAL PROGRESS REPORTS

October 1, 2009-September 30, 2010

Dry Grain Pulses Collaborative Research Support Program (CRSP)

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

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

TABLE OF CONTENTS

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

Principle Investigator

Julie Lauren, Cornell University, USA

Collaboratoring Scientists

John Ojiem, KARI, Kenya
Beth Medvecky, Cornell, USA
Alice Pell, Cornell, USA
John Duxbury, Cornell, USA
Peter Hobbs, Cornell, USA
Rebecca Stoltzfus, Cornell, USA
Christopher Barrett, Cornell, USA
Martins Odendo, KARI, Kenya
Samuel Mwonga, Egerton, Kenya
John Okalebo, Moi University, Kenya
John Nderitu, UNairobi, Kenya
James Muthomi, UNairobi, Kenya
Robin Buruchara, CIAT, Uganda

Abstract of Research Achievements and Impacts

A second Short Rains-Long Rains cropping cycle was completed in the South Nandi region of Western Kenya focusing on crop vigor enhancing strategies that improve production of staple crops, maize and bean, while also introducing a new multipurpose grain legume *Lablab purpureus* with good potential for improving household food security and addressing soil degradation. Major activities in FY10 have included: participatory evaluation of vigor enhancing strategies by 70 collaborating farmers across a soil fertility gradient; training and on-farm testing of the strategies by 175 farmers associated with NGO/CBO groups in Busia, Teso, Butula and Vihiga districts; facilitating exchange visits to promote farmer learning & knowledge sharing; implementation of researcher managed replicated experiments at 4 sites across the gradient; and technical/financial support for 6 students (3 women, 3 men) pursuing Masters degrees at Kenyan universities.

Short Rains 2009-10 results were consistent with those obtained last year, despite higher than normal rainfall due to El Nino climate conditions and intense disease/pest pressure. Averaged across all verification trials, farmers were able to realize a 15% yield increase by substituting improved bean variety KK8 for their own variety. By substituting KK8 and adding TSP fertilizer, farmers were able to achieve a 41-71% yield gain. Lablab grain production in 2010 was variable due to the climate and severe halo blight (replicated experiments). Nevertheless at 3 of the sites, unfertilized lablab grain yields ranged from 677 to 1200 kg/ha and were 1.4 to 2.2x greater than farmers' local bean varieties. Phosphorus fertilizer increased lablab grain and biomass productivity, although the effect was not as pronounced as with beans.

During the Long Rains season, farmers were able to make substantial gains in maize productivity by utilizing the alternative fertilization strategies particularly incorporated lablab residues or ½ compost +½ DAP. Maize yield gains relative to farmer practices were greatest at the low soil fertility site (25-59%) and smallest at the high soil fertility site (-2-10%). In the replicated experiments incorporated lablab increased intercropped

bean yields by 22% but in most of the farmer verification trials, lablab residues did not increase yields relative to farmer practices. We hypothesize that residue management/placement differences explain these results.

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

Five Masters students enrolled at either Moi University or Egerton University have completed their Masters degrees or are in the process of finalizing their thesis write-ups. Two new students were recruited for Masters degrees at Moi University and the University of Nairobi with FY10 HC Capacity Building funds support.

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. We hypothesize that practices that promote 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.

Consumption of pulses is essential for addressing iron deficiency, anemia and stunting caused by inadequate intakes of zinc. Recent national or regional level food composition data on the mineral nutrient content of staple food products, including iron and zinc, 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 learning partnerships. Providing opportunities for current and future scientific leaders to gain experience and expertise with participatory research and development approaches also are an essential part of the education process. These experiences will help students and research scientists to 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, 2009 - September 30, 2010

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

Approaches and Methods:
1. In Community Farmers Meetings/Training Sessions
2. On Farm Verification Trials

Results, Achievements and Outputs of Research:
1. In community meetings/trainings – During both the Short Rains (SR) and Long Rains (LR) seasons of FY10, KARI field staff conducted numerous meetings in the South Nandi project area to educate farmers within the initial core groups and interested farmers in the surrounding communities on the use of vigor enhancing strategies (seed priming, root rot tolerant bean germplasm, boma compost, Triple Super Phosphate (TSP) & Minjingu Rock Phosphate (MRP) fertilizers, combining inorganic + organic fertilizers and multipurpose lablab); to facilitate farmer testing of these strategies (supplying seed & fertilizers, hands-on demonstration) and to promote farmer learning through exchange visits and knowledge sharing with scientists, university faculty and students. KARI scientists also attended and led similar programs with the three NGO/CBO organizations (REFSO, ARDAP, AVENE) and their lead farmers (see Objective 2, Activity 1 below).

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

A total of 70 farmers participated in lablab and common bean verification trials during the Short Rains 2009-10 including an additional 20 farmers from the surrounding communities. Farmers selected root rot tolerant KK8 bean and/or lablab treatments according to their interests and available resources. Fifty-eight farmers compared their own bean varieties and planting practices to the following treatments: unfertilized KK8 beans, bean seed priming, KK8 fertilized with 20 kg/ha P fertilizer MRP or TSP, or a combination treatment that included both priming and P fertilization. Fifty-six farmers experimented with various strategies for growing lablab. Farmers compared a control plot of unfertilized and unprimed lablab to various treatments including lablab seed primed, lablab planted with 20 kg/ha P fertilizer (TSP, MRP), and lablab primed and planted with P fertilizer. The 3 treatments that were tested by the largest numbers of farmers were TSP (55 farmers), priming (44 farmers) and TSP+priming (43 farmers).

During LR 2010, 58 farmers conducted a final round of verification trials on alternative fertilization strategies for their main maize-bean intercrop -- 13 farmers in Kapkerer, 14 in Kiptaruswo, 19 in Bonjoge and 12 in Koibem. Farmers tested the following treatments, according to their interests and resources: (1) a more targeted and concentrated application of DAP (1 level soda cap /plant); (2) compost applied in the planting furrows (three - two kg cooking fat containers/6 m row); or (3) a half dose of compost mixed with half the amount of the DAP applied in treatment #1; (4) a lablab residue treatment that consisted of all lablab residues (less any harvestable grain and pod) produced in situ the previous season, incorporated into the soil several weeks before planting; and (5) a half lablab DAP treatment with half the quantity of residue used in treatment #4 combined with half the quantity of DAP used in treatment #1. Farmers compared the above treatments to their own fertilization strategies which mostly consisted of low application rates of diammonium phosphate (DAP) fertilizer spread thinly over a larger area. Several farmers used compost, manure or no fertilizer at all. Each farmer used his or her own maize and beans spacing method in their farmer practice plot, while both maize and beans were sown at the recommended spacing in all of the verification plots.

Farmers used their own seed of their preferred bean and maize varieties in the LR trials. For beans, 89% of the farmers preferred KK8 beans. For maize, farmers chose either early or late-maturing hybrids or their own local landraces, depending on the community. Late maturing hybrids were most important at Koibem (92% of farmers) and Kiptaruswo (72%), the two communities that have a more market-oriented agriculture. In contrast, local landraces were more important in Kapkerer (60%) and Bonjoge (62%). At Kapkerer, approximately 20% of the participating farmers chose to plant early maturing maize hybrids, possibly because this is a community where farm sizes are small and households are more food insecure.

The results from the SR and LR farmer verification trials are detailed below (Objective 2, Activity 2).

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. Collaborations with NGO and farmer groups
2. Crop performance evaluation and in season exchange visits
3. Develop and distribute project-related training materials
4. Complete socioeconomic survey and continue to monitor technology diffusion trends

Results, Achievements and Outputs of Research:

1. Collaborations with NGO and farmer groups – The project continued to support two NGOs (ARDAP and REFSO) and one CBO (AVENE) working with farmers to scale-up and disseminate vigor enhancement strategies and monitor farmer's reaction and crop responses to these strategies in Busia, Teso, Butula and Vihiga districts of Western Province. During FY10, ARDAP conducted farmer verification trials and seed bulking activities, while REFSO concentrated on bulking bean and lablab seed in readiness for farmer testing. AVENE activities mainly consisted of farmer verification trials. In all

cases, treatments for the verification trials were selected by the farmers according to their interest and available resources and were limited to those that showed the greatest promise. The project supplied sufficient quantities of KK8 bean and lablab seed to ARDAP, REFSO and AVENE for seed bulking and dissemination activities, and fertilizers (TSP, MRP) to ARDAP and AVENE for verification trials. Where possible, participating farmers were encouraged to use their own seed saved from previous harvests. Collaboration with these three organizations enabled us evaluate the performance of the vigor enhancing strategies in other agro-ecological zones and to confirm that these approaches can be successfully used in different environments. In addition, the activities served to build the capacity of the NGOs and provided a platform for future scaling up activities.

ARDAP - A total of 20 farmers were initially recruited to participate in verification trials which compared the performance of different vigor enhancement strategies with farmers' production practices. Strategies evaluated by ARDAP farmers included seed priming, MPR, TSP, compost and lablab. Later the number of farmers increased from 20 to 60 farmers and all installed verification trials. The project provided the new farmers with starter KK8 and lablab seed and P fertilizers. An additional root rot tolerant bean variety, KK71 was also introduced by KARI for evaluation by farmers alongside KK8 variety.

At the conclusion of the Long Rains, participating farmers attended and participated in a result sharing workshop which was organized to provide an opportunity for farmers to discuss and compare results of the previous season along with ARDAP and KARI staff. Farmers continued to be impressed with priming and MRP, and a majority settled on MRP as the preferred choice of fertilizer. Despite severe diseases & pests (especially aphids), all the tested crop vigor enhancement options substantially outperformed farmer practices.

Initially a 1 acre KK8 bean bulking plot was established to produce seed for future use. During the Long Rains, seed bulking of KK8 and lablab was enhanced by increasing the size of the bulking plot from 1 to 2 acres.

REFSO - worked with Agro-Farmers, a CBO in Busia district to bulk KK8 bean seed for distribution to farmers during the Long Rains season. A total of 19 farmers participated in this activity. REFSO also organized KK8 bean bulking plots on 2 acres in Ngelechom village during the Long Rains in order to target farmers in Teso district. Heavy rains adversely affected seed production at both sites, so the bulking activity is being repeated during the current Short Rains season with 12 farmers at Busia and on 2 acres at Amukara in Teso district. The plots are currently doing well and KK71 seems to be doing much better than KK8. REFSO also bulked lablab seed during the Long Rains 2010.

AVENE is working with a total of 65 farmers in 5 locations of Sabatia and Chavakali divisions of Vihiga district, Western Province. Farmers tested a variety of crop vigor enhancement options on bean, lablab or both, depending on land availability and preference. Farmer verification trials were established during the Short Rains and Long Rains seasons. The treatments farmers found promising and wanted to verify further were: i) KK8 beans +TSP, ii) KK8 Beans primed+compost and iii) KK8 beans+lablab residue. These were compared to farmer practice in demonstration plots. The project supplied TSP fertilizer, while the farmers supplied KK8 bean and lablab seed (saved from previous seed bulking activities). Farmers also made compost manure which was used in the verification trials, having been trained by the project on how to prepare high quality compost.

Figure 1 shows the results of bean and maize grain yields in response to the vigor enhancing options tested by AVENE farmers during the Long Rains 2010. Plots planted with KK8 bean plus compost or DAP outperformed farmer practice on most of the farms that were involved in the trials. The superiority of compost and lablab residues was especially found on farms with low soil pH and lower soil fertility. Farmers were generally reluctant to use these fields due to poor crop performance; however, the excellent performance shown by compost and lablab residue incorporation proved to farmers that these plots could be rejuvenated with organic inputs and improved bean germplasm.

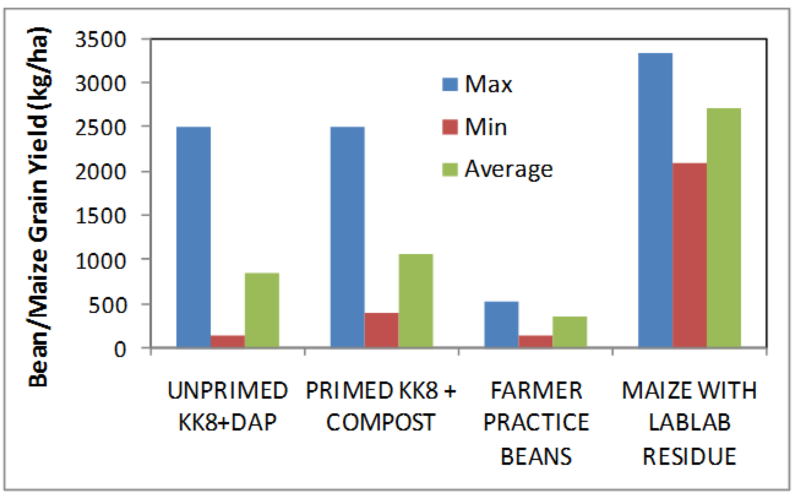


Figure 1 Maximum, minimum and average bean & maize grain yields obtained with vigor enhancing strategies by 40 AVENE farmers during Long Rains 2010

AVENE also works with two women's groups namely Givudianyi Women's Group in Wodanga and Kulala Women's Group from Busali East in Vihiga district. Givudianyi Women's Group has 40 members with the objective of promoting small scale entrepreneurship through table banking, small scale farming and adult education. During FY10, the group was trained on high quality compost making and management. All group members participated in this activity and about 48 farmers have constructed compost piles. Some have used the compost on their farms and found it extremely useful and economical compared to chemical fertilizers. Members have also been given lablab and KK8 bean seed for bulking to use in subsequent seasons. Two members of the Kulala Women's Group were trained on compost manure making and educated about crop vigor enhancement strategies. These women are now involved in the training of the other 22 group members on compost making and crop vigor enhancement. The group also has been provided with lablab and KK 8 bean seeds for bulking.

2. Crop performance evaluation & in season exchange visits - Data from the farmer

verification trials for 2009-10 Short and Long Rains crops have been collected, compiled and shared amongst the farmers and scientists. Datasets include plant emergence and mortality, nodule counts, pods per plant as well as grain and biomass yields of lablab (SR only), beans (SR & LR) and maize (LR only). Pest/disease incidence/severity data for bean root rot, bean stem maggot (*Ophiomyia* spp.) and aphids (*Aphis fabae*) were also collected.

The following sections summarize the findings from the second year of farmer validation trials:

A. *Short Rains 09-10 crop performance results*

<u>Beans</u> - Farmers were most interested in comparing: (a) how unfertilized KK8 performed relative to their own unfertilized varieties and (b) how KK8 performed with or without TSP fertilizer. The results of these comparisons are the focus below.

Site effects: Bean productivity did not follow the gradient this season due to more intense disease pressure at Kiptaruswo and Bonjoge. Mean bean yields moving from low fertility to high fertility site were 754 kg/ha in Kapkerer, 586 kg/ha in Kiptaruswo, 637 kg/ha in Bonjoge and 1117 kg/ha in Koibem.

Treatment effects: Yield trends by treatment were similar to previous seasons. They were also consistent across the gradient (Figure 2). Mean yields by treatment were (i) 635 kg/ha for unfertilized farmer varieties; (ii)728 kg/ha for unfertilized KK8; and (iii) 958 kg/ha for KK8 fertilized with TSP. Thus, on average, farmers were able to realize a 0-31% yield increase (going across the fertility gradient from Kapkerer to Koibem) simply by substituting improved germplasm for their own variety. By substituting KK8 *and* adding TSP fertilizer, farmers were able to achieve a 41-71% yield increment. Additional data, collected this season, helps to explain some of the factors that contribute to these yield effects:

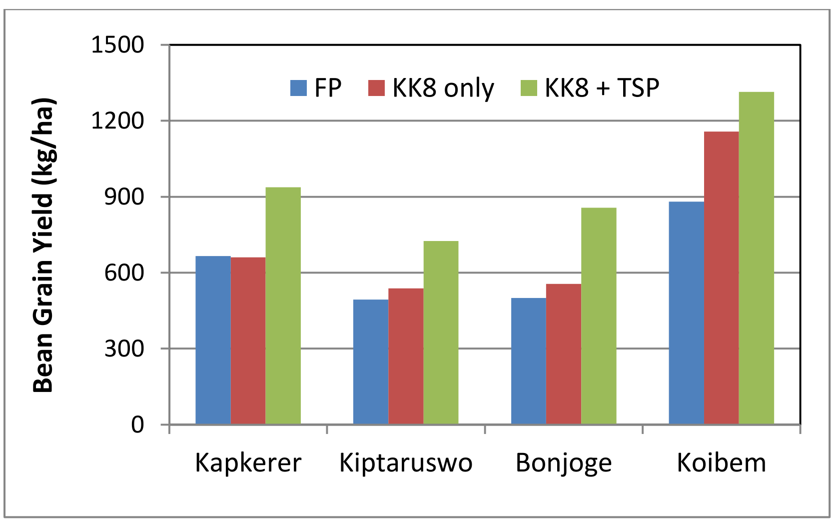


Figure 2 Mean bean yields (kg/ha) at the four sites for unfertilized farmer bean varieties (FP), unfertilized KK8 beans (KK8 only) and KK8 beans planted with TSP (KK8 + TSP), Short Rains 2009-10

Germplasm contribution When we compare trends in the difference between the average numbers of pods/plant for KK8 versus the average numbers for farmers' own varieties (i.e. planted in the FP plot), the data show that KK8 plants have consistently more pods at harvest across sites (Figure 3) and farmer varieties. Thus, KK8 appears to have a higher yield potential than the varieties farmers are currently growing.

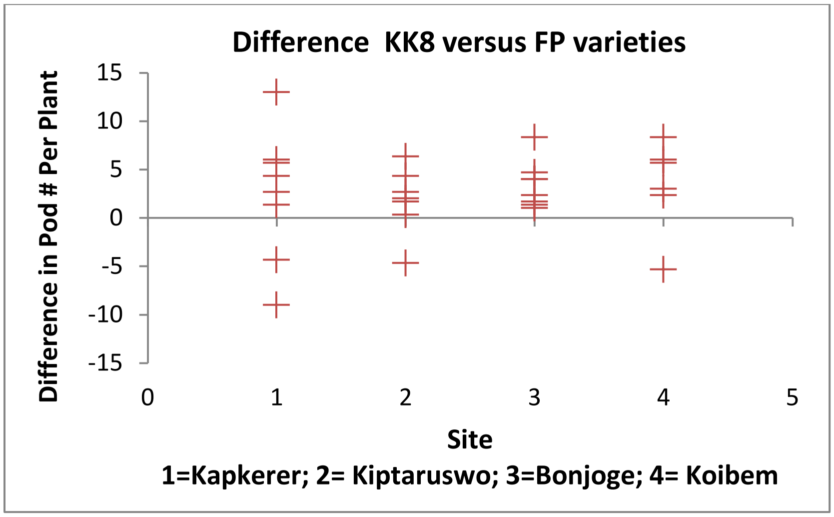


Figure 3 Differences in numbers of pods per plant between KK8 beans and farmer bean varieties grown on Nandi farms during the Short Rains 2009-10. (Difference = the average numbers of pods (3 plants/variety) of plants in the unfertilized KK8 beans treatment on an individual farm – the average numbers of pods for the farmer variety grown in the FP treatment on the same farm).

TSP's contribution: Making the same type of comparison used above for the difference between average numbers of KK8 pods with and without fertilizer, the results showed that, at the lower fertility sites, applying TSP fertilizer increased the numbers of pods per plant even further relative to unfertilized KK8 (Figure 4). Moreover, TSP application also enhanced the survival of plants to harvest. Across farms, an average of 43 more KK8 plants/plot survived to harvest when they were fertilized compared to those not fertilized.

Thus, both increased pod production and increased numbers of plants per plot help to explain the substantial bean yield increments that farmers realized using improved germplasm and phosphorus fertilization.

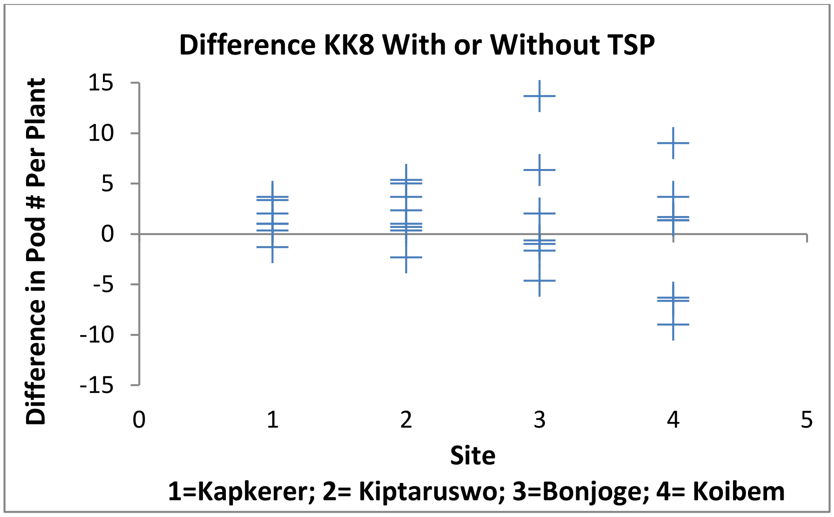


Figure 4 Differences in numbers of pods per plant between unfertilized KK8 beans versus fertilized KK8 grown on Nandi farms during the Short Rains 2009-10. (Difference = the average numbers of pods (3 plants/treatment) of the fertilized KK8 bean treatment on an individual farm – the average numbers of pods from the unfertilized KK8 treatment on the same farm).

<u>*Lablab*</u> - As in previous seasons, lablab grain yields followed the fertility gradient, with yields increasing from the lowest to highest fertility sites (Figure 5A). Mean grain yields were 437 kg/ha in Kapkerer, 730 kg/ha in Kiptaruswo, 1025 kg/ha in Bionjoge and 1288 kg/ha in Koibem. Aboveground biomass yields did not show the same fertility level-response pattern, although they were also highest at the highest fertility site (Figure 5B).

Generally, treatment effects were inconsistent across sites for most of the variables evaluated (emergence, stand counts, pest infestation incidence and yield). However, using the difference method for evaluating ‘improved practice’ versus its counterpart treatment in the same farmer’s experiment, several potential trends were detected. These included: (i) that P fertilization and/or priming enhanced plant survival (by decreasing both root rot and bean stem maggot–related mortality) at the two lower fertility sites; and (ii) TSP application increased lablab productivity, although these effects were not as pronounced as with common beans, possibly due to lablab characteristics (extensive root system, long period to maturity and its ability to establish strong mycorrhizal associations).

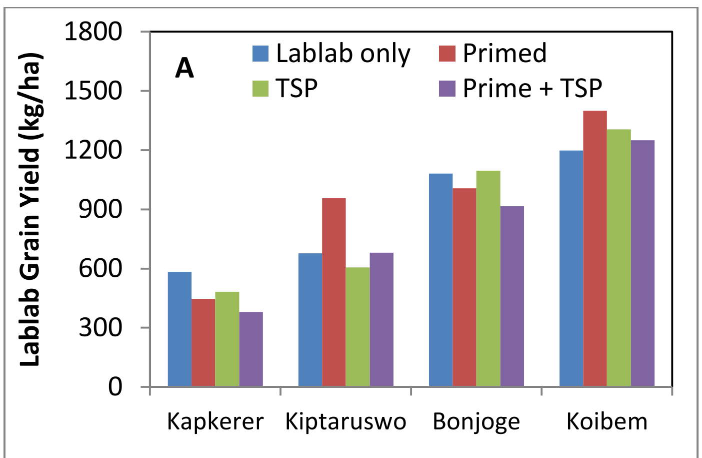


Figure 5 A: Lablab grain;

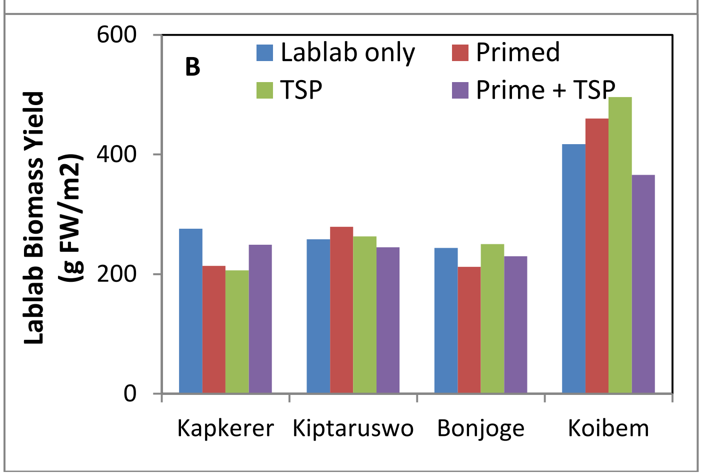


Figure 5 B: Lablab aboveground biomass yields for the 4 different lablab treatments that were most widely tested by Nandi farmers in the 2009-20 Short rains.

B. *Long Rains 09-10 crop performance results*

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

½ lablab - ½DAP mixture (Table 1). At individual communities, plant composts were popular at Kapkerer and composted manure at Koibem.

Table 1 Numbers of Nandi farmers electing to test alternative fertilization strategies during the Long Rains 2010.

Fertilization Strategy	Kapkerer (n=13)	Kiptaruswo (n=14)	Bonjoge (n=19)	Koibem (n=12)
DAP	11	12	19	11
Compost	9	6	7	6
Half compost DAP	6	7	4	4
Lablab	8	10	12	8
Half lablab DAP	8	10	11	9

Stand count data were collected at 2 and 3 weeks after planting (WAP). Because counts were still increasing between 2 and 3 WAP (i.e. due to non-uniform/delayed germination) the crop establishment results presented are from the 3 WAP stand counts. Data were also collected separately on the numbers of bean plants dying from post-emergence damping-off at 2, 3 and 4 WAP.

Bean seedling mortality at 2 WAP - The bean seedling mortality data show extremely similar mortality trends to those observed last year (Figure 6). The highest post-emergence damping off tended to occur on the lower fertility soils (Kiptaruswo and Kapkerer) and in those treatments with either the lowest level of nutrients (i.e. farmer practice or compost) or in the incorporated lablab residue treatment, which is characterized by imperfectly understood nutrient decomposition and/or disease interactions, as discussed in last year's report.

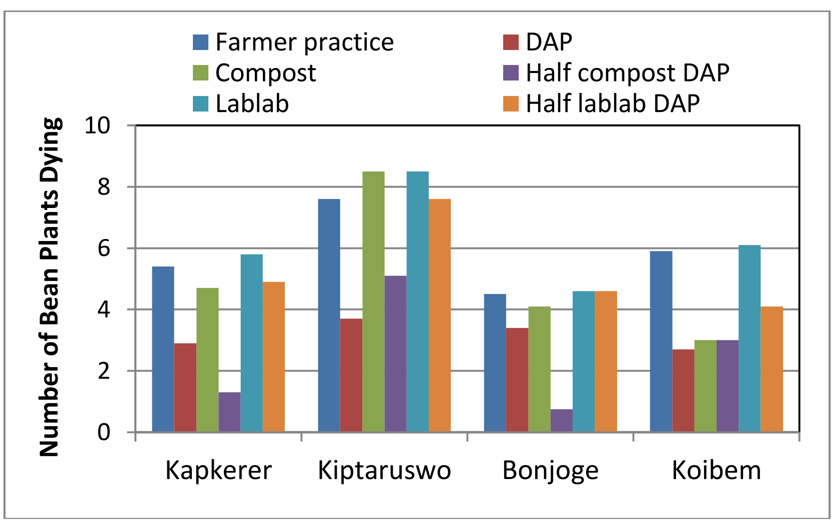


Figure 6 Numbers of bean plants dying from post-emergence damping off at 2 WAP in farmers' verification trials during the long rains 2010.

Plant populations/stand establishment at 3 WAP - We have noted that Nandi farmers sow greater quantities of both maize and bean seed than needed for recommended plant populations for these crops. In a year such as this, when weather conditions were not conducive to rapid, uniform germination, farmer oversowing meant that the farmer practice maize stands came closer (an average of 98% of the target, across communities) to achieving the target stand (i.e. 100% of seeds sown) than the maize stands in the alternative fertilization strategy plots, which were on average, only 69% of the target stand across communities and alternative treatments (Figure 7). This suggests that, on average, farmer sowing rates are around 30% greater than the recommended rate. Also of note was the inferior germination of farmers' local maize seed compared to the hybrid maize seed; there were 6 farmers who achieved stands with less than 50% of the target population present across treatments, using their local seed. Perhaps high incidences of poor stand establishment and/or poor seed viability are factors that motivate farmers to oversow.

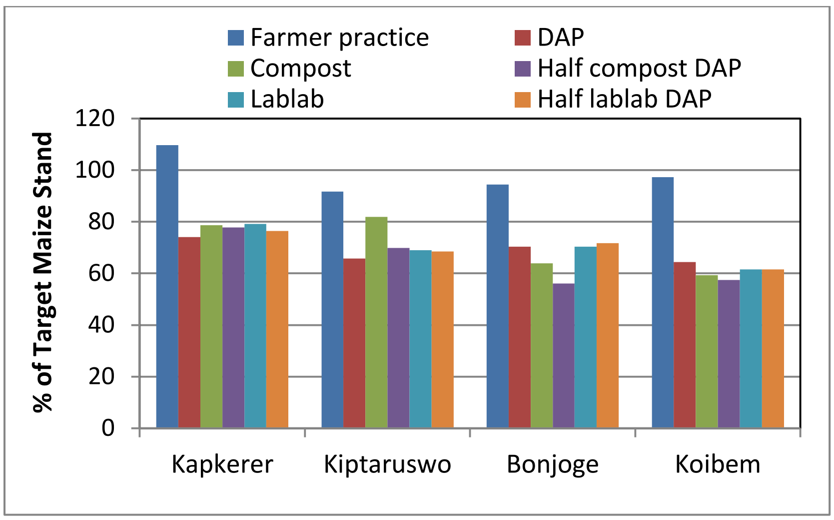


Figure 7 Maize stand establishment at 3WAP by fertilization strategy and site, Long Rains 2010.

Overall, bean stand establishment was better at Bonjoge (66% of target stand) and Koibem (63%) than at Kapkerer (57%) and Kiptaruswo (59%) (Figure 8). These trends were the opposite of those for maize stand establishment but may be related to the differences in bean seedling mortality explained above. Also notable was that the two full organic treatments (compost; lablab) had a higher % stand establishment - 67% compared to an average of 58% for the other fertilization strategies, including the farmers' practice. This result suggests that the residues may have been important for helping to retain moister conditions more suitable for seed germination.

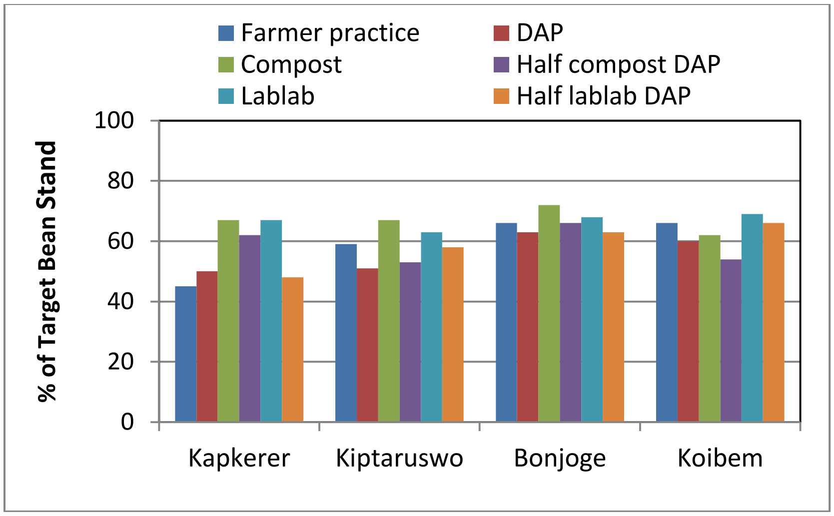


Figure 8 Bean stand establishment at 3 WAP by fertilization strategy & site, Long Rains 2010

Maize and bean yields - Overall, mean yields of the bean intercrop were slightly higher in 2010 than in 2009 (157 vs 120 kg/ha). Bean performance was best at Kapkerer (mean yield 216 kg/ha) and worst at Kiptaruswo (63 kg/ha), likely due to differences in weather and late season disease pressure. As in 2009, the 2010 bean performance varied substantially by treatment. Moreover, the same general yield trends were observed in both years (Figure 9); bean productivity was poorest in farmer practice, lablab, and compost and best in the half DAP and full DAP treatments.

Yields of the companion maize crop were also higher in 2010 than in 2009 (overall means, 3261 vs 2398 kg/ha). Maize yield gains relative to the farmer practices were greatest at the lowest fertility site and smallest at the highest site (25-59% higher than the farmer practice at Kapkerer vs. -2-10% higher at Koibem).

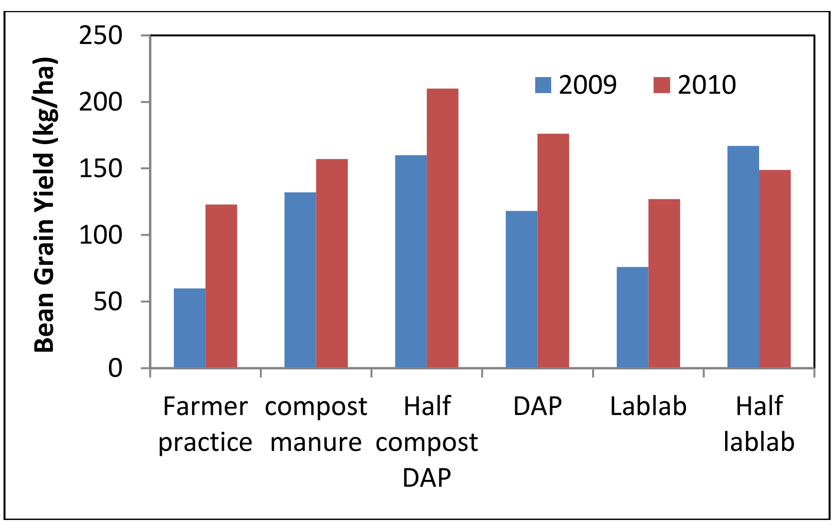


Figure 9 Mean bean yields by treatment for the 2009 and 2010 Long Rains season.

Across communities, mean maize yields in the alternative fertilization treatments were consistently higher than mean farmer practice maize yields (17 out of 20 comparisons) despite the fact that maize stands in these treatments were, on average, 30% lower than the target stand (Figure 7). The productivity trends by fertilization treatment, averaged across communities, were, like beans, similar to those observed in 2009 (Figure 10). These results demonstrate that farmers can make fairly substantial gains in maize productivity simply by utilizing improved agronomic practices and alternative fertilization strategies. Moreover, the trials have shown farmers that they have multiple options for achieving increased maize productivity, depending on the type and amounts of purchased and/or locally available inputs they might have available in a particular season. This enables farmers to respond to dynamically changing conditions more effectively than if they were shown a single, fixed package of improved maize production practices.

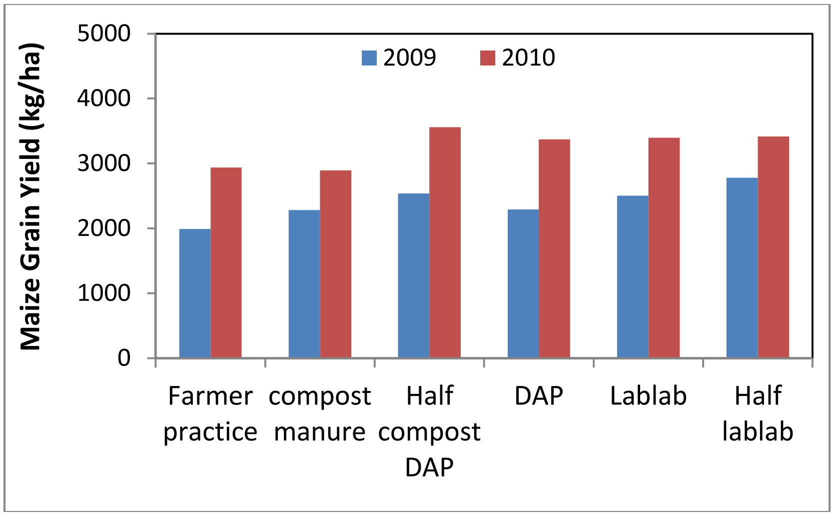


Figure 10 Mean maize yields by treatment during the 2009 and 2010 Long Rains

C. *Farmer-to farmer exchange visits*

Exchange visits during the 2009 Short Rains season did not take place because the farmers were engaged in traditional ceremonies and were not available for the visits. Exchanges were resumed in 2010 during the Long Rains season. Discussions about the previous Short Rains season were included.

Farmer exchange groups were switched in 2010 to expose the participants to different agro-ecological conditions. In particular we wanted to create awareness with the Koibem farmers (high soil fertility group) about the effects of soil fertility degradation. As a result Kapkerer farmers (low soil fertility) exchanged with Koibem farmers; and Kiptaruswo farmers (medium low soil fertility) swapped with Bonjoge farmers (medium high soil fertility). A total of 25 farmers attended the Kapkerer visit and 30 came for the Koibem visit. At Kiptaruswo 27 farmers participated and 26 farmers attended the Bonjoge tour. An equal number of men and women attended across all sites. Two KARI field staff and a scientist from the Socieconomics unit participated in all the visits.

At each site, groups toured 4 farmer verification trials and the researcher managed replicated experiment under maize cultivation. Host farmers explained the alternative fertilization options being tested in their verification experiments. Question & discussion periods after each presentation provided a forum for farmers to discuss benefits and constraints. Farmers were then asked to rate the performance of the Long Rains treatments on maize using colored ribbons. After the field tour, there was a further discussion and ranking focused on the Short Rains treatments.

Incorporated lablab residues (lablab only) were ranked highest at Bonjoge and Kiptaruswo sites, while ½ boma compost+½ DAP was given the highest rating at Kapkerer and Koibem. Lower rankings were given for other alternative fertilization treatments but all were greater than the farmer practice which was uniformly ranked poorest. Some of the Kiptaruswo-Bonjoge group commented that the process of cutting and incorporating lablab was too laborious, but others felt that with sharp tools the work was easy. Two of the Kapkerer host farmers noted that after using lablab, the incidence of Striga was substantially less and that they expected higher maize yields as a consequence.

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

Across all sites, farmers reported using some or all of the vigor enhancing strategies on other parts of their farms. Within the Kapkerer-Koibem exchange group, 32% of the participants had upscaled boma compost, 40% were using KK8 beans instead of local varieties, 75% were growing lablab and 8% were following improved spacing/seed rate strategies. Boma compost was being used by 42% of farmers from the Kiptaruswo-Bonjoge exchange group, and KK8 bean and lablab were being grown by 38% and 80% of the farmers, respectively. Only one farmer in the Kiptaruswo-Bonjoge group reported using the improved spacing/seed rate on his farm. Seed priming was considered too labor intensive by Bonjoge participants and only one farmer was using the technique to improve bean germination.

All the exchange visit participants preferred lablab first for soil fertility, but had somewhat different preferences for its other uses. Market sales, grain and fodder uses were equally favored by the Kapkerer-Koibem exchange group; but lablab was least preferred as a vegetable because of its "beanie smell" and different shape. In the Kiptaruswo-Bonjoge group, lablab for grain was only slightly less popular than lablab for soil fertility, 20% of the farmers liked lablab as a vegetable and 15% used the biomass for fodder. Lablab for market sale was of least importance since no markets have been identified outside of the Kiptaruswo-Bonjoge communities where local demand is still growing.

3. Project-related training materials – Simple, pictorial training materials for farmers and development workers have been prepared. These materials focus on: (i) how to grow lablab and its multipurpose benefits (Figure 11); (ii) use of boma compost, organic/inorganic fertilizer mixtures, and lablab residues as alternative fertilization strategies for intercropped maize and beans; and (iii) P fertilizer use to improve productivity of grain legumes. The materials will be distributed through KARI to NGO, CBOs and other extension trainers in Kenya.

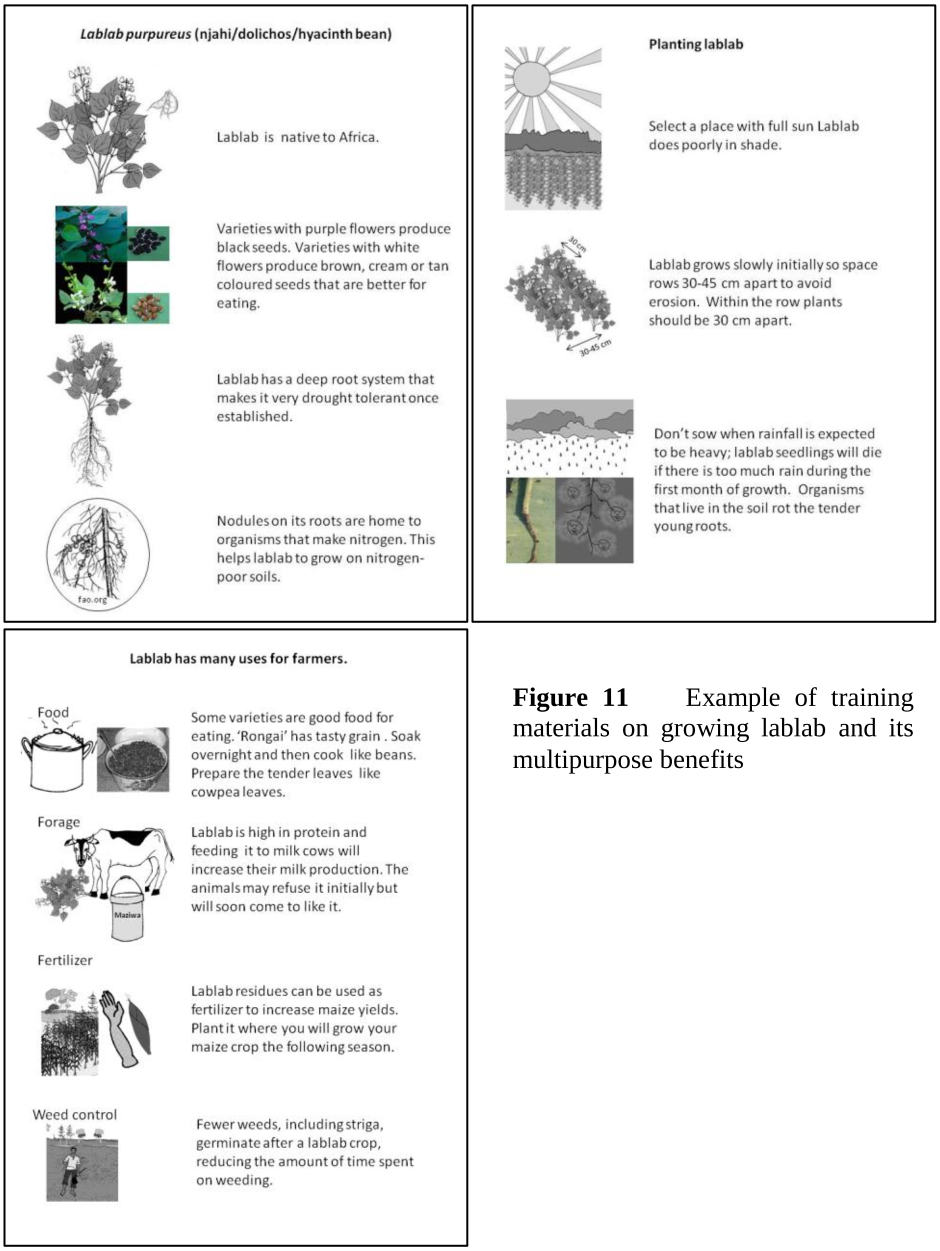


Figure 11 Example of training materials on growing lablab and its multipurpose benefits

4. Socioeconomic survey completion and technology diffusion trends – Ms. Eunice Onyango completed individual household surveys in early FY10 as part of her Masters research program. This activity was a follow-up to the Focal Group Discussions reported in the FY09 Annual Report.

A total of 130 households were surveyed in the South Nandi project area focusing on the four core communities of Kapkerer, Kiptaruswo, Bonjoge and Koibem. Overall, 55% of the respondents were women. All 65 households who had participated in the initial farmer workshop and 2008-09 verification trials were interviewed along with an equal number of farm households in the same communities who had not directly participated in the project activities. Project participants were asked to indicate which of the vigor enhancing strategies they preferred and which they planned to scale up. They were also questioned about the extent of labor involved with the lablab residue incorporation. Survey questions for the non-project participants focused on farmer to farmer knowledge dissemination.

Project participants indicated that ½ compost+½ DAP and incorporated lablab residues (lablab only) were most preferred, but seed priming was not mentioned by many of the farmers. There was no significant correlation between the ranking of the various vigor enhancing strategies and household socio-economic factors e.g. age, education, gender. However preference responses differed across the soil fertility gradient. For example at the high soil fertility site (Koibem), lablab only was least preferred compared to the other strategies but at the lower soil fertility sites (Kapkerer, Kiptaruswo) lablab only was highly ranked. Improved maize seed rates/plant spacing was highly ranked at Koibem but not at the other sites. Strategies for upscaling tended to follow the household preferences. When questioned about the amount of labor needed for incorporating lablab residues, most respondents recognized the level of work was more, but felt the outcomes were worth the extra effort. Only 17% of respondents felt that incorporating lablab residues was too much work.

Farmers who had not participated in the DGPCRSP project were quite aware of the various strategies and a number were either using the approaches or planning to use them in the upcoming season. Forty-three percent (43%) of the non-project participant households were aware of lablab with 5% already growing the crop and 34% planning to grow lablab in the next season. KK8 beans, boma compost and improved seed rate/plant spacing were known by 26-29% of respondents and 1-3% were already practicing these strategies on their farms. Only 3-14% of the non-project participants were aware of the ½ compost+½ DAP, ½ lab+½ DAP, TSP and MRP strategies.

Diffusion trends – Farmers associated with NGO/CBO groups REFSO, ARDAP and AVENE were monitored by the NGO/CBO and KARI staff during FY10. Objective 2, Activity 1 (above) details their perceptions about the impacts/constraints encountered with the vigor enhancing strategies.

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

Approaches and Methods:

1. Implement replicated experimental trials
2. Data collection and evaluation
3. In-season field visits and annual meeting review of results
4. Germplasm testing
5. Nutrient analysis of grain and edible leaf samples
6. Publication preparation

Results, Achievements and Outputs of Research:

1. Implement replicated experimental trials – KARI staff repeated the Main replicated experiment during the Short Rains 2009-10 and Long Rains 2010 seasons at the same 4 sites across the soil fertility gradient. The factorial design for the Short Rains season evaluated the effect of seed priming and TSP fertilizer application on lablab productivity and disease/pest severity. Bean control plots (with and without TSP) were also included. During the LR2010 season, plots were split 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); ½ boma compost+ ½ DAP or no fertilizer and bean variety (root rot susceptible (GLP2) and tolerant (KK8 lines) on maize-bean intercrop productivity as well as bean pests and diseases.

2. Data collection and evaluation – Data from 2009-10 Short and Long Rains crops have been collected, compiled and shared amongst all collaborators. Datasets include plant emergence and mortality, nodule counts as well as grain and biomass yields of lablab (SR only), beans (SR & LR) and maize (LR only). Pest/disease incidence or severity data for bean root rot, bean fly maggot (*Ophiomyia* spp.) and aphids (*Aphis fabae*) are included for both seasons, while chafer grubs (*Schizonycha* spp), maize lodging, common bean blight and bean common mosaic virus incidence were only recorded during the Long Rains season.

The following sections summarize our findings from the second year's results:
SR0910 Replicated Experiment (Lablab or Bean) – Higher than normal rainfall in 2009-10 associated with the El Nino phenomenon depressed lablab and bean yields compared to 2008-09. Nevertheless at Bonjoge and Koibem, average lablab yields were greater than 1000 kg/ha and either outperformed or gave comparable grain yields as bean (Figure 12). The Bonjoge and Koibem results were similar to the farmer verification plots in the same clusters, but at Kapkerer and Kiptaruswo halo blight reduced the replicated experiment lablab grain yields to very low levels compared to the farmer plots in the same communities. Likewise, bean yields from the replicated plots at all sites except Koibem were 50% less than those obtained on the farmer trials (305 kg/ha versus 659 kg/ha). Koibem bean yields were good (1046 kg/ha) and comparable to the farmer plot yields (1117 kg/ha). Such high variability within soil fertility clusters is a constant challenge and points to the need for a number of replicated experiments per site rather than a single replicated experiment.

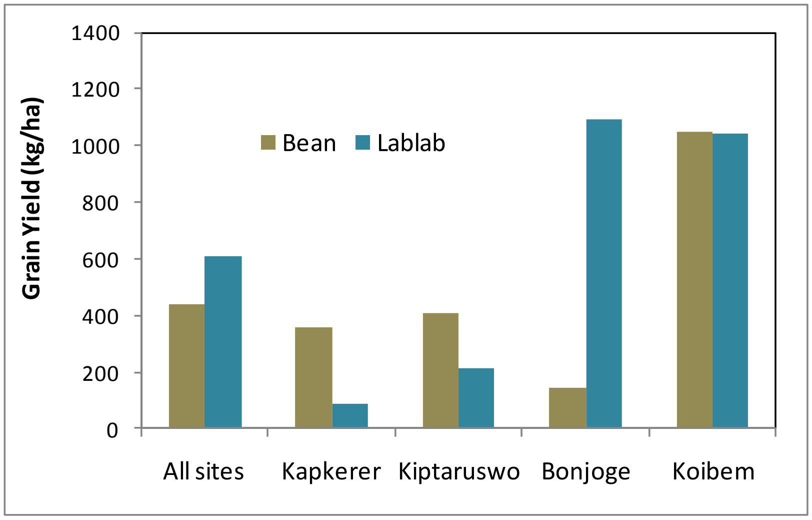


Figure 12 Mean bean and lablab grain yields by site from replicated experiments, Short Rains 2009-10

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

The Short Rains treatments had little/no impact on pest-disease incidence or survival of lablab plants in 2009-10. The TSP treatment had significantly reduced aphid incidence across all sites (Figure 14A) and reduced halo blight at Kapkerer (Figure 14B), but had no effect on plant stand or root rot. Seed priming significantly reduced plant stands by 5% across all sites; however, there were no priming treatment impacts on lablab pests or diseases.

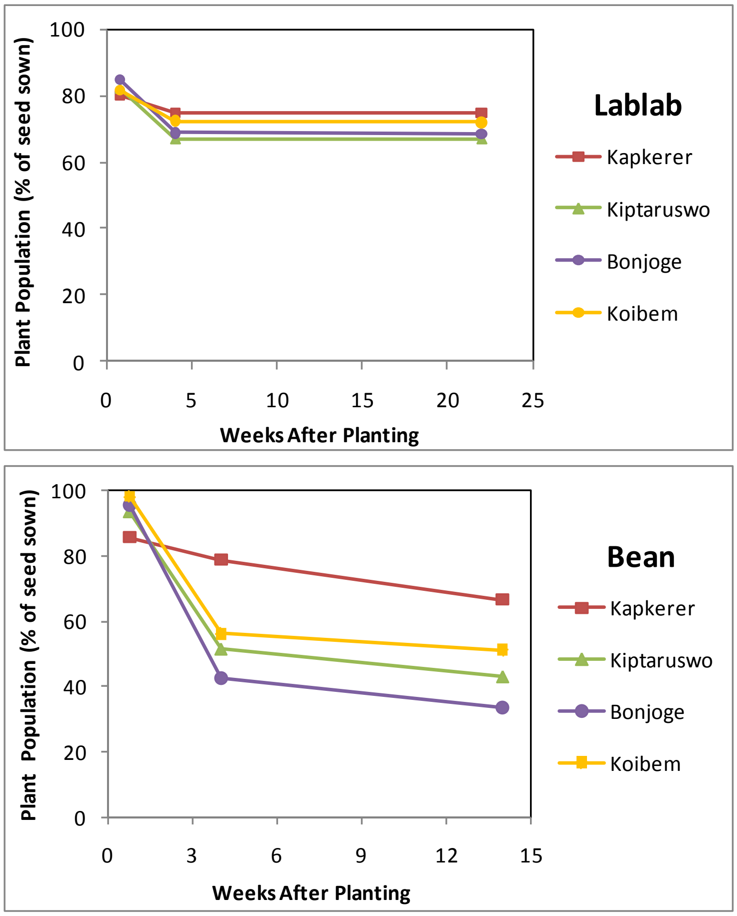
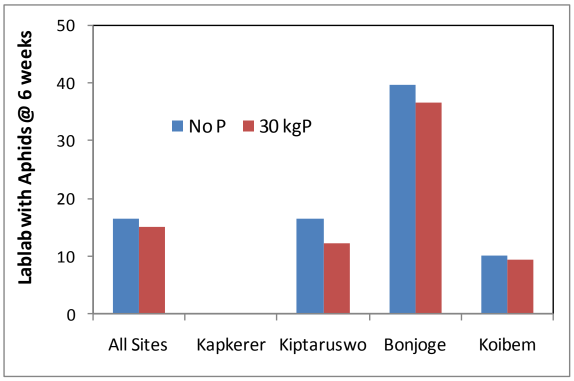
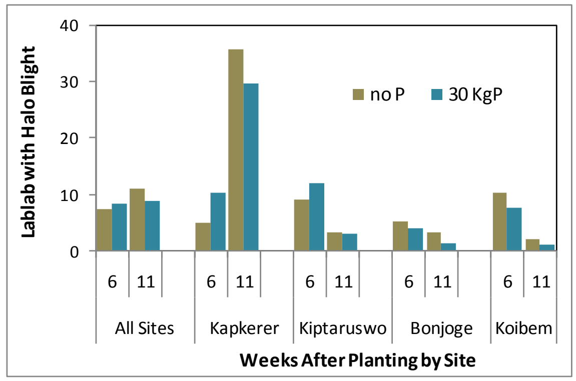


Figure 13 Mean lablab (**A**) and bean (**B**) plant populations from replicated experiments, Short Rains 2009-10

At Kiptaruswo, Bonjoge and Koibem bean populations dropped dramatically over the season with stand losses between 47% and 62% (Figure 13B). At Kapkerer bean stands were higher and relatively stable with a decline of only 19% over the season which was caused primarily by beanfly. Root rot incidence was very low at Kapkerer (1.6% of stand) and no aphids were observed. A combined effect of root rot, aphids and beanfly were the main causes of the bean stand declines at Kiptaruswo, Bonjoge and Koibem. Bonjoge had the highest incidence of aphids (44% of stand) and root rot (35% of stand). Beanfly severity scores were on average 16 pupae/larvae per plant at Bonjoge and Koibem. The TSP treatment did not have significant impact on bean plant populations, root rot, aphid incidence or beanfly pupae/larvae; however the results indicated slight reduction trends in root rot and beanfly pupae/larvae with TSP.

Figure 14 Mean aphid (**A**) and halo blight (**B**) incidence in lablab by P treatment across sites in replicated experiments, Short Rains 2009-10





El Nino climate conditions also reduced lablab biomass yields in 2009-10 compared to 2008-09. Biomass yields were highest at Kapkerer but there was no pattern with respect to soil fertility as previously observed in FY09 (Figure 15). The devastating impact of halo blight particularly at Kapkerer and Kiptaruswo obscured any potential impact of the TSP treatment on lablab grain yields; however, TSP significantly increased lablab biomass yields by 18% across all sites (Figure 15). The seed priming treatment did not translate into an effect on either lablab biomass or grain yields despite the negative effects of seed priming on lablab plant stand. The Unlike the strong response to TSP found in the farmer verification plots, TSP had no impact on bean biomass or grain yields in the replicated experiments.

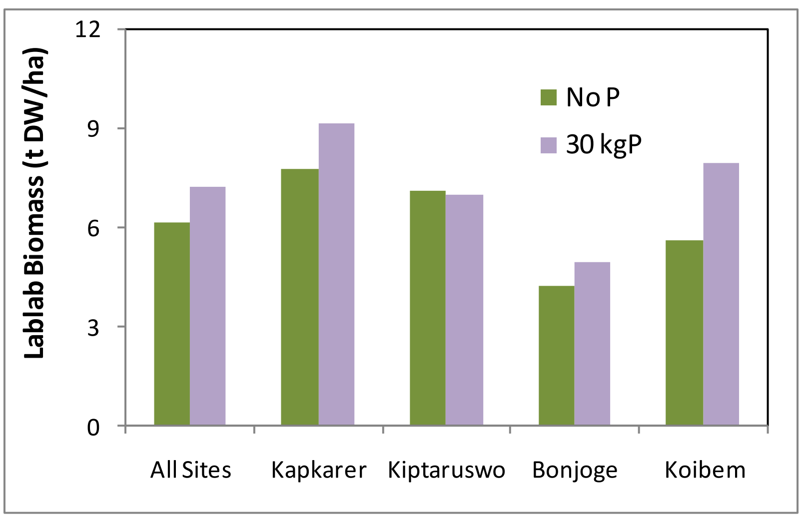


Figure 15 Mean lablab biomass yields by P treatment across sites from replicated experiments, Short Rains 2009-10

<u>LR 2010 Replicated Experiment (Maize-Bean Intercrop)</u> – At all sites bean yields were substantially higher than 2009 yields and were comparable with typical intercropped bean yields in Western Kenya (Odhiambo and Ariga, 2001). Across all sites and treatments, bean yields averaged 237 kg/ha, with peak yields occurring at the low fertility site, Kapkerer (356 kg/ha), which we attribute to lower seasonal rainfall and diseases/pests compared to the other sites. Maize yields in 2010 were similar to 2009 despite a

substantial amount of lodging due to high winds just after cob set. Across all sites and treatments, maize yields averaged 4087 kg/ha with the highest found at the high fertility site, Koibem (5552 kg/ha).

The lablab residue treatments alone produced a 22% increase in bean yield, but the effect was dominated by Kapkerer and Bonjoge, while at Kiptaruswo and Koibem lablab residues had a slight negative or negligible effect on bean yields (Figure 16). Consequently the lablab residue treatment effect was not statistically significant across all sites.

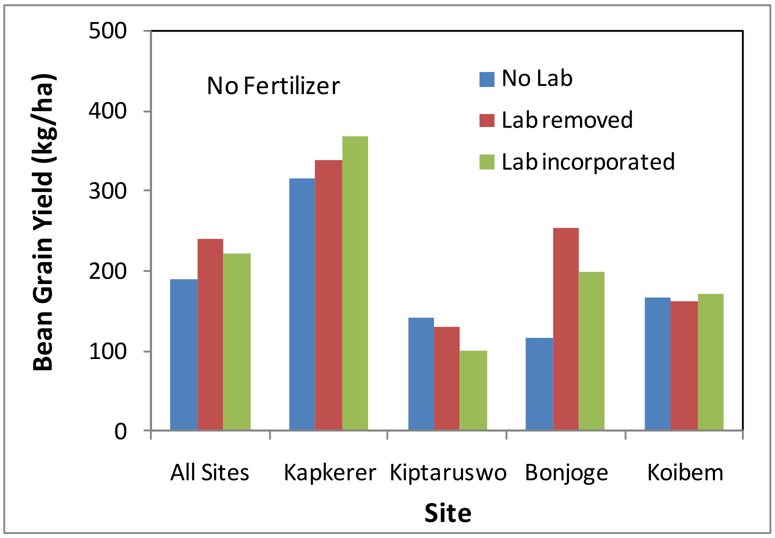
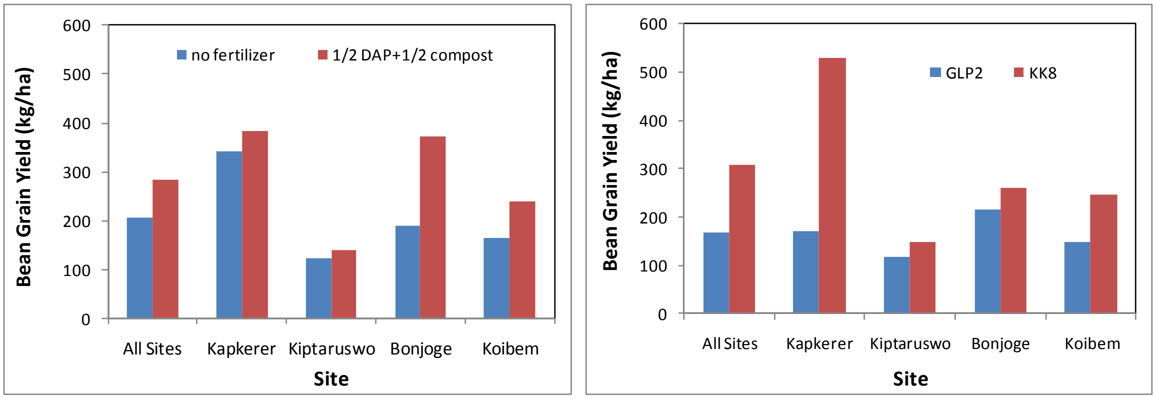


Figure 16 Mean bean grain yields by lablab residue treatment across sites from replicated experiments, Long Rains 2010

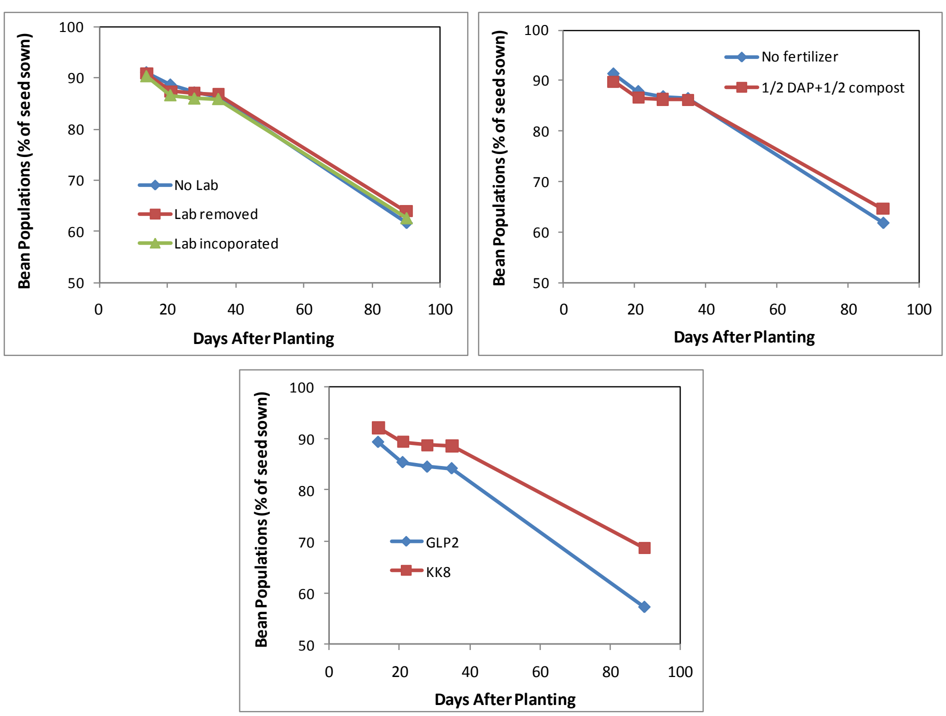
Both the fertilizer and bean variety treatments had large and significant impacts on bean yield at all sites. The ½ compost-½ DAP fertilizer treatment increased bean yields on average 37% compared to the no fertilizer treatment (Figure 17A). The greatest response was at Bonjoge (96%) while at the other sites ½ compost-½ DAP increased bean yields 12%-44% over no fertilizer. Yields from the root rot tolerant bean variety, KK8 were on average 84% higher than the root rot susceptible bean variety, GLP2 (Figure 17B). This was particularly the case at Kapkerer, where there was a 3 fold increase in bean yield with KK8 compared to GLP2. Responses to KK8 relative to GLP2 were substantial but lower at Kiptaruswo (26%), Bonjoge (20%) and Koibem (68%).

Figure 14 Mean aphid (**A**) and halo blight (**B**) incidence in lablab by P treatment across sites in replicated experiments, Short Rains 2009-10



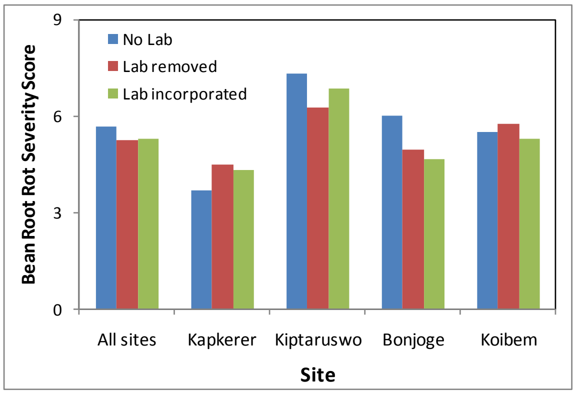
Due to timely planting and low pest/disease incidence, bean plant populations at 2 weeks were high averaging 91% of seeds sown across all sites (Figure 18). Stands remained relatively stable up to flowering; however, by harvest a substantial amount of plant mortality reduced average populations to 63%. We can infer from the high plant populations that the incidence of root rot, chafer grubs, common bean blight and bean common mosaic virus must have been low early in the season, but that the severity of these diseases, pests plus late season maize lodging combined to substantially reduce plant stands later in the season. The plant population results did not support our earlier assertion that lablab residues may increase seedling mortality. Only the bean variety treatment had a significant impact on plant populations. Over the course of the season, plant populations with KK8 were higher than GLP2 (3% to 11.5% difference).

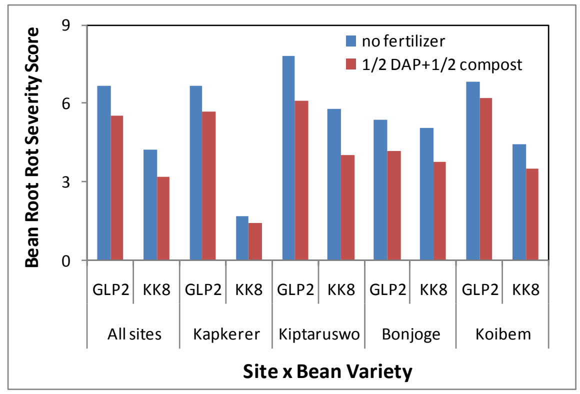
Figure 18 Mean bean plant populations by lablab residue, fertilizer and bean variety treatments from replicated experiments, Long Rains 2010



In addition the lablab residue treatments did not appear to exacerbate root rot severity in 2010. Data from all sites combined indicated that lablab residues had a slight but insignificant impact in reducing root rot severity (Figure 19A). Root rot severity was highest at Kiptaruswo, but only at Kapkerer was there an indication that root rot severity was increased with lablab residues. Substantial reductions in root rot severity across all sites explain the observed yield benefits associated with the fertilizer and bean variety treatments (Figure 19B).

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





The impacts of lablab residues on seedling mortality and root rot severity in the replicated experiments were quite different from those observed in the farmer verification plots. We believe differences in management of the residues explain the results. In the replicated experiments, lablab residues were cut, windrowed and then incorporated in the soil to a depth of ~ 6 inches. Maize and bean seeds were planted to the side of the incorporated residues. Once the lablab was cut, farmers incorporated shallowly (~ 2-3 inches) and planted the maize and beans directly on top of the incorporated residue. Planting the maize and bean seeds directly into the decomposing lablab residues appeared to improve stand establishment compared to the other fertilization practices by assuring moist soil conditions. However the farmer results indicated that this management practice also increased post-emergent damping off in the lablab only treatments. No negative effects on seedling mortality were observed in the replicated experiments where seeds were planted to the side of the incorporated residue. Lablab residue placement in the replicated experiments may have also contributed to the negligible impacts of the residue treatments on root rot severity.

As we observed last year, no chafer grubs (*Schizonycha* spp.) were recorded at Kapkerer, presumably because of the drier soil conditions. At Kiptaruswo, Bonjoge and Koibem there was a consistent increase in chafer grubs associated with the lablab residue incorporation treatment (Figure 20) but no impact of the ½-½ fertilizer treatment or the bean variety treatments on chafer grub counts. A similar impact of lablab residues on chafer grubs at Trans Nzoia district was reported by Medvecky et al. (2006) along with increased bean seedling mortality and potential productivity loss. Despite the grub-residue treatment association found in our experiment, the grubs did not affect early season plant populations of bean or maize, presumably because the grub populations were fairly low and possibly due to the position of the lab residues relative to the bean/maize seedlings. The impact of chafer grubs on seasonal bean mortality or bean yields in 2010 was inconsistent. At Kiptaruswo, increasing chafer grubs were associated with greater bean mortality and lower bean yields. However at Koibem, chafer grubs were not correlated with either bean mortality or yield. At Bonjoge chafer grubs correlated negatively with bean mortality and positively with yield which is not consistent with our model. So while the replicated experiment data to date have not demonstrated a negative impact of chafer grubs in association with incorporated lablab residues; the lower bean yields in the farmer verification trials with incorporated lablab residues does suggest that chafer grubs may be a contributing factor that needs continued monitoring.

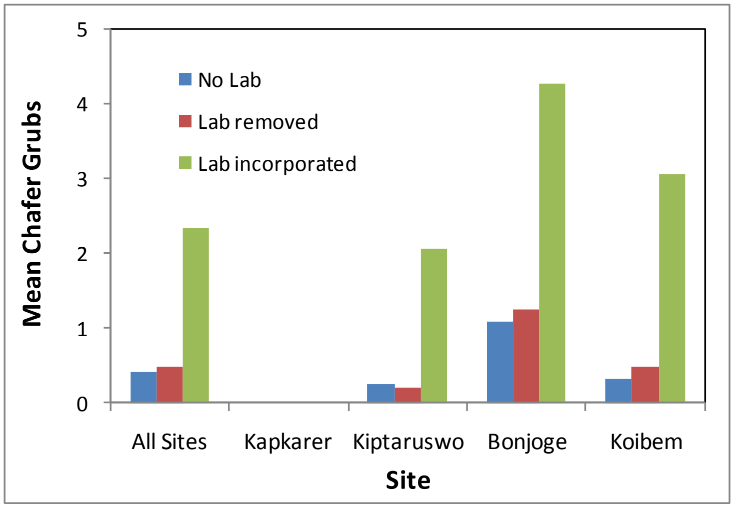
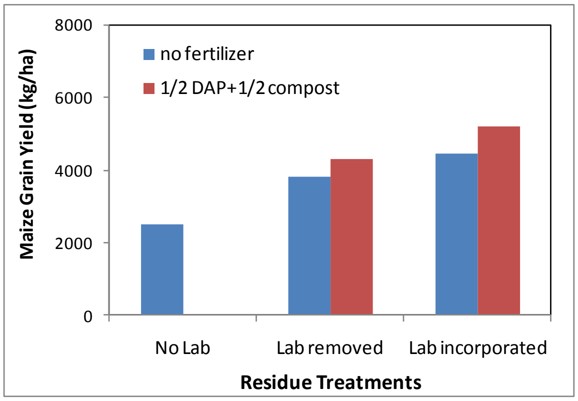
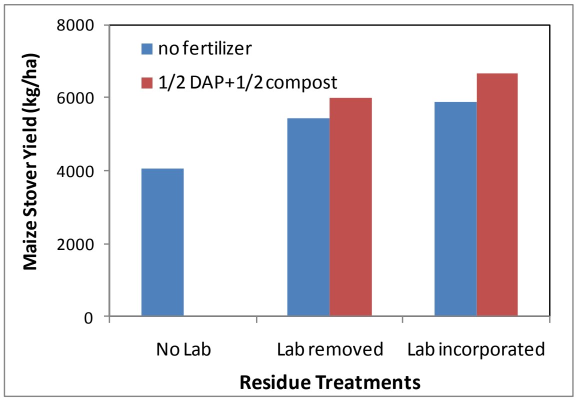


Figure 20 Mean chafer grub counts per plot by lablab residue treatments across sites in replicated experiments, Long Rains 2010

Lablab residue treatments had the biggest impact on maize grain and stover yields. Averaged across all sites, lablab treatments increased maize grain yields 52% (lablab removed) to 78% (lablab incorporated), while stover yields were increased 34% (lablab removed) and 46% (lablab incorporated) (Figure 21). Also a significant impact of the ½-½ fertilizer treatment on maize yields was found across all sites, but the increase was only an additional 13-17%.

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





3. <u>In-season field visits & annual meeting review of results</u> – Cornell, KARI and the university partners made field visits to the replicated experiments and farmer plots in October 2009, March 2010 and July 2010. Dr. Irv Widders, from the DGPCRSP Management Office and Dr. Ndiaga Cisse from the Technical Management Advisory Committee accompanied the Cornell, KARI and University team during the October 2009 field visits.

KARI staff, University faculty and students and Cornell partners participated in the annual project meeting September 14-15, 2010 in Kisumu. Experiences and results from the farmer verification trials were summarized along with results from the replicated experiments. Four of the Masters students also made presentations on their research findings.

4. <u>Germplasm testing</u>

A. *Cowpea materials from UCR* - Silvester Odundo, a Masters student at Moi University worked with cowpea cultivars obtained from the Univ. of California Riverside in order to identify varieties with the most potential for cowpea grain production in the wet, cool and higher elevation environments of Western Kenya. During the Short Rains 2009-10 season, Mr. Odundo compared the agronomic responses of cowpea lines ICV6, ICV12, CB46, IT90K-284-2, IT83D-442 and local check Khaki at each of the four project sites across the soil fertility gradient.

Mean cowpea grain yields at Bonjoge (316 kg/ha) were 65% greater than at Koibem (192 kg/ha) which is at a higher elevation and generally cooler than Bonjoge. The warmer and drier environments of Kapkerer and Kiptaruswo should have favored cowpea grain production over that of Bonjoge and Koibem. Thus it is particularly disappointing that no grain yields were obtained at Kapkerer and Kiptaruswo because of poor management, especially in controlling thrips. Despite the disappointing results, Mr. Odundo was able to identify some promising cowpea varieties for future grain production research at the higher elevation sites. This is a significant step because up to now farmers in Western Kenya have been limited to the traditional varieties (Khaki, Enzegu, Ilanda) which are grown primarily for leaf harvest for making a cooked vegetable (*mboga)*.

Variety CB46 produced the highest yield (434 kg/ha) at Bonjoge, but the result was not statistically different from IT83D-442 (322 kg/ha), Khaki (305 kg/ha) or ICV12 (272 kg/ha) due to high variability. IT90K-284-2 (217 kg/ha) and ICV6 (205 kg/ha) had significantly lower yields than the other varieties at Bonjoge. While CB46 also performed well at Koibem (215 kg/ha), ICV12 produced the highest yield (342 kg/ha). IT83D-442 and Khaki appeared to be more sensitive to the cooler temperatures of Koibem and produced the lowest yields (127 kg/ha).

B. *P efficient bean varieties from Zamorano-PSU program* - During the 2009-10 Short Rains season, the KARI Grain Legume Program did further evaluation and selection with 23 nutrient efficient bean lines from the Zamorano-PSU program: XRAV 187-3, XRAV 40-4, Amadeus 77, Carrizalito, MER 2222-48, XRAV 68-1, IBC 308-15, MER 2226-12, MER 2226-35, MHR 311-17, MHR 312-13, IBC 302-29VR, MHR 314-3, MER 2226-29,

MHC 2-11-33, IBC 309-23, MER 2226-36, MER 2226-34, MER 2221-20, IBC 308-81, MER 2212-28, IBC 305-6 and IBC 306-95. A local, small seeded, red variety GLP585 and medium seeded, mottled variety GLP-2 were also included as checks. Varieties were planted in a completely randomized design with 3 replications. Seeds of each line were sown in 2 m long rows without any added P fertilizer. The soil used for the evaluation was tested and found to be deficient in phosphorus (Olsen P = 8.4 mg/kg). Stand counts, days to flowering, disease/pest rankings, days to maturity and yield were recorded.

Days to flowering and days to maturity did not vary much across the introduced lines (42.7-44.5 days; 80.7-82.7 days), and were not strikingly different from the local checks (43 days; 81 days). Plant mortality was quite variable ranging from 21.9% to 77.1% across the introduced lines and 49.6% to 53% by the local checks. Mortality was most strongly associated with bean common mosaic necrotic virus (BCMNV). In particular IBC 306-81, IBC 309-23, MER 2212-28 and MER 2221-20 had the highest incidence of BCMNV and mortalities of 77.1%, 53.9%, 75.7% and 61.1%, respectively. Introduced lines XRAV 68-1 and XRAV 187-3 had the lowest BCMNV incidence and mortalities of only 24% and 34%, respectively. The incidence of angular leaf spot, rust and common bean mosaic virus was generally low across all lines including the local checks.

Yields from the introduced bean varieties ranged from 133 g/plot to 1000 g/plot and the local check yields averaged 467 g/plot (GLP585) and 458 g/plot (GLP2). The top five highest yielders were: XRAV 187-3, MER 2226-35, MER 2226-36, Amadeus-77 and IBC 308-15. Seven of the lines tested in SR09-10 were selected for utilization in future breeding efforts by the KARI Grain Legume program. The lines selected were: MER 2226-12, XRAV 40-4, IBC 308-15, IBC 309-23, MER 2226-36, IBC 308-81 and IBC 305-6. KARI is currently seeking bc-3 breeding materials to cross with the selected lines to protect against BCMNV.

C. *Germplasm screening for resistance to BCMV and BCMNV* - Ms. Roselyne Juma is a bean breeder at KARI-Kakamega who was recently recruited to do a Master's degree at Moi University with FY10 HC Capacity Building funds from the DGPCRSP. Ms. Juma's Masters research was initiated during the Long Rains 2010 season with 4 screening trials distributed across the project soil fertility gradient sites: (i) to characterize commercial and advanced breeding bean germplasm for its reaction to BCMV and BCNMV; and (ii) to verify the prevalence of BCMV and BCMNV in Western Kenya.

A total of 32 breeding lines from the KARI-Kakamega breeding program were tested at each site using an alpha lattice design with 3 replications. Three lines from the Zamorano-PSU program were included in the testing: XRAV 187-3, MER 2226-34 and MHR 314-3. Stand counts, number of plants with BCMV and BCMNV symptoms and severity of BCMV and BCMNV symptom scores were collected along with grain yields at maturity.

Ms. Juma is currently analyzing her data, but preliminary results indicated that both BCMV and BCMNV were prevalent across all sites within the South Nandi project area. In addition, she observed that there is sufficient genetic variation for manipulation to develop bean varieties with multiple disease tolerance to BCMV and BCNMV. Varieties showing tolerance to BCMV that were common across all sites were: BCO-05/07 and KK-8. Varieties with tolerance to BCMNV that were common across all 4 sites were: BCO-05/10, BCO-05/32, BCO-05/18, BCO-05/137, BO-05/25, BCO-05/49, BO-05/35, BCO-05/03, BCO-05/09 and KK-RR 05/23.

5. <u>Nutrient analysis of grain and edible leaf samples</u> – Our objective with this activity was to document the nutrient content of bean and lablab food products generated from local varieties and under farm environmental conditions in order to obtain accurate assessments of potential food nutrient intakes by smallholder farm households in Western Kenya. Bean and lablab grain as well as lablab leaf samples were collected from 10 farms per cluster across the soil fertility gradient after 2008-09 harvests. Farmers' local bean varieties and KK8 were collected as well as bean and lablab grain from TSP and no P treatments. Young leaves of lablab were plucked just before flowering representing the common household practice of leaf harvest for *mboga*.

All samples were oven dried at 60°C and sent to Cornell University for nutrient analysis. The grain and leaf materials were ground and microwave digested with nitric acid. Nutrient concentrations (except N) in the digests were determined by ICP analysis. Nitrogen was analyzed directly on dried, ground samples via a combustion-gas chromatograph unit. NBS tomato and apple standards were included to assess accuracy. Standard recoveries averaged 91% for macro/micro nutrients and 93% for total N. Results summarized by site and plant products are presented in Table 2.

Table 2 Macro- and micronutrient content of bean grain, lablab grain and lablab leaves from South Nandi farms

Bean Grain											
Site	**Nitrogen**	**Boron**	**Magnesium**	**Phosphorus**	**Sulfur**	**Potassium**	**Calcium**	**Manganese**	**Iron**	**Copper**	**Zinc**
	%	µg/g	%	%	%	%	%	µg/g	µg/g	µg/g	µg/g
Kapkerer	3.07 ± 0.52	9.84 ± 1.97	0.183 ± 0.023	0.409 ± 0.076	0.182 ± 0.031	1.39 ± 0.19	0.165 ± 0.040	17.09 ± 3.16	52.82 ± 8.95	8.34 ± 1.46	31.26 ± 4.55
Kiptaruswo	2.88 ± 0.23	9.32 ± 1.67	0.195 ± 0.016	0.420 ± 0.078	0.196 ± 0.016	1.56 ± 0.12	0.157 ± 0.035	16.33 ± 4.34	45.52 ± 6.38	8.30 ± 1.93	33.93 ± 3.41
Bonjoge	3.01 ± 0.22	7.82 ± 2.14	0.163 ± 0.017	0.349 ± 0.053	0.181 ± 0.018	1.29 ± 0.11	0.133 ± 0.026	13.51 ± 2.47	46.12 ± 11.09	7.99 ± 1.57	29.46 ± 3.19
Koibem	2.77 ± 0.22	10.74 ± 1.29	0.189 ± 0.020	0.381 ± 0.028	0.173 ± 0.011	1.50 ± 0.08	0.157 ± 0.035	17.96 ± 2.17	49.47 ± 5.45	8.76 ± 0.80	30.31 ± 3.34
Average	**2.93 ± 0.33**	**9.42 ± 2.05**	**0.182 ± 0.022**	**0.389 ± 0.066**	**0.183 ± 0.021**	**1.44 ± 0.16**	**0.153 ± 0.035**	**16.19 ± 3.51**	**48.33 ± 8.52**	**8.35 ± 1.48**	**31.24 ± 3.93**
CV	**11%**	**22%**	**12%**	**17%**	**12%**	**11%**	**23%**	**22%**	**18%**	**18%**	**13%**
Lablab Grain											
Site	**Nitrogen**	**Boron**	**Magnesium**	**Phosphorus**	**Sulfur**	**Potassium**	**Calcium**	**Manganese**	**Iron**	**Copper**	**Zinc**
	%	µg/g	%	%	%	%	%	µg/g	µg/g	µg/g	µg/g
Kapkerer	3.77 ± 0.28	9.47 ± 1.16	0.165 ± 0.016	0.423 ± 0.120	0.178 ± 0.025	1.20 ± 0.10	0.093 ± 0.012	25.68 ± 4.93	51.16 ± 13.23	13.28 ± 2.05	31.96 ± 4.85
Kiptaruswo	3.61 ± 0.26	8.67 ± 1.66	0.188 ± 0.016	0.492 ± 0.084	0.195 ± 0.024	1.44 ± 0.15	0.084 ± 0.015	24.30 ± 3.75	57.61 ± 12.15	8.24 ± 1.58	35.73 ± 4.32
Bonjoge	3.38 ± 0.39	9.63 ± 1.74	0.180 ± 0.013	0.413 ± 0.063	0.207 ± 0.014	1.32 ± 0.13	0.081 ± 0.018	23.87 ± 2.09	59.11 ± 6.58	8.52 ± 1.12	33.03 ± 1.72
Koibem	3.68 ± 0.29	9.96 ± 1.82	0.188 ± 0.013	0.418 ± 0.058	0.201 ± 0.012	1.38 ± 0.10	0.082 ± 0.014	31.24 ± 8.83	57.42 ± 9.37	10.09 ± 1.81	34.45 ± 3.42
Average	**3.60 ± 0.32**	**9.41 ± 1.68**	**0.183 ± 0.016**	**0.440 ± 0.083**	**0.197 ± 0.020**	**1.36 ± 0.14**	**0.084 ± 0.015**	**26.51 ± 6.34**	**56.94 ± 10.21**	**9.63 ± 2.34**	**34.27 ± 3.67**
CV	**9%**	**18%**	**9%**	**19%**	**10%**	**11%**	**18%**	**24%**	**18%**	**24%**	**11%**
Lablab Leaf											
Site	**Nitrogen**	**Boron**	**Magnesium**	**Phosphorus**	**Sulfur**	**Potassium**	**Calcium**	**Manganese**	**Iron**	**Copper**	**Zinc**
	%	µg/g	%	%	%	%	%	µg/g	µg/g	µg/g	µg/g
Kapkerer	4.56 ± 0.73	28.42 ± 9.96	0.313 ± 0.083	0.361 ± 0.159	0.295 ± 0.046	1.95 ± 1.03	1.55 ± 0.56	187.05 ± 75.87	320.97 ± 101.37	8.67 ± 1.55	38.26 ± 10.63
Kiptaruswo	4.13 ± 0.33	22.40 ± 5.21	0.277 ± 0.080	0.266 ± 0.038	0.256 ± 0.022	1.37 ± 0.33	1.47 ± 0.25	126.67 ± 47.14	210.57 ± 37.82	6.63 ± 0.86	27.10 ± 5.52
Bonjoge	4.00 ± 0.46	33.66 ± 5.82	0.391 ± 0.133	0.217 ± 0.042	0.249 ± 0.034	1.31 ± 0.37	2.08 ± 0.49	213.75 ± 53.59	382.14 ± 157.71	6.54 ± 0.79	26.84 ± 4.55
Koibem	4.21 ± 0.27	31.59 ± 6.40	0.315 ± 0.088	0.320 ± 0.062	0.279 ± 0.019	1.64 ± 0.34	1.47 ± 0.55	187.58 ± 79.23	194.84 ± 30.89	7.64 ± 0.84	26.50 ± 3.28
Average	**4.22 ± 0.51**	**29.02 ± 8.06**	**0.324 ± 0.104**	**0.291 ± 0.103**	**0.270 ± 0.036**	**1.57 ± 0.63**	**1.64 ± 0.53**	**178.76 ± 70.71**	**277.13 ± 121.87**	**7.37 ± 1.34**	**29.68 ± 8.10**
CV	**12%**	**28%**	**32%**	**35%**	**13%**	**40%**	**32%**	**40%**	**44%**	**18%**	**27%**

Bean grain nutrient contents at Kapkerer, Kiptaruswo and Koibem were not significantly different from each other, but Bonjoge samples had consistently lower bean nutrients (except N, Ca, Fe, Cu). This may be explained by the particularly high pest and disease severity observed at the site during the SR 2008-09 season. Despite the differences seen at Bonjoge, our nutrient results were within the ranges observed in the large CIAT bean accession nutrient analysis study of Beebe et al. (2000). Surprisingly there were no differences in nutrient content between the farmers' local bean varieties or KK8 which suggests similarity in genetic potential between these bean varieties in terms of nutrient content. There were no significant effects of the TSP treatment on bean grain nutrient contents.

Lablab grain nutrient contents were statistically similar across the sites, except for Cu, Mg and K. Kapkerer samples were lower in Mg and K than the other sites, but had the highest Cu of all sites. The lower Mg and K results are consistent with the depleted soil conditions at this site compared to the others, but it surprising that we did not see a similar response with bean grain. There was no impact of the TSP treatments on the lablab grain nutrient contents.

Significant site differences were found in lablab leaf P, S, Ca, Mn, B, Fe, Cu and Zn content results, but there were no consistent patterns to help in explaining why these differences arose. There were no effects of the TSP treatments on the nutrient content results for lablab leaf.

Very little nutrient content data for lablab is found in the literature, making these results for lablab grain & leaf the most comprehensive dataset available to date. Our results indicate that with the exception of Ca, lablab grain is generally more nutrient dense than bean with 8 to 23% more of macro nutrients N, P and S and higher micronutrients (64% more Mn, 18% more Fe, 15% more copper, 10% greater Zn). Calcium, however, was 81% less in lablab grain than in bean grain. Lablab leaves were also high in important human nutrients (especially Ca, Mg, Fe) but the level of intake of leaf materials is much less than for grain, so the potential impact on diets would only be supplemental to the grain. Crude protein levels derived from the total N contents were: 18% in bean grain, 23% in lablab grain and 26% in lablab leaf.

6. <u>Publication preparation</u> - It has taken us a bit longer than expected to key in and check all the data from the Replicated Experiments. All data is now in electronic form, statistical analysis is complete and work is ongoing to develop draft manuscripts for publication.

<u>Objective 4</u>: To facilitate and support on-farm participatory research opportunities for Kenyan agricultural scientists and graduate students

Approaches and Methods:

1. Implementation of student research projects
2. Masters theses
3. Sharing of results in annual meetings
4. Publications/Conference presentations

Results, Achievements and Outputs of Research:

1. Implementation of student research projects – The field research of Silvester Odundo, Eunice Onyango and Belinda Weya was completed during FY10. All students who entered the program in FY08 or FY09 (with one exception) have completed their Masters degrees or are in the process of finalizing their thesis write-ups (see below). Caren Oloo at the University of Nairobi had to withdraw and was unable to complete the degree program.

FY10 HC Capacity Building funds were obtained to support field research for two new students to undertake Masters research within the project:

- Roselyne Juma is employed at KARI-Kakamega in the Plant Breeding Division and is enrolled at Moi University in the Department of Plant Breeding. She completed her field research during the Long Rains 2010 season to characterize bean germplasm reaction to BCMV and BCNMV. Ms. Juma is finalizing her data analysis and will present her complete thesis for review by the end of 2010.
- Stanley Onyango is enrolled in the Department of Food Technology & Nutrition at the University of Nairobi. His Masters research focuses on the human nutrition outcomes/ opportunities of lablab grain. During the Long Rains 2010, Mr. Onyango completed a field survey of South Nandi households to assess consumptive patterns of grain legumes and to determine the various methods that woman used to prepare lablab grain for eating. In addition lablab grain samples were collected for proximate analysis and determining antinutrient content changes with soaking & cooking. Mr. Onyango will complete all the laboratory analysis this Fall and will submit his final thesis for review by March 2011.

2. Masters theses – The following summarizes student progress to date:

- Crispus Njeru successfully defended his Masters thesis in Soil Science at Moi University during FY10. Mr. Njeru studied the productivity of lablab during the Short Rains across the soil fertility gradient and the impact of lablab residue incorporation on soil fertility and productivity of maize-bean intercrop during the Long Rains.
- Eunice Onyango has finalized her thesis and submitted it for review by the Dept. of Applied Environmental Social Sciences at Moi University. Ms. Onyango’s thesis documented South Nandi farmers’ reactions to the introduced crop vigor enhancing strategies.
- Belinda Weya has completed analysis of her Short Rains 09-10 experimental data and is currently finalizing her thesis on the use of seed priming with added nutrients to address soil deficiencies of molybdenum or phosphorus. The final document will be submitted for review by the Department of Soil Science at Egerton University by December 2010.
- Silvester Odundo has completed analysis of his data from Long Rains 2009 and Short Rains 09-10 on the response of improved cowpea germplasm to P fertilizer and the potential to produce grain in the suboptimal growing environments of Western Kenya. Mr. Odundo is currently finalizing his thesis write-up and will submit it for review by the Department of Soil Science at Moi University by December 2010.

3. Sharing of results in annual meetings – Silvester Odundo, Belinda Weya, Roselyne Juma and Stanley Onyango gave presentations on their Masters research at the annual project meeting September 14-15, 2010 in Kisumu, Kenya.

4. Publications/Conference presentations – During FY10, three of the Masters students presented their thesis research at professional conferences/congresses in Kenya (3rd National Conference on Dissemination of Research Results & Exhibition of Innovations), Tanzania (25th Conference of the Soil Science Society of East Africa) and Senegal (5th World Cowpea Research Conference 2010). Another presentation is forthcoming at the 12th KARI Biennial Scientific Conference in Nairobi. See section VII for citations.

Explanation for Changes
No changes

Networking and Linkages with Stakeholders
1. USAID Mission Nairobi - Courtesy visit on November 1, 2009 accompanied by Dr. Irv Widders (DGPCRSP-MO); met with the Regional Agricultural Advisor for the Regional Economic Growth & Integration Office and Director of the Agriculture, Business & Environment Office. Dr. Lauren discussed project progress to date, while Dr. Widders presented on overview of the Global Pulse CRSP Program's research and technology dissemination activities in Central and Eastern Africa.

2. Collaborations with 2 NGOs (REFSO, ARDAP) and one CBO (Avene) continued in FY10 (see Objective 2, activity 1).

3. Collaboration with Leldet, Inc., a private seed company based in Nakuru, Kenya continued in FY10. Lablab, KK8 and KK15 bean seed were produced from materials sourced by the project. Dr. Lauren along with Dr. Widders and Drs. Mwonga & Tabu (Egerton Univ.) visited the Leldet farm and seed production operation on October 30, 2009.

4. The project provided farmer contact information to Syngenta East Africa Ltd. who was interested in purchasing lablab seed. One farmer from the Koibem site sold 4 kg of lablab to Syngenta in 2010.

Leveraged Funds

Name of PI	Description of Project	Dollar Amount	Donor Agency
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

Master Theses:

Njeru, C.M. 2010. Effect of different soil fertility improving practices on productivity of a cereal-legume cropping system in low and high soil fertility areas in Western Kenya. M.Sc. Thesis. Dept. Soil Science, Moi University. Eldoret, Kenya. 96 p.

Odundo, S.N. 2011. Effect of phosphorus on survival, biomass, P accumulation and yield of cowpea [*Vigna unguiculata* (L.) Walp]. across a soil fertility gradient in Western Kenya. M.Sc. Thesis. Dept. Soil Science, Moi University. Eldoret, Kenya.

Onyango, E.M. 2010. Perception of farmers on crop vigour enhancing strategies for soil fetility management in Nandi South District. M.Sc. Thesis. Dept. Applied Environmental Social Sciences, Moi University. Eldoret, Kenya. 118 p.

Weya, B.A. 2011. Effect of seed priming on growth and yield of common bean (*Phaseolus vulgaris* L.) and lablab (*Lablab purpureus* (L.) Sweet) along a soil fertility gradient in Nandi South District, Western Kenya. M.Sc. Thesis. Dept. Soil Science, Egerton University. Nakuru, Kenya.

Conference Presentations:

Njeru, C.M., R.O. Okalebo, J.O. Ojiem, C.O. Othieno, J. Lauren and B. Medvecky. 2009. Effect of seed priming and phosphorus application on growth and production of *Lablab purpureus* L. in low and high fertility areas in Nandi South District of Western Kenya. 25th Conference of the Soil Science Society of East Africa. Moshi, Tanzania. 7-11 December 2009.

Njeru, C.M., R.O. Okalebo, J.O. Ojiem, C.O. Othieno, J. Lauren and B. Medvecky. 2010. Maize-bean intercrop response to sole and combined organic and inorganic fertilizers applications in low and high fertility areas of Nandi South district. 12th KARI Biennial Scientific Conference. Nairobi, Kenya. 8-12 November 2010.

Odundo S.N., J. R. Okalebo, J.O. Ojiem, J.G. Lauren and B. A. Medvecky. 2010. Productivity response of cowpea [*Vigna unguiculata (L.) Walp]* to phosphorus application across a soil fertility gradient. 3rd National Conference on Dissemination of Research Results & Exhibition of Innovations. National Council of Science and Technology. Nairobi, Kenya. 3-7 May 2010.

Odundo, S.N., J.O. Ojiem, J.R. Okalebo, C.O. Othieno, J.G. Lauren and B.A. Medvecky. 2010. Effect of phosphorus on productivity of cowpea [*Vigna unguiculata* (L.) Walp] varieties across a soil fertility degradation gradient in Western Kenya. 5th World Cowpea Research Conference 2010. Saly, Senegal. 27 September – 1 October 2010.

Onyango, E.M., M.Odendo and W. Reginalda. 2010. Perception of farmers on crop vigor enhancing strategies for soil fertility management in Nandi South District. 3rd National Conference on Dissemination of Research Results & Exhibition of Innovations. National Council of Science and Technology. Nairobi, Kenya. 3-7 May 2010.

Contribution of Project to Target USAID Performance Indicators

A total of 5 female students have been supported by the project to obtain Masters degrees, but only 4 will complete their degrees. Five 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 with the 175 households benefiting from this intervention. All of the 8 project vigor enhancing strategies continue to be under field testing by farmers. Five cowpea varieties obtained from the University of California Riverside and 10 nutrient efficient bean lines obtained from Zamoranao-Pennsylvania State are under research for grain production (cowpea), response to BCMV/BCNMV (bean) or performance under low soil P conditions (bean).

We are providing technical assistance to 2 women's groups through the CBO AVENE. All four HC partner organizations: KARI, University of Nairobi, Moi University and Egerton University continue to benefit from the project.

After 2 years experimenting with our vigor enhancing strategies, farmers have started to scale up within their farms: approximately 32-42% have upscaled boma compost, 38-40% were using KK8 beans instead of local varieties 75-80% were growing lablab and 8% were following improved spacing/seed rate strategies. However, due to the small size of these farms, this only constitutes a cumulative area of 10 hectares compared to the projected 20 hectares.

Two public-private partnerships were achieved through linkages with the Leldet Seed Company and Syngenta East Africa Ltd.

Contribution to Gender Equity Goal

Women have been a major target of trainings, on-farm verification trials and exchange visits. To date a total of 180 women have participated in the project from the core South Nandi farmers and interested neighbors in surrounding communities plus clients with the NGO/CBO groups. Women comprise 59% of the lead participants to date.

Three female KARI staff members have participated on the project to date. One is a Post Harvest-Value Addition specialist; another is a social scientist, who undertook socioeconomic surveys as part of her project sponsored Masters degree program. The most recent recruit is a plant breeder working on BCMV and BCMNV characterization

Three mid-career, professional women working at the Ministry of Agriculture as Extension Officers have been sponsored for Masters degrees at the University of Nairobi and Egerton University. One student has completed her degree and has resumed work and one is currently finalizing her thesis. Unfortunately the student at University of Nairobi was not able to complete her degree

Progress Report on Activities Funded Through Supplemental Funds

Host country capacity building activities undertaken during FY10:

Additional MSc students - HC Capacity Building funds supported the Master research projects of Roselyne Juma and Stanley Onyango (see report under Objective 4 above). All field research activities have been completed and both students are now completing analysis and thesis write-up.

Literature Cited

Beebe, S., A. V. Gonzalez and J. Rengifo. 2000. Research on trace metals in the common bean. Food and Nutrition Bulletin. 21(4): 387-391

Medvecky, B.A., Q.M. Ketterings, and F.M. Vermeylen. 2006. Bean seedling damage by root-feeding grubs (*Schizonycha* spp.) in Kenya as influenced by planting time, variety, and crop residue management. App. Soil Ecol. 34:240-249.

Odhiambo, G.D. and E.S. Ariga. 2001. Effect of intercropping maize and bean on Striga incidence and grain yield. p. 183-186. *In* Proc. 7th Eastern and Southern Africa Regional Maize Conference. 11-15 February 2001. Nairobi, Kenya.

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2009 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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							
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*						
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1	*To develop & assess farmer capacity for improving vigor & growth of pulse crops ...*											
Reports on in-community trainings & meetings												
Farmer trials established												
Objective 2	*To disseminate & evaluate through participatory approaches ...*											
NGO partner monitoring reports received				x	√							
Farmer data collected				x	√							
Exchange visits conducted & technologies evaluated				x	√							
Lessons learned reported	x	√		x	√							
Extension materials developed and distributed	x	√		x	√							
Objective 3	*To research factors (nutrients, pest/diseases and their interactions) affecting pulse productivity ...*											
Research experiments established for 2nd year												
Seasonal research results reported	x	√		x	√							
Site visit trip reports	x	√		x	√							
Germplasm testing reports												
Annual meeting report	x	√		x	√							
Nutrient analysis report												
Publications in preparation	x		√	x		√						
Objective 4	*To facilitate and support on-farm participatory research opportunities for Kenyan ...*											
Faculty progress reports				x	√							
Student research reports at annual meeting				x	√							
Masters degrees completed	x	√		x	√							
Publications submitted or presentations given at conference	x	√		x	√							
HC Institutional Capacity Building												
Progress report on new students				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	J.G. Lauren

Signature

10/1/2010
Date

Explanation for Not Achieving Benchmark

Objective 3

Publications in Preparation

It has taken us a bit longer than expected to key in and check all the data from the Replicated Experiments. All data is now in electronic form, statistical analysis is currently underway and will be followed by draft manuscripts for publication.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2009 -- September 30, 2010)

PERFORMANCE INDICATORS
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	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	4	3
Number of men	2	3
Short-term Training: Number of individuals who received short-term training		
Number of women	100	180
Number of men	50	125
Technologies and Policies		
Number of technologies and management practices under research	2	15
Number of technologies and management practices under field testing	9	8
Number of technologies and management practices made available for transfer	9	8
Number of policy studies undertaken	0	0
Beneficiaries:		
Number of rural households benefiting directly	150	245
Number of agricultural firms/enterprises benefiting	1	2
Number of producer and/or community-based organizations receiving technical assistance	4	4
Number of women organizations receiving technical assistance	1	2
Number of HC partner organizations/institutions benefiting	4	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	20	10

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

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

that can promote increased consumption. A rapid market survey of diverse market channels in Kampala focused on nutrient enhanced flours for porridges, weaning foods, supplementary feeding for children, ready-to-eat snacks and foods, and bread. This identified market opportunities for bean products.

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

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

Our recent efforts to introduce new agronomic practices and technologies demonstrate encouraging progress. Ongoing collaboration since 2004 of Iowa State University (ISU), Makerere University (MAK), and Volunteer Efforts for Development Concerns (VEDCO) in Uganda's Kamuli District using a sustainable livelihoods approach increased food security and market readiness from 9% to 77% among 800+ farm households. The main crops are maize, beans, sweet potatoes, cassava, bananas, rice and coffee. Most (90%) of participating households produce beans, but few (20%) sell some. The SL approach focuses on understanding and supporting individual and community capabilities, assets (natural, physical, human, financial, social, cultural and political capital), goals, strategies and activities. Diversification of livelihood opportunities and activities is crucial to sustainability. In combination with SL approaches, scientific knowledge, improved technologies, financial assistance, and changes in government policies can have significant positive local impacts. Participatory research methods can generate knowledge that people can apply to improve their individual and collective well-being.

Beans provide a strategic opportunity to help meet the Millennium Development Goal targets of reducing hunger and poverty. Improved 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 offer 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 with better nutritive value (Objective 1) or processing characteristics (Objective 2) is an important under-researched issue in this region. Improved linkages to emerging markets are also essential (Objective 3).

Central problems limiting production of quality beans and higher yields

- Declining soil fertility and inefficient cropping systems unable to utilize available resources effectively and efficiently
- Limited accessibility and affordability of quality seeds, 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, bruchids)

Central problems relating to nutritional value and processing of beans

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

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

Central problems inhibiting increased marketing of beans and derived food products

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

Planned Project Activities for April 1, 2009 - September 30, 2010

Objective 1: To Improve Harvested Bean Quality and Yields

Approaches and Methods:

Obj. 1a. Determine and Prioritize Key Production Constraints of Six Priority Bean Varieties

Quantify the effects of abiotic stresses on physiology and yield formation of priority bean varieties

- Meta-analysis of the effect of the biotic and abiotic factors on the yield of common beans. The methodology will involve collecting data on yield from all published papers and subjecting them to meta-analysis to determine major constraints and trends in bean yields.
- Controlled environment (greenhouse) experiments conducted to compare the physiological responses of five priority varieties to limited water supply during grain filling.
- Controlled environment (growth chamber) experiments to compare the physiological responses of five priority varieties to high temperature stress during grain filling.
- Document impacts on seed number, seed size, and seed nutrient composition.

Benchmarks

Oct. 2009 – Mar. 2010

- Meta-analysis report on the effect of water stress.
- Relative sensitivity of varieties to water stress documented
- Impact of stress on seed nutrient composition documented

Apr. 2010 – Sept. 2010

- Relative sensitivity of varieties to high temperature stress documented
- Impact of stress on seed nutrient composition documented

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

- Repeat season 1 in 2009 replicated field trials with 6 cooperating farmer groups (30 locations) to compare the yield of (NABE 6 [white dry bean, small seeded] and K 131 [carioca dry bean] and K 132 and NABE 4 [red mottled beans] in Kamuli district)
- Repeat season 1 in 2009 assessment of benefits of improved soil fertility by comparing the yield of manure fertilized vs. non-fertilized treatments on K 132 [red mottled bean] in Kamuli district in Uganda.
- Establish irrigation/fertization demonstration at VEDCO office garden in Kamuli. Document benefits for production, nutrient value, and economic returns on beans.
- Document and analyze location x genotype effects on yield, yield components, and seed nutrient composition.
- Compare impact of timely harvesting on initial seed quality (germination, fungal and insect infestation, physical damage) and maintenance during storage.
- Compare storage techniques and their impact on germination.

Benchmarks

Oct. 2009 – Mar. 2010

- 2009 yield data collected and analyzed
- 2009 seed composition analyzed
- Impacts on bean quality from improved harvest and storage techniques documented
- Irrigation/fertigation demonstration established

Apr. 2010 – Sept. 2010

- 2010 trials conducted using improved production practices
- Yield and nutritional profile of priority varieties confirmed
- Optimum response and economic return on irrigation determined

Obj. 1c. Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices

- 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
- Train cooperating farmers in bean production practices, including pre- and post-harvest handling, and marketing, and the importance of careful record keeping for research and demonstration activities using the production manual prepared for this project.
- Conduct field days at research/demonstration sites for farmers outside of VEDCO cooperator groups.

Benchmarks

Oct. 2009 – Mar. 2010

- All cooperating farmers and farmer group members trained in research methods
- Open field days conducted at selected variety trial and fertilizer trial sites
- Irrigation/fertigation techniques demonstrated to RDEs and CNHWs

Apr. 2010 – Sept. 2010

- Farmer knowledge on participatory research methodologies/designs put into practice for improved field trial implementation
- Trainee follow-up conducted to reinforce implementation of recommended practices
- Recommended research results incorporated into training procedures and promotion protocols RDEs in other VEDCO operational areas and beyond (NaCRRI can use the 'lessons learned' to apply to their other areas of operation)
- Field days conducted for other NGOs, international agencies, and foundation representatives interested in the farmer-to-farmer approach to achieve sustainable food security – include other researchers from NARO institutes and other relevant organizations
- Results from objectives 1a and 1b (above) to be applied to other bean producing districts by NaCRRI and other research units or institutions

Results, Achievements and Outputs of Research:

Determine and Prioritize Key Production Constraints of Five Priority Bean Varieties

Meta-analysis of the effects of water and temperature stress on yields is underway. The literature review is completed, and analysis is focusing on yield and its components. Previous research provided limited information on seed composition. Preliminary experiments on sensitivity of varieties to water stress have been completed. There was difficulty is controlling the level of stress due to aggressive plant growth with adequate fertility. Morphological plasticity and varietal differences to stress were determined. Two varieties (K131 and NABE2) were more tolerant to stress, while NABE4 was the most prone to water stress, probably due to its luscious growth under the adequately fertilized greenhouse soil mix. Initial research to documented impact of stress on seed nutrient composition has involved assessing commercial varieties from Uganda (K131, K132, NABE2, NABE4 and NABE6) in the greenhouse.

At present, results are inconclusive because we could not sufficiently control the stress due to the wide plasticity in plant growth. Varieties from NaCRRI selected as stress tolerant currently in our studies include K131 and NABE2. These have undergone preliminary trials for drought tolerance in the greenhouse at ISU. Water stress studies at ISU will be completed this winter following replication in the greenhouse. Nitrogen free soil has been obtained for studies which will enable better management of vegetative germination**.**

Collaboration has been initiated and a Material Transfer Agreement (MTA) signed between CIAT-Colombia and Iowa State University. With this agreement, we shall receive germplasm from breeders that reflects variation in drought and seed nutritive composition. Recombinant Inbred Lines and their parents will be very useful in understanding the physiology of seed nutrient composition. Use of RILs will enable us to compare lines with the same growth habit.

We are also working to increase the quantities of seed for processing and nutritional studies. A total of 60 kg of clean bean seed was produced at ISU (NABE6 - 40 kg, NABE2 - 10 kg and K131 – 10 kg). Other varieties (NABE4, K132 and Kanyebwa) planted at ISU were destroyed by flooding and residual herbicides. Land has been secured for multiplication of more seed on organically managed land at the ISU horticulture farm in 2011.

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

Improve Quality and Yields through Evaluation of Better Production Practices

In 2009, 30 trial sites were established for both season 1 and season 2. Data were collected from planting through harvest. After harvesting, samples were taken to NaCRRI where measurements of seed total weight, clean seed weight, 100 seed weight and moisture contents were taken.

These results represent combined data of two seasons carried out in 2009. Four improved varieties (K132, NABE4, K131, NABE6) developed at NaCRRI, and a popular local variety (Kanyebwa) were evaluated at each site. The fertility trial involved application of 10 T/ha organic manure applied at planting. Plots were 5m x 5m, arranged in a randomized complete block design with two replications. Seed yield per plot was quantified on 'cleaned seed' (shriveled seed removed) and adjusted to kg/ha.

Only K131 yielded significantly more than the local variety - Kanyebwa (Figure 1). The yield of all varieties was far below the potential yield of 1500-2000 kg/ha [meaning 600-800 kg/acre] observed on NaCRRI research station fields. Manure application increased seed yield of all varieties except NABE4. Yield increases up to 34% for K131, 53% for K132, and 70% for Kanyebwa were observed (Figure 2). Yield increases were due to corresponding increases in the number of pods and seeds per plant (data not shown). However, even the best yields with manure were less than 50% of the yield potential. This could be due to insufficient and unbalanced nutrient supply as well as diseases and pests.

Based on these results, other sets of experiments have been initiated to assess on farm the effect of phosphorous, manure and the interaction between manure and phosphorous on the yield of common beans. Further, pest and disease incidence and severity, as affected by soil fertility treatments and intercropping, will be assessed. Intercropping beans with maize and other crops is a common practice in Uganda. Performance in terms of yield and ease of management in a crop mix is one of the criteria that farmers use in selection of varieties. On farm trials will assess the yield advantages that accrue from a bean-maize intercrop on farm. Important pests and diseases will be assessed during pod filling to determine how the incidence and severity relates to the fertility treatments and its relationship to yield.

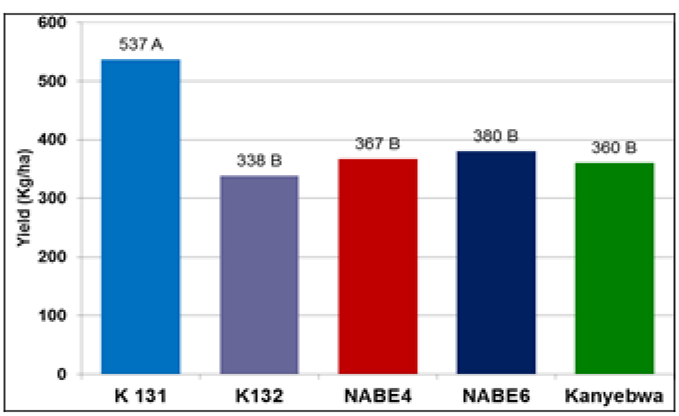


Figure 1: Genotypic variation in yield of common beans under farmers' conditions. Data are the mean for two growing seasons. Means with the same letters are not significantly different at $p < 0.10$.

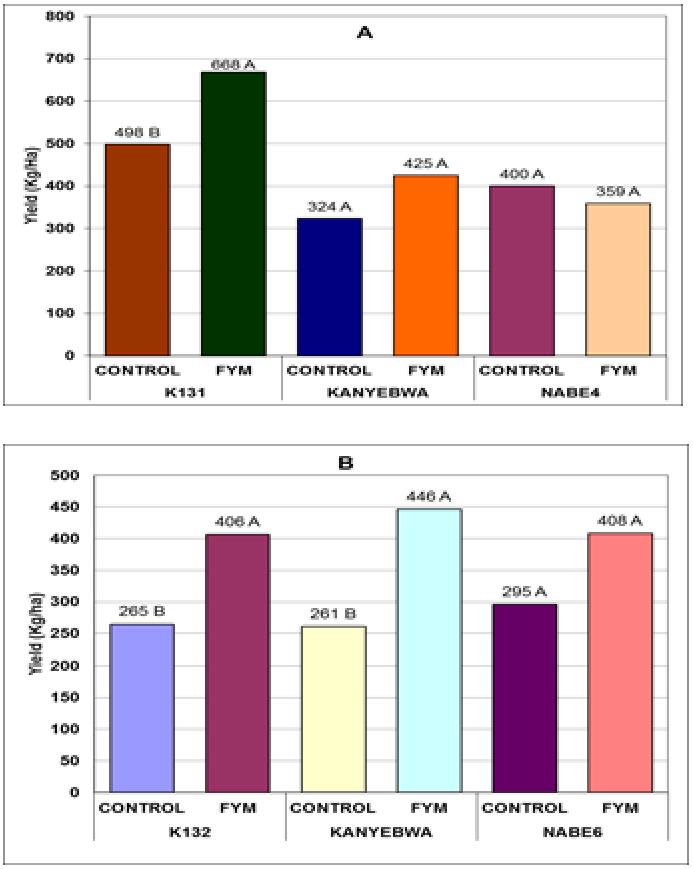


Figure 2: Response of common bean yields to 10T/ha manure application
Part A: Comparisons between K131, Kanyebwa and NABE4
Part B: Comparisons between K132, Kanyebwa and NABE6
Data are the mean for two seasons. Means with the same letters are not significantly different at $p < 0.10$.

Seed samples were obtained from each of the harvested trial plots during the first season of 2010. The seeds were fumigated to prevent them from becoming infested with weevils. Once the phytosanitary certificate papers were obtained for export to the U.S., seed samples were sent to ISU for analysis.

To determine the effect of soil fertility on seed composition, seed samples from Kamuli were analyzed for mineral composition, total carbon and percentage protein content. Mineral analysis was done using inductively coupled plasma (ICP) mass spectrometry. The percentage total carbon and percentage total nitrogen were determined by combustion technique (TruSpec CN, LECO). Seed protein concentration was estimated by nitrogen concentration x 6.25. Nitrogen content was determined by combustion.

There were no significant effects of manure application on seed composition for Phosphorous (P), Potassium (K), Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Aluminum (Al), Calcium (Ca), Magnesium (Mg), % total carbon (TC) and protein content. Significant manure effects were only documented for Sodium (Na). Significant variety differences in composition were only present for K, Fe, Mg and protein content. In all cases, the Variety x Manure interaction was not significant. Correlation analysis showed that Fe content was positively correlated with Mn (0.58, $p<0.001$), Ca (0.82, $p<0.001$), Na (0.71, $p<0.001$), TC (0.37, $p<0.05$) and protein concentration (0.40, $p<0.05$). Protein concentration was also positively correlated with Mg (0.50, $p<0.001$). Zinc had no significant correlation with all the other seed components analyzed.

The first season 2010 trials were established April 7-25. A total of 30 sites were established. Three out of the five sites for each group were for variety trials, and the remaining two were for fertility trials. However, the fertility trials this time consisted of 24 plots compared to 18 during the last season. Before planting the trial plots, soil samples were collected and taken to Kawanda Agricultural Research Institute for analysis. The amount of phosphorous applied depended on the soil test results. Phosphorous levels used were 60, 40 and 20 kg/ha. In plots where Phosphorous x Manure interaction was used, half of the corresponding levels of phosphorous were added. Both farm yard manure and phosphate were applied to the different plots this time. For this report, results from plots where 60 kg/ha of Phosphorous was applied are reported. For the other Phosphorous levels, the number of farms was insufficient for statistical comparisons.

Farmers conducted germination tests before planting of the trials, as learned during project training. Planting was done with spacing of 50 cm between rows and 10 cm between plants within each row. Each plot was 5m x 5m. Weeding of the trials varied from group to group, depending on the planting dates. Overall, weeding was carried out two to three weeks after planting. Harvesting occurred before mid-day, as recommended, to avoid shattering and losses.

Results showed that the there was a significant effect of Location x Variety interaction for total seed yield, clean seed yield and seed size (100 seed weight inherently varies among the varieties due to differences in seed size, though soil fertility treatments could have some effect). However, there were no significant differences in the total yield among varieties (see Table 1). K131 had the highest clean yield, while NABE4 had the lowest clean yield, with 48% of the seed classified bad seed (poorly filled, diseased). Drought and heavy rain affected growth and yield in some locations.

Table 1: Variety Differences in the Mean Yields of Five Common Bean Genotypes

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

Means values with the same letter are not significantly different ($p \leq 0.10$)

In this trial, three varieties, K131, NABE4 and Kanyebwa were compared in 3m x 3m plots. The on-farm trials were arranged in Randomized Complete Design with two replicates per treatment. Soil fertility treatments included: (1) Farm Yard Manure (10T/ha), (2) Single Super Phosphorous (60 kg/ha), (3) Farm Yard Manure (10T/ha) and Super Single Phosphorous (30 kg/ha), and (4) Control. For seed collection, boundary rows were excluded and the equivalent to 6 m^2 was harvested. Yields per plot were then standardized to 13% moisture content and to kg/ha.

There were significant differences in yields among farmers, but no significant effect of soil fertility treatments, variety and soil fertility x variety interaction on the total and clean seed yields. The limited response could be due to insufficient soil fertility amendment levels or unbalanced nutrients during the flowering and seed filling. The climate in Uganda is warm, such that any applied organic manure quickly decomposes and therefore nitrogen (N) becomes available early in growth, while the excess is leached or volatilized. The beans may therefore have had insufficient levels of N during the critical stages of flowering and seed filling. Further, in Phosphorous (P) deficient soils, P applied as fertilizer is quickly fixed by the Iron and Aluminum oxides prevalent in Kamuli soils. Thus, only a small amount is left in the available form for plant uptake. These factors could partly explain the lack of significant effects of N and P on the yield of common beans.

Despite the overall lack of significant differences, the fertility treatments generally yielded higher than the control, with higher yields where phosphorous was part of the treatment (see Table 2). Application of phosphorous alone led to a 32% increase in clean yield compared to the control. The response to phosphorous shows that it is needed for higher bean yields. Analysis of the 100 seed weight showed significant differences among varieties, as expected, and a significant soil fertility treatment effect on seed weight. However, the variety by soil fertility interaction was not significant. Farm yard manure application seemed to lead to a bigger seed size. Other experiments should compare increasing rates of phosphorous to determine the most appropriate range for the soils in Kamuli.

Table 2: Effect of Manure (M), Phosphorous (P), and Manure by Phosphorous (M x P) by interaction on the yield of common beans

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

Means values with the same letter are not significantly different ($p \leq 0.1$).

Seed samples for all three seasons completed in Kamuli have been received at ISU for processing and nutritional studies. The following quantities of seeds have been received: K131 = 20.4 kg, K132 = 18.15 kg, NABE4 = 20.55 kg, NABE6 = 17.65 kg, and Kanyebwa = 14.8 kg.

Drought is becoming increasingly common in Uganda, including Kamuli district. Farmers are in no position to time planting as they used to as weather has become unpredictable. Farmers noted that they used to plant in June and July to take advantage of the second, albeit shorter, rainy season; now, however, the reliability of efforts to successfully ‘time’ planning has become very difficult or impossible. NaCRRI has identified eight early maturing lines, with two already released for farmer use. These varieties/lines mature in 60-65 days, which can help farmers to produce beans in the context of unpredictable variation in the timing and duration of the rainy season. These lines are currently being evaluated in Kamuli for their performance. Data from those trials will soon be sent to ISU for analysis.

Evaluate and Reduce Post-Harvest Losses

Members of the six farmers groups were mobilized in their respective sub-counties for this training. NaCRRI research technicians Richard Sekabembe and John Sulume trained 70 farmers (59 women and 11 men) on proper methods of harvesting seeds as soon as they reach physiological maturity. To avoid losses, farmers were shown how to use string or banana fibers to tie bunches of harvested beans and to use sacks for transport to their homes. Using tarpaulins for a clean drying environment was emphasized, as were sorting and re-drying of seeds to achieve and maintain the recommended moisture content. Farmers were shown that using less violent methods of threshing avoids splitting the seeds. They were also trained on proper storage, with sacks on a raised platform and not touching the wall of the house. For seeds, proper use of fungicides and pesticides was demonstrated to minimize losses during storage and maintain seed quality. For consumption, regular drying and use of preservatives from the neem tree and ash can be used. Farmers indicated that adoption of recommended post-harvest management practices (harvesting, transporting, drying, threshing, sorting and storage) resulted in loss reductions.

Materials for post-harvest training materials for use by extension agents and farmers have been developed with input from a consultant from Mango Tree, a non-governmental organization specializing in education and communication. These materials cover crop production (land selection, land preparation, planting, weeding, and soil fertility management), pest and disease management, and pre- and post-harvest handling. The training materials were pre-tested in the field, followed by workshops with farmers to incorporate suggestions into the process of revision. Each group was subsequently given one set of charts for use during their training sessions.

An experiment was conducted in rural Kamuli during July-August, 2010, to determine the effectiveness of hermetic storage in controlling insects in beans and corn. Heavily infested beans (bruchids) and corn (weevils) were purchased in the local market and stored in used but clean edible oil 10L plastic containers under two conditions: (1) hermetically sealed (airtight) and (2) open to air infiltration but closed to insect migration in or out of the container. The containers were stored at ambient conditions (approximately 22˚C) for four weeks. The weight, quality characteristics and degree of infestation (live and dead insects) were determined before and after storage. After four weeks of storage, the total number of insects approximately doubled in the hermetically sealed containers and tripled in the open containers. However, the hermetically sealed containers resulted in 100% insect mortality. In the open containers, approximately 50% of the insects were alive and actively feeding on the beans and corn beans which resulted in significant quality deterioration compared to hermetic storage. The CRSP project team is currently investigating the feasibility of replicating this experiment using larger containers, such as 200L plastic barrels typically used for water storage.

Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices
Continuing training on research methods and procedures to be used for the 2010 field trials involved all six farmer groups. NaCRRI research technicians conducted this training in March prior to the onset of the first season trials. The topics covered included farmers roles and benefits, site selection, plot layout, treatments and randomization. It helps farmers understand why and how treatments and activities are involved, the outputs that are expected, and how they can internalize and institutionalize these actions. This enhances farmers' confidence in trial management and their sense of ownerships of the process and the results.

Improved and non-improved seeds were planted near each other for comparison purposes. During the field trials, farmers observed that their local variety has a shorter maturity period compared to the other varieties, though it can be significantly affected by diseases and attacked by pests. In response to this, the NaCRRI technical team introduced a new variety, similar to the farmers' own Kanyebwa. Farmers observed the crop performance. When the four original improved varieties did not perform as expected, farmers identified a local variety that is similar to NABE6 (white in color) and planted it near the established trials. When harvested, it yielded better than NABE6. NaCRRI researchers are examining these results and determining appropriate action for future field trials. Research results have been incorporated in subsequent trainings sessions.

Trainee follow-up was conducted by VEDCO and NaCRRI staff immediately after the training and thereafter VEDCO follow-up the trainees on a regular basis. Through these follow-ups, VEDCO has been able to note that the adoption rate was high. Farmers practice what they have learned on their own fields share with their neighbors. Project recommended practices are already being informally disseminated to non-project households and areas, Project team members are also incorporating other innovative practices, such as improved bean recipes, to help farmers increase consumption and improve nutrition.

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



The field day enabled the project team and participating farmers to obtain suggestions from other farmers and stakeholders to improve practices or approaches which will be useful in dissemination and scaling up. Agronomic management practices (soil fertility enhancement, planting, management of diseases and pests, etc.) are being applied on other crops, by non-project households, and in other communities. We have been informally exploring approaches for hope when disseminating recommended practices and technologies within the next year to non-CRSP households in Kamuli and subsequently beyond, once ongoing experimentation and application are completed.

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

Approaches and Methods:
Obj. 2a. Evaluate and Reduce Post-Harvest Losses

- Development of post-harvest training materials and adoption of existing ones
- Training of farmers in pre and post-harvest handling of beans for minimal deterioration

- Evaluation for extent of adoption of innovations from training
- Evaluation of influence of farmer innovation uptake on post-harvest losses

Benchmarks

Oct. 2009 – Mar. 2010

- Materials for post-harvest training developed
- Farmers training in pre- and post harvest handling completed

Apr. 2010 – Sept. 2010

- Evaluation of extent of adoption completed
- Influence of innovations on post-harvest losses evaluated

Obj. 2b. Analyze Influences of Agronomic Conditions and Processing on Nutritional Qualities of Beans

- Five bean varieties (NABE 2, NABE 4, NABE 6, K 131 and K 132) harvested from experimental farms in Wakiso district in central Uganda have been obtained. These varieties will be subjected to various processing techniques, performed according to procedures developed by Dr. Nakimbugwe at MAK and Drs. Hendrich and Murphy at ISU. They will be assessed for nutrition quality. Nutritional quality analysis will focus on nutrient and mineral content (done in collaboration with Dr. Westgate's laboratory in Agronomy at ISU), protein and starch digestibility, iron bioavailability, bean ferritin and anti-nutritional factor (phytate, polyphenols) contents as key determinants of iron bioavailability.
- Iron bioavailability will be determined according to methods proposed by Garcia *et* al. (1996) and Au and Reddy (2000), with bean ferritin done by ELISA according to methods in Dr. Reddy's laboratory at ISU. Starch digestibility will be determined using official AACC method 32-40 (AACC, 2000), Protein digestibility, phytate content according to AOAC Official Method 986.11 and polyphenolic compounds according to AOAC Official Method 965.31, as well as by HPLC methods to be developed in Dr. Murphy's laboratory.

Benchmarks

Oct. 2009 – Mar. 2010

- Nutritional analysis of harvested beans from Season 1 in 2009 will be completed
- Nutritional analysis of effects of processing (first round of improvements) will be completed

Apr. 2010 – Sept. 2010

- Nutritional analysis of harvested beans from Season 2 in 2009 will be completed
- Nutritional analysis of effects of processing (second round of improvements) will be completed

Obj. 2c. Develop Processing Techniques with Improved Efficiency, Feasibility and Consumer Acceptance of Bean-Based Food Products

- Based on the results of Mar.-Sept. 2009 bean flour protocol development research, the best approach (combination of processing methods) for developing the bean flour will be refined and later promoted for uptake. Nutritional analysis of the bean flour will be done to determine the shelf-stability of the bean flour with time.
- Members of a Kamuli community will be involved in developing acceptable protocols that utilize the developed bean flour and the most acceptable recipes using the bean flour will be promoted within the community. The potential of the bean flour to contribute to improved nutrition will be assessed based on existing dietary patterns and intake data that CSRL affiliates have been collecting since 2006.
- The protocol for processing products based on the bean flour will be promoted for uptake.

Benchmarks

Oct. 2009 – Mar. 2010

- Protocols for products utilizing bean flour developed
- Potential contributions of developed bean-based products to nutrition assessed

Apr. 2010 – Sept. 2010

- Assessment of the shelf-stability of the developed bean flour-based products completed
- Processing protocols for bean flour-based products promoted
- Assessment of consumer acceptability of products utilizing bean flour determined
- Follow-up on community adoption of promoted practices undertaken

Results, Achievements and Outputs of Research:

Determine the Influence of Agronomic Conditions on Nutritional Quality of Beans

We tested the hypothesis that implementation of improved farming practices would increase yield and the nutritional value of the beans. It also sought to determine the most effective processing parameters to maximize nutritional value of beans with respect to decreasing anti-nutritional factors and increasing protein and starch digestibility. Application of farm yard manure over two growing seasons had no significant effect ($p<0.05$) on anti-nutritional factors (phytate and polyphenols), though significant differences existed between varieties and between harvests. Difference between harvests could have been due to locations and soil conditions since paired data were received from different farmers. Total polyphenol content ranged from 0.31 to 1.58 and from 0.33 to 1.37 mg/100g in the control and farm yard manure treatment, respectively. The total polyphenol content was lowest in NABE 6 (small white) and highest in Kanyebwa (medium sized, mottled) (see Table 3). Phytate content varied from 0.49 to 0.81 and from 0.31 to 1.38 in the control and farm yard manure treatment, respectively. The phytate content was lowest in NABE 4 and highest in the K131 variety. Studies on the effect of agronomical practices on iron bioavailability using a Caco-2 cell culture model are ongoing.

Table 3: Total polyphenol and phytate content of bean varieties over the two growing seasons

Variety	Total Polyphenols (mg/100g)		Phytate (g/100g)	
	Control	FYM*	Control	FYM*
K131	1.08	1.37	0.65	1.38
K132	0.84	0.85	0.65	0.58
Kanyebwa	1.58	1.37	0.75	1.09
NABE4	1.49	1.01	0.49	0.31
NABE6	0.31	0.33	0.81	1.23

*FYM=Farm yard manure

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

The effect of soaking, malting and steaming on protein and starch digestibility, as well as on polyphenols and phytic acid, were determined using K131 and NABE6 varieties. Individual processing techniques had significant effect on total polyphenol and phytate content. However, the magnitude of these effects was variety and factor specific, ranging from 15-38% reduction (both polyphenol and phytate) in K131 to 22-39% (polyphenol) and 73-83% (phytate) reduction in NABE6. The combined effects of these processing techniques were evaluated using K131, and optimized for minimizing polyphenol and phytate contents and maximizing starch and protein digestibility.

In Uganda, the protocol initially developed for processing bean-flour, using K131 as the model variety, involved the following steps:
Soaking (12 hours) → malting (48 hours) → de-hulling → steaming (15 minutes) → roasting (15minutes). It was then refined to: soaking (12 hours) → malting (24 hours) → steaming under pressure (20 minutes) → oven drying (at 65°C for 8 hours) → fine milling. The malting time was reduced from 48 to 24 hours because the beans were sufficiently sprouted after that time. Steaming replaced roasting, followed by oven drying; the reason for this is that when the flour was used for porridge, it tasted burnt.

Since soaking, malting and steaming times have greater influence on nutritional quality and sensory acceptability of the processed bean flour, they were selected for optimization. Three levels of each of the three processes were tested as shown in Table 5 below.

Table 5: Criteria used for optimizing bean flour processing protocol

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

The influence of different levels of the independent variables on starch digestion, protein digestion and polyphenol/phytate contents were optimized using Statease software. Optimal levels of the three sets of variables were 24 hours soaking, 48 hours malting, and 18.7 minutes steaming. These processes resulted in optimal starch and protein digestibility values of 91.16 and 87.73, respectively, and phytate and total polyphenol levels of 0.22% and 0.58 mg/100g, respectively. Processing also lowered the viscosity of the porridge prepared from the bean-based flour to 3.4 times (70%) less than that maize flour and 5 times (80%) less than the viscosity of millet flour, based on same proportions of the flours in the porridge, on dry matter basis. The sensory acceptability of the product made with bean based flour was also improved by processing, particularly by steaming compared to non-steamed beans. Based on the sensory evaluation studies for consumer acceptance using a nine point hedonic scale, the overall acceptability was found to be of 7.67. Studies are ongoing to validate this protocol for all the other varieties covered by the project and to correlate reduction in anti-nutritional factor content to iron bioavailability.

While the bean flour can be consumed solely as a sauce to accompany staple dishes, it has also been incorporated into a composite flour that can be consumed either as porridge or sauce. The composite flour was developed with 40% bean, 30% grain amaranth, and 30% rice flours. Grain amaranth was oven roasted at 220°C for 8-10 minutes followed by fine milling, while the rice flour is just fine milled. The combination was adopted after several combinations were tested consumer acceptability. The potential contribution of bean-based products to nutrient intake for children will be determined based on serving size and the nutrient requirements for that specific age group. Similar estimations will be made for other vulnerable groups that are at risk for nutritional deficiencies.

Studies on development of extruded flour as well as an extruded snack were scheduled to be carried out at ISU. However, this depended on the ability to multiply seed material in quantities necessary for product development experiments at the pilot plant. The harvest from the Summer 2009 multiplication trials did not produce enough material, so a larger area was planted in Summer of 2010. The latter harvest has generated sufficient raw material for use in developing extruded products, and the trials are scheduled for late Fall 2010.

Once the extruded snack and flour have been developed, their nutritional and sensory characteristics will be evaluated. Plans to assess the effect of bean consumption on nutritional status in humans were eliminated due to logistical constraints and cost. Implementation would have required performing the activity in Uganda where the population is already consuming beans and is the target of new developed products, but the equipment and facilities required to collect primary data are not available in-country.

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

In Rwanda, beans were soaked in water (ratio 1:1) for 16 hours at ambient temperature. The beans doubled their weight upon soaking and were subjected to germination for 4-6 days at ambient temperature. They were de-hulled and dried at 105°C for 5 hours. The de-hulled beans were milled and made into flour. The flour was made into dough (1:0.4 flour to water ratio) and fermented for 8 hours at ambient room temperature. It was dried in a mechanical drier at 105°C for 3 hours and then milled to obtain uniform flour. This treatment can be applied in the development of processed weaning foods for children.

The effect of thermal processing methods on the functional properties of bean flour was also studied. The thermal processing treatments were boiling, roasting and autoclaving. In the boiling method, 2 kg of dry common beans were boiled in a closed pan for 2 hours, until soft to touch when pressing between the fingers. The samples were oven dried overnight at 70°C followed by sun drying. In the roasting method, 1 kg of dry beans was mixed with clean fine sand and stirred frequently to prevent burning of the seed coat and to ensure uniform distribution of heat. The materials were roasted for 30 minutes. The sand was thereafter separated from the seeds (sorting) and allowed to cool. In the autoclaving method, 2 kg of bean seeds were autoclaved at 121°C for 30 minutes and then sun dried. All the processed samples and the raw seeds were mechanically milled.

Bulk density (net weight of the flour divided by the volume of the container), water absorption capacity (Beuchat 1977), oil absorption capacity (Beuchat 1977), emulsion capacity (Beuchat 1977), foam capacity and stability (Coffman & Gracia 1991) of raw, boiled, roasted, and autoclaved common bean flours were determined. The results showed that there was no change in bulk density of bean flours. The bulk density values reported are slightly higher than the value (0.29 g/ml) observed by Glami et al. (1992) for full fat winged bean flour but lower than 0.93 g/ml reported (Bello & Okesie 1982) for winged bean protein isolated. The value 0.55 g/ml obtained for common beans compares favorably with 0.55 g/ml reported for African bread fruit kernel flour but lower than 0.7g/ml reported for wheat flour (Akubor & Badifu 2004). For a reduction of paste thickness, a high bulk density is desirable; this in an important factor in convalescence and child feeding.

Water absorption was higher in roasted common bean flour and no difference was observed between raw, boiled and autoclaved bean flours. Water absorption represents the ability to process beans under conditions where water is limiting, e.g., dough and pastes. Proteins are capable of binding large quantities of water due to their ability to form hydrogen bonds between water molecules and polar groups on the polypeptide chains. These properties enable bakers to add more water to dough and, as such, improve on the handling qualities and maintain freshness in the bread. The higher water uptake by the processed seed flours compared with their raw form could be due to the more exposed active surface area in the latter. The increased absorption capacity of heat processed flours is due to heat-induced dissociation (denaturation) of proteins, gelatinization of carbohydrate in the flours, and swelling of crude fiber.

The results obtained suggest that common bean flour can be an important functional ingredient in bakery products. Oil absorption was high in autoclaved bean flour and low in raw bean flour. The oil absorption capacity determines whether the protein material of the flour will perform well as meat extenders or analogs. Fats improve flavor and increase the mouth feel of foods. Fat absorption is therefore a significant factor in food formulations (Eke & Akobundu 1993). In this research, fat absorption capacities were higher in processed common bean samples than in the raw one. The increase in oil absorption of processed samples over the raw one could be due to both the heat dissociation of the proteins and denaturation. The oil absorption capacity of protein is required in ground meat formulations, meat replacers and extenders, doughnuts, pancakes, baked foods and soups. Less oil absorption components are lower flavor retainers (Narayania & Narasing 1982). The lower oil absorption capacity might be due to low hydrophobicity proteins which show superior binding of lipids (Kinsella 1976).

Wettability among the samples varied according to the dispersability. It is important in food formulations. Wettability of protein is affected by surface polarity, texture, and area and microstructure of the protein particles. In this research, the flours were very stable and there was no quick movement of water through bean flours; the most stable flour was from boiled common beans.

Emulsion capacity was high in raw bean flour and low in boiled bean flour. The emulsion capacity of the raw common bean flour is higher than that of processed bean flours. Protein modification associated with heat was responsible for the reduction in the value obtained from the processed common bean samples. The reduction in values is attributed to protein denaturation and similar to the results of steeped, malted, and roasted African yam bean flours (Eke & Akobundo 1993). From our research results, it is evident that boiling as a processing method is less effective when compared to autoclaved and roasted beans for which emulsion capacity of the flour is required for spread formulation.

Differences between foaming capacity of flour from unprocessed beans and those from beans processed before blending were identified: foam of raw bean flour after whipping = 49 ml, boiled bean flour = 12 ml, autoclaved bean flour = 4 ml, and roasted bean flour = 7ml. These differences in functional properties showed that there was denaturation of proteins which affect the reactivity, attraction and binding capacity of common bean flours with other food compounds. From the study, it is recommended that boiled and roasted bean flours can be used as thickeners and in child feeding because they are denser. It is also recommended that raw bean flour be used as aerating agents in food systems such as whipped toppings and ice cream mixes which require the production of high stable foam volumes when whipped.

In Uganda, the optimized protocol for producing bean flour, using variety K131 as the model, has been up-scaled to semi-commercial level. Clean dry beans are soaked for 24 hours in large plastic bins, malted for 48 hours between moist sisal mats, roasted at 200-220°C for 40-60 minutes with constant stirring, and then milled into a fine flour. Roasting was selected because of its practicality compared to steaming under pressure. The optimization was done in collaboration with Nutreal Limited, a private company partnering with the business incubation program of the Department of Food Science & Technology (DFST) at Makerere University. DFST is providing technical support for production, product branding, acceptability and shelf-life studies, all of which are currently underway.

In Rwanda, formulation of composite flour of bean and maize was carried out after appropriate pre-treatments. They were blended in different combination and the cold extruded snack was processed and subjected to organoleptic evaluation (Kamala 2009; Ramasamy & Suseelama 2005). The combinations indicated in Table 4 were acceptable. These combinations were subjected to proximate analysis in the laboratory. Simultaneously, storage stability studies were conducted, and results indicated that the product was shelf stable for a period of four months.

Table 4: Organoleptically Acceptable Combinations of Bean Composite Flour

Bean Variety	**Composite Flour**
Colta	100% Bean flour
Decelaya	70% Bean, 30% Maize
RWR 22-45	100% Bean flour
White beans	60% Bean, 40% Maize

In Rwanda, a metallic hand operated extruder was used to cold press the dough before frying in oil. The extruder consists of a die, dough holder and dough presser. The dies used were of different shapes: star, round, rectangle, etc. The selected die was placed and screwed in the die holder of the dough holder. The dough made out of the blended flour was placed in the dough holder. The dough presser was placed on the dough and squeezed by pressing the handles of both the dough holder and the dough presser. This resulted in the extrusion of the snack. The extruded product was directly placed into hot cooking oil and deep fried. The cooked snack food was then cooled, since the cooling process improves the crispness of the product. Finally, the product was vacuum packed and placed in a plastic container.

<u>Objective 3</u>: To Identify Solutions for Constraints to Increased Marketing & Consumption.

Approaches and Methods:

Obj. 3a. Identify Solutions to Production and Marketing Constraints Faced by Bean Producers

- Identify strategies to address barriers and challenges in market access faced by farmers/producers. This work builds on the 'Baseline Data for Participating Households in Kamuli Bean Production and Marketing' questionnaire in 2009. A follow up household survey will be conducted in Feb.-Mar. 2010.
- Identify strategies and approaches to strengthen value chain and returns to producers through value-added marketing efforts. This work builds on the 'Business and

Trading' questionnaire in 2009. A follow up survey will be conducted in Feb.-Mar. 2010. Case studies of successful marketing efforts will be developed.

- Help farmers and farm groups to more successfully market beans by developing chain partnerships. This involves improving market information systems, building farmers' entrepreneurial and negotiation skills, and training them to participate effectively in decision making.

Benchmarks

Oct. 2009 – Mar. 2010

- Value chain and marketing analyses completed
- Successful producer marketing strategies identified

Apr. 2010 – Sept. 2010

- Market information system improved
- Farmers and farmer organizations trained in improved bean marketing

Obj. 3b. Characterize Consumer Demand and Preferences for Beans and Agro Processed Products

- Determine market values of bean varieties and products. Collect market price information on bean varieties sold in market and at different stages in the value chain. This analysis will be used to identify opportunities for improved marketing, as well as confirm values attached to different bean varieties by consumers and by processors.
- Develop and evaluate marketing information and marketing plans that incorporating market values and production traits in marketing plan.

Benchmarks

Oct. 2009 – Mar. 2010

- Identify value of various bean varieties and value-added products in the market.

Apr. 2010 – Sept. 2010

- Train farmers in developing marketing plans by incorporating market and production information.

Obj. 3c. Increase Awareness of Benefits of Consuming Beans and Value-Added Products and their Access to New Products

- Investigate the role of nutritional awareness in consumer choice and valuation of beans and bean products. This follows up nutrition education efforts.
- Develop and evaluate marketing strategies that take account of consumers' enhanced nutritional awareness.
- Assess emerging opportunities for processors and others in the bean value chain

Benchmarks

Oct. 2009 – Mar. 2010

- Identification of successful marketing approaches to consumers and for value added products
- Training of producers on effective bean marketing

Apr. 2010 – Sept. 2010

- Training of producers on successful marketing methods for beans and new products
- Training of processors and others in value chain on successful marketing methods for beans and new products

Results, Achievements and Outputs of Research:

Identify Solutions to Production and Marketing Constraints Faced by Bean Producers

Research by MSc. agricultural economics student Simon Okiror found that although there has been an increase in bean market participation (42%) among households compared to 2005 when only 20% of the surveyed households in rural Kamuli had sold some beans, bean production has tended to be for domestic consumption rather than for commercial purposes. The average farm-household markets a relatively small quantity of beans (33 kg). Price is positively associated with the probability of selling beans. Barriers to market participation by smallholder farmers include the transaction costs of marketing, especially market distance and searching for market information. The marketing information system for VEDCO assisted farmers has been improving throughout Kamuli district. Market price boards in all VEDCO operation areas publicly display market prices for crops that are updated on a weekly basis. In addition, farmers are being informed about market prices for crops through cell phone messages.

VEDCO has recently invested in a new text-based information technology system that will enable messages to be sent and received in both English and Luganda. During the first phase, VEDCO can send text messages to the mobile phones of registered farmers or other units. Messages can contain current market prices and/or 'extension' information, targeting specific crops and/or regions. During the second stage, VEDCO could receive questions, comments, etc. from farmers. The system could be used to systematically collect questions about farmers' concerns and then disseminate responses to them. It could also be used to collect trend data to inform field activities. Further, it is possible that farmers' remarks could be posted adjacent to messages from VEDCO extension staff (this could be done on a text-based system by simply labeling the origin of the message). This system takes advantage of existing technology available to the small farmers and conveys market information rapidly and at times when farmers are making critical production and marketing decisions.

Costs associated with the process by which farmers obtain and submit information needs to be changed before this initiative moves ahead. Currently, farmers must pay when they send a text message to obtain or submit information. They do not pay to receive messages. Given scarce resources, farmers might initiate a text message only when having net positive value or perhaps only when necessary. Similarly, it would cost

VEDCO $1,000 per message if 10,000 farmers signed up and current billing rates ($0.10 per message) continue to apply to send a text message to all of them.

To enhance its capacity to monitor the new information system users and design appropriate messages for them, VEDCO is currently planning to hire a communication manager who would work with field staff to assess needed messages, and then help design messages for delivery via the new system (as well as other appropriate channels). It is expected that this new person will start working by March 2011 or earlier.

There is recognized value in encouraging and strengthening associations for collective marketing among farmers. In addition, proper management of the crop will result in higher quality grain, thereby stimulating participation in the market. The improved management through collective marketing efforts effectively increases the quantity harvested and enables farmers to obtain higher prices for higher quality produce. Schools, hospitals and central markets are some of the channels that farmers have identified for marketing their beans. They also identified establishment of storage facilities as important to enable them to earn more by controlling the timing of sales, and further stimulate production increases.

VEDCO organized the first value chain stakeholder workshop in Kamuli on September 22, 2010, and is committed to playing a facilitative role to achieve success in value chain development. The focus of the collective efforts of the 25 participants from 15 organizations (farmer marketing groups and associations, government agencies, non-governmental organizations, private sector traders, transporters, distributors, and processors) is development of the maize and bean value chains. Participants committed themselves to coordinate efforts to accomplish these intermediate and long terms goals:

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

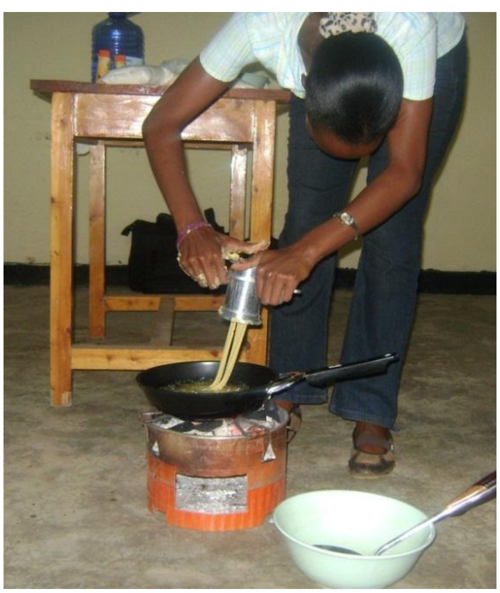
Characterize Consumer Demand and Preferences for Beans and Agro-Processed Products

The MSc. agricultural extension student George Jjagwe carried out a rapid market survey to establish the extent to which nutrient enhanced foods are present in different types of market channels in Kampala. He surveyed a range of outlets, including small retail outlets, medium and large supermarkets. The survey focused on flours used for preparing nutrient-dense porridges, e.g., weaning foods and supplementary feeding for children, ready-to-eat foods, and snacks such as bread, made with nutrient enhanced flours. A very limited range of such nutrient-enhanced products was observed, implying that there is great potential to increase the range. A more detailed survey to establish the consumer levels of nutrition knowledge as well as their criteria for buying nutrient enhanced foods (influencing factors) among others is needed.

Flour for porridge is in 1-2 kg packages that sell for U.S. $1-2, depending on the size and locality of the retail outlet. In a planned consumer survey, the consumers' values regarding product frequency usage as well as perceived nutritional and health benefits awareness will be determined. The survey tool for assessing consumer knowledge and preferences has been developed and is under review. Both qualitative and quantitative consumer considerations will be determined. The market channels identified during the rapid market assessment include processors who also function as wholesalers and transporters of products, delivering them directly to retail outlets where consumers access them.

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

On September 22-23, 2010, in Nyagatare in Rwanda's Eastern province, farmer community extension was carried out by Dr. Hilda Vasanthakaalam four 3rd and 4th year undergraduate students from KIST (3 male and 1 female). The demonstrated the cold extrusion method to rural community members in 2 villages with 15 farmer participants in each village. Ingredients used for processing the cold extruded snack food**:** composite flour (150g), rice flour - for binding (15g), black pepper powder (2.5g), oil (5g), turmeric (a pinch), salt (to taste), Asofoetida powder - used to decrease flatulence (a pinch), water, and oil for frying. The farmers were excited to see this demonstration and learn about this process. Farmers also indicated their interest to mobilize 100 farmers the following month so that many more could benefit. One farmer expressed interest in becoming a bean flour processing entrepreneur.



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

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

The Technology Business Incubation Centre in the Department of Food Science & Technology at Makerere University is currently working with a private sector company (Nutreal Limited) to refine, brand and market bean-based composite flour, suitable for use both in porridge and sauces. The product was based on the composite flour developed by Catherine Ndagire as part of her MSc. work for the project. Packaging has been designed; nutrient composition of the products determined and shelf-life studies are underway. The product has appeared in several exhibitions, including the Uganda Manufacturers' Association Annual Exhibition and received promising feedback.

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

The training programs of two M.Sc. Ugandan students at Makerere, Simon Okiror in Agricultural Economics & Agribusiness, and Aisha Nakitto in Food Science & Technology, are essentially completed. Simon's thesis is in final review and a manuscript is in preparation. Aisha is conducting her final experiments and writing her thesis. Training of the student from KIST, Cyrille Sinayobye, was terminated when he withdrew from the university.

Two new MSc. students at Makerere University are making contributions to the project. Catherine Ndagire in the Department of Food Science & Technology is pursuing a specialization in human nutrition. George Jjagwe in the Department of Agricultural Extension / Education officially registered in May 2010.

Another student from KIST, Ms. Rose Kambabazi, wrote an initial research proposal and helped with KIST B.S. students in their research. The Co-PI at Makerere submitted and followed up Rose's application documents and facilitated her trip to Uganda for an interview. However, Makerere University's Graduate School required evidence that the university that she attended in Algeria is chartered / certified; such evidence has not been received to date.

In Rwanda, the four undergraduate student projects are in progress. They are continuing analysis and write up; their reports are expected to be ready by early December 2010. Their findings will inform ongoing research and community-based dissemination activities in the coming year.

Gerald Sebuwufu is making good progress in courses required for his Ph.D. in Crop Production and Physiology, with a minor in Sustainable Agriculture. Recent courses covered plant growth and development, protein techniques, plant transformation organic agriculture, foundations of sustainable agriculture, and program development and evaluation. In 2011, Gerald will finish with courses in sustainable agriculture and seed science. His dissertation research focus is on understanding the physiological basis for accretion of iron and zinc in the common bean seed and assessing the effect of genotype and soil fertility interactions on seed yield and seed composition. Experiments at ISU aimed at understanding the basis for partitioning of Fe and Zn to the seed are ongoing and collaboration has been initiated with CIAT - Colombia for provision of germplasm needed for the study. In Uganda, the focus is on understanding the physiology of genotype x soil fertility effects on the yield of common beans. Three seasons have been planted and more experiments on soil fertility and inter-cropping are planned for 2011.

Martin Mutambuka is making good progress in courses required for his Ph.D. in Food Science and beginning to write up his dissertation on the effects of processing technologies on phytate/polyphenol content and iron bioavailability and development of nutritional and consumer acceptable bean products. Content of the first three chapters have been discussed and approved by his advisors. Research is ongoing to address the two principal research questions. Partial results are available but not yet conclusive for publication of manuscripts.

Project collaborators in VEDCO, Makerere, and NaCRRI communicate regularly and co-organize events and activities in Kamuli. Most prominent during the past year have been the farmers' field day, training and experimentation with bean recipes, and the bean cook day completion. Occasionally, Ugandan collaborators visit the Rwandese collaborator and vice versa. Four ISU collaborators visited and participated in project activities in Uganda. In addition, ISU specialists in development communication and agricultural and biosystems engineering traveled to Uganda to contribute to CSRL program and CRSP project activities. Similarly, Co-PIs from VEDCO, Makerere (along with the M.Sc. student in Food Science & Technology), and KIST, visited ISU to work and plan activities with the Lead PI and Co-PIs based at ISU.

Catherine Ndagire, MSc. in Food Science and Technology, disseminated her research findings on bean storage to the farmers in Kamuli District as did Simon Okiror, MSc in Agricultural Economics / Agribusiness, regarding his findings about marketing.

During the farmers' community field day, Co-PI Dorothy Nakimbugwe (Makerere University) and research technicians from NaCRRI staff made presentations on issues related to research findings to date. Proceedings of the day were video recorded and will be used in developing or refining training materials.

KIST Co-PI Hilda Vasanthakaalam has worked with the Centre for Communication and Extension of the Ministry of Agriculture. Several processing and value addition methods for selected bean varieties in Rwanda have completed in the Food Science & Technology lab at KIST. The results are being assembled in book form for publication. In addition, reports for three of the seven research projects carried out this year at KIST are being prepared for publication.

<u>Degree Training:</u>
Trainee #1
First and Other Given Names: Gerald
Last Name: Sebuwufu
Citizenship: Ugandan
Gender: Male
Degree: Ph.D.
Discipline: Agronomy
Host Country Institution to Benefit: National Crops Resources Research Institute, Uganda
Training Location: Iowa State University
Supervising CRSP PI: Mark Westgate
Start Date of Degree Program: August 2008
Program Completion Date: August 2012
Training Status during Fiscal Year 2010: full-time student
Type of CRSP Support (full, partial or indirect): Partial

Trainee #2
First and Other Given Names: Martin
Last Name: Mutambuka
Citizenship: Ugandan
Gender: Male
Degree training: Ph.D.
Discipline: Food Science and Human Nutrition
Host Country Institution to Benefit: Makerere University, Uganda
Training Location: Iowa State University
Supervising CRSP PI: Patricia Murphy
Start Date: January 2009
Projected Completion Date: May 2012
Type of CRSP Support (full, partial or indirect): Partial

Trainee #3
First and given names: Catherine Tamale
Last name: Ndagire
Citizenship: Ugandan
Gender: Female
Degree: M.Sc.
Discipline: Food Science & Technology
Host Country Institution to benefit: Makerere University, Uganda
Training Location: Makerere University and Iowa State University
Supervising CRSP PI: Dorothy Nakimbugwe
Start date: August 2009
Project completion date: May 2011
Type of CRSP Support (full, partial or indirect): Partial

Trainee #4
First and given names: George
Last name: Jjagwe
Citizenship: Ugandan
Gender: Male
Degree: M.Sc.
Discipline: Agricultural Extension & Education
Host Country Institution to benefit: Makerere University, Uganda
Training Location: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe (Co-PI Paul Kibwika)
Start date: August 2010
Project completion date: August 2012
Type of CRSP Support (full, partial or indirect): Partial

Short-Term Training:

Type of Training: Mentored refinement and implementation of lab experiments

Description of Training Activity: Development of nutritious, quick-cooking composite flour

Status of this Activity as of September 30, 2010: Completed

When did the Short Term Training Activity occur? May 18 – August 18, 2010

Location of Short Term Training: Iowa State University

If Training was not completed as planned, provide a rationale: N/A

Who benefitted from this Short Term Training Activity? Makerere University

Number of Beneficiaries by Gender: Male - 0
Female - 1
Total - 1

Explanation for Changes

Plans to assess the effect of bean consumption on human metabolism were eliminated due to logistical constraints and cost. Implementation would have required performing the activities in Uganda and Rwanda where the population is already consuming beans and is the target of new developed products, but the equipment and facilities required to collect primary data are not available in-country.

Networking and Linkages with Stakeholders

- NaCRRI recently received over 200 nutri-bean lines (lines high in iron, zinc and protein) from the University of Nairobi through CIAT for multiplication.
- Collaboration has been initiated and a Material Transfer Agreement (MTA) signed between CIAT-Colombia and Iowa State University. With this agreement, ISU will receive germplasm from breeders that reflects variation in drought and seed nutritive composition. Recombinant Inbred Lines and their parents will be very useful in understanding the physiology of seed nutrient composition.
- NaCRRI researchers Michael Otim (entomologist) and Pamella Paparu (pathologist) are developing research activities that will involve advanced training of farmers to identify insect pests (bean aphids, thrips, bean stem maggot and flower beetles) and diseases (bean root rot, web blight, and bean rust) and participatory evaluation of biological and cultural control for key pests and diseases, to reduce crop losses and diseases.
- VEDCO organized the first value chain stakeholder workshop in Kamuli in September, 2010, and is committed to playing a facilitative role to achieve success in value chain development for beans and maize. The initial workshop involved 25 participants from 15 organizations (farmer marketing groups and associations, government agencies, non-governmental organizations, private sector traders, transporters, distributors, and processors).
- Visits to ISU by Co-PIs from Makerere University (Uganda) and KIST (Rwanda) resulted in useful learning about parallel and complementary research interests, and discussions regarding bases for long term collaboration

- ISU faculty members visited Uganda – bringing expertise in agricultural and biosystems engineering, agronomy, development communications, human nutrition, and sociology.
- VEDCO holds biannual community review meetings in its areas of operation; CRSP project partners and farmers participate in these review and planning meetings.

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

Bikorimana, Alexis. 2009. "Effect of germination and fermentation on the nutritional composition." Final project report for B.S. degree. Department of Food Science & Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

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Contribution of Project to Target USAID Performance Indicators

Our project has a strong record of achieving performance indicators/targets:
We have been mentoring 12 students for degree training, of whom 5 are women. Exceeding our original estimate is due to the efforts of Co-PI Nakimbugwe and Co-PI Vasanthakaalam who actively involve B.S. students in the CRSP project while they undertake research for their 4th year projects at Makerere University and KIST, respectively.

With regard to 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.

As planned, we have progressed well in terms of the number of technologies and management practices that are under research (7), and under field testing (4), and ready to be made available for transfer (3).

The number of farmers receiving training and participating in the project's set of field trial experiments is 67, as planned. However, management practices and technologies are already being informally disseminated within the farmers' communities. The field day and community recipe extension demonstrations are benefitting an additional 200 households. Since CSRL's Kamuli program is now providing assistance to 1,200 farm households, we plan to utilize this opportunity in FY11 to begin disseminating applicable management practices and technologies to more farmers, monitoring and evaluating the process and impacts to identify any barriers and most effective strategies. In FY12, we expect to be able to reach even more farmers. Moreover, VEDCO's network of 30,500+ farm households in eleven other districts (VEDCO 2010) and NaCRRI's nationwide network will greatly facilitate even wider dissemination as project work continues and lessons are learned. Two farmers marketing associations are directly benefitting from project activities. We are providing technical assistance directly to six community based organizations (CBOs) and indirectly to an additional eight, as planned. Women constitute the majority of members in these CBOs. There are four host country partner organizations benefitting, as planned.

The number of additional hectares under improved technologies or management practices (15) corresponds to what was originally anticipated.

The public-private sector partnership between Makerere University and Nutreal Limited is being established as a result of this USAID-funded project. Others may emerge as the bean value chain stakeholder forum in Kamuli continues and effectively realizes its goals.

Contribution to Gender Equity Goal
Among the team of research scientists and professional practitioners, there are 7 women and 5 men.

During the recently completed year, there are 2 female and 4 male students receiving graduate level training and mentorship in research at Makerere and ISU. There have been 4 female and 4 male undergraduate students involved in project research at KIST.

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. Approximately two-thirds of the 150 participants in the farmer field day are women, as were the majority of those involved in the rural recipe training and 'bean cook day.'

Progress Report on Activities Funded Through Supplemental Funds
Supplemental funds were provided to cover travel and research expenses at Iowa State University for Catherine Ndagire, MSc student in Food Science & Technology at Makerere University, whose work focuses on development of a nutritious, quick-cooking composite bean-based flour. During her period of research at ISU (May 18 – August 18, 2010), Catherine received training and mentoring from ISU Co-PIs regarding refinement and implementation of a series of lab experiments and sensory evaluation. All planned research activities were completed on schedule. She also made a presentation of her research question, methodology, and results in early August before returning to Uganda.

Supplemental funds provided to KIST for the purchase of a single screw extruder and supplies have helped strengthen the research capacity in food extrusion methods in the Department of Food Science & Technology.

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Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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														
	Iowa State			Makerere			NaCCRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Quality and Yields*														
1a. Meta-analysis report on effect of water & temp. stress on yields	0			0			0			0			0		
1a. Completed experiments on sensitivity of varieties to water stress	0			0			0			0			0		
1a. Documented impact of stress on seed nutrient composition	0			0			0			0			0		
1a. Increased quantities of seed for processing & nutritional studies	0			0			0			0			0		
1a. Manuscripts on physiological studies & meta-analysis completed	x	√		0			x			0			0		
1a. Collaborative studies initiated, selected stress tolerant varieties	x	√		0			x			0			0		
1b. Collected and analyzed 2009 yield data	0			0			0			0			0		
1b. Analyzed 2009 seed composition from field trials	0			0			0			0			0		
1b. Document. impacts on quality from improved harvest & storage	0			0			0			0			0		
1b. Conducted 2010 trials using improved production practices	x	√		0			x			x			0		
1b. Confirmed yield and nutritional profile of priority varieties	x	√		0			x			0			0		
1b. Provided seed from field trials for analyses in Objective 2	x	√		0			x			0			0		
1b. Identified agro-ecological regions for using stress tolerance char.	x	√		0			x			0			0		
1c. Developed materials for post-harvest training	0			0			0			0			0		
1c. Completed farmers' training in pre- and post harvest handling	0			0			x			x			0		
1c. Evaluated influence of innovations on post-harvest losses	x	√		0			x			x			0		
1d. Farmers/group members trained in research methods	0			0			0			0			0		
1d. Open field days conducted at selected trial sites	0			0			0			0			0		
1d. Farmer knowledge put into practice for field trial	0			0			x			x			0		
1d. Trainee follow-up conducted	0			0			x			x			0		
1d. Recommended research results incorporated into training	0			0			x			x			0		
1d. Field days conducted	0			0			x			x			0		
1d. Results applied to other bean producing districts	0			0			x			x			0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Nutritional analysis of effects of agronomy on harvested beans	x	√		x			0			0			0		
2a. Analysis of effects of processing on nutrition quality	x	√		x			0			0			0		
2b. Processing protocol for an extruded bean snack developed	0			0			0			0			0		
2b. Nutritional and sensory characteristics of bean snack optimized	0			0			0			0			0		

2b. Effects of processing on nutritional quality determined	0			0			0			0			0		
2b. Bean flour for soups & porridges produced from extruded flour	x		√	0			0			0			0		
2b. Effect of bean consumption on human metabolism assessed	x		√	0			0			0			0		
2c. Protocol for producing bean flour up scaled and refined	0			0			0			0			0		
2c. Recipes using bean flour developed & evaluated in competition	0			0			0			0			0		
2c. Winning recipes promoted in communities	0			x			0			0			x		
2c. Protocol for bean flour-based product developed and optimized	x	√		x			0			0			x		
2c. Contribution of bean-based products to nutrient intake assessed	x	√		x			0			0			x		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
3a. Value chain and marketing analyses completed	0			0			0			0			0		
3a. Consumer requir. & market channels for bean flour identified	0			0			0			0			0		
3a. Successful producer marketing strategies identified	0			0			0			0			0		
3a. Market information system improved	x	√		x			x			x			0		
3a. Farmers/farmer orgs. trained in improved bean marketing	x	√		x			x			x			0		
3b. Consumer req. & market channels for bean products identified	0			0			0			0			0		
3b. Value of bean vars. and value-added prod. in markets identified	0			0			0			0			0		
3b. Consumer req. for the bean flour-based food determined	x	√		x			x			x			0		
3b. Farmers & farmer orgs. trained in developing marketing plans	x	√		x			x			x			0		
3c. Identification of successful marketing approaches	0			0			0			0			0		
3c. Producers trained on effective bean marketing	0			0			0			0			0		
3c. Producers trained on marketing for new beans products	x	√		x			x			x			0		
3c. Processors/value chain trained to market beans, new products	x	√		x			x			x			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
Training 2 new M.S. (FST and AgEcon) at MAK initiated	0			0			0			0			0		
Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
Training 3 M.S. students at Makerere University completed	0			x			0			0			x		
Training 2 Ph.D. at Iowa State University ongoing	x	√		0			0			0			0		
Inter-organizational learning fostered	x	√		x			x			x			x		
Preliminary results disseminated (conferences, publications, websites)	x	√		x			x			x			x		

Name of the PI reporting on benchmarks by institution	R. Mazur	D. Nakimbigwe	M. Ugen	H.K. Musoke	H. Vasanthakaalam

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

Signature [signature] Date 09/30/10

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

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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

	Iowa State			Makerere			NaCCRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Quality and Yields*														
1a. Meta-analysis report on effect of water & temp. stress on yields	0			0			0			0			0		
1a. Completed experiments on sensitivity of varieties to water stress	0			0			0			0			0		
1a. Documented impact of stress on seed nutrient composition	0			0			0			0			0		
1a. Increased quantities of seed for processing & nutritional studies	0			0			0			0			0		
1a. Manuscripts on physiological studies & meta-analysis completed	x			0			x			0			0		
1a. Collaborative studies initiated, selected stress tolerant varieties	x			0			x			0			0		
1b. Collected and analyzed 2009 yield data	0			0			0			0			0		
1b. Analyzed 2009 seed composition from field trials	0			0			0			0			0		
1b. Document. impacts on quality from improved harvest & storage	0			0			0			0			0		
1b. Conducted 2010 trials using improved production practices	x			0			x			x			0		
1b. Confirmed yield and nutritional profile of priority varieties	x			0			x			0			0		
1b. Provided seed from field trials for analyses in Objective 2	x			0			x			0			0		
1b. Identified agro-ecological regions for using stress tolerance char.	x			0			x			0			0		
1c. Developed materials for post-harvest training	0			0			0			0			0		
1c. Completed farmers' training in pre- and post harvest handling	0			0			x			x			0		
1c. Evaluated influence of innovations on post-harvest losses	x			0			x			x			0		
1d. Farmers/group members trained in research methods	0			0			0			0			0		
1d. Open field days conducted at selected trial sites	0			0			0			0			0		
1d. Farmer knowledge put into practice for field trial	0			0			x			x			0		
1d. Trainee follow-up conducted	0			0			x			x			0		
1d. Recommended research results incorporated into training	0			0			x			x			0		
1d. Field days conducted	0			0			x			x			0		
1d. Results applied to other bean producing districts	0			0			x			x			0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Nutritional analysis of effects of agronomy on harvested beans	x			x	Y		0			0			0		
2a. Analysis of effects of processing on nutrition quality	x			x	Y		0			0			0		
2b. Processing protocol for an extruded bean snack developed	0			0			0			0			0		
2b. Nutritional and sensory characteristics of bean snack optimized	0			0			0			0			0		

2b. Effects of processing on nutritional quality determined	0			0			0			0			0		
2b. Bean flour for soups & porridges produced from extruded flour	x			0			0			0			0		
2b. Effect of bean consumption on human metabolism assessed	x			0			0			0			0		
2c. Protocol for producing bean flour up scaled and refined	0			0			0			0			0		
2c. Recipes using bean flour developed & evaluated in competition	0			0			0			0			0		
2c. Winning recipes promoted in communities	0			x	Y		0			0			x		
2c. Protocol for bean flour-based product developed and optimized	x			x	Y		0			0			x		
2c. Contribution of bean-based products to nutrient intake assessed	x			x	Y		0			0			x		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
3a. Value chain and marketing analyses completed	0			0			0			0			0		
3a. Consumer requir. & market channels for bean flour identified	0			0			0			0			0		
3a. Successful producer marketing strategies identified	0			0			0			0			0		
3a. Market information system improved	x			x	Y		x			x			0		
3a. Farmers/farmer orgs. trained in improved bean marketing	x			x	Y		x			x			0		
3b. Consumer req. & market channels for bean products identified	0			0			0			0			0		
3b. Value of bean vars. and value-added prod. in markets identified	0			0			0			0			0		
3b. Consumer req. for the bean flour-based food determined	x			x	Y		x			x			0		
3b. Farmers & farmer orgs. trained in developing marketing plans	x			x	Y		x			x			0		
3c. Identification of successful marketing approaches	0			0			0			0			0		
3c. Producers trained on effective bean marketing	0			0			0			0			0		
3c. Producers trained on marketing for new beans products	x			x	Y		x			x			0		
3c. Processors/value chain trained to market beans, new products	x			x	Y		x			x			0		
Objective 4	*Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
Training 2 new M.S. (FST and AgEcon) at MAK initiated	0			0	Y		0			0			0		
Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
Training 3 M.S. students at Makerere University completed	0			x	Y		0			0			x		
Training 2 Ph.D. at Iowa State University ongoing	x			0			0			0			0		
Inter-organizational learning fostered	x			x	Y		x			x			x		
Preliminary results disseminated (conferences, publications, websites)	x			x	Y		x			x			x		

Name of the PI reporting on benchmarks by institution	R. Mazur	D. Nakimbugwe	M. Ugen	H.K. Musoke	H. Vasanthakaalam

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

[signature] 30th Sept. 2010

Signature Date

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

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2010 -- September 30, 2010)

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	Abbreviated name of institutions														
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	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	***Improve Bean Quality and Yields***														
1a. Meta-analysis report on effect of water & temp. stress on yields	0			0			0			0			0		
1a. Completed experiments on sensitivity of varieties to water stress	0			0			0			0			0		
1a. Documented impact of stress on seed nutrient composition	0			0			0			0			0		
1a. Increased quantities of seed for processing & nutritional studies	0			0			0			0			0		
1a. Manuscripts on physiological studies & meta-analysis completed	x			0			x	Y		0			0		
1a. Collaborative studies initiated, selected stress tolerant varieties	x			0			x	Y		0			0		
1b. Collected and analyzed 2009 yield data	0			0			0			0			0		
1b. Analyzed 2009 seed composition from field trials	0			0			0			0			0		
1b. Document. impacts on quality from improved harvest & storage	0			0			0			0			0		
1b. Conducted 2010 trials using improved production practices	x			0			x	Y		x			0		
1b. Confirmed yield and nutritional profile of priority varieties	x			0			x	Y		0			0		
1b. Provided seed from field trials for analyses in Objective 2	x			0			x	Y		0			0		
1b. Identified agro-ecological regions for using stress tolerance char.	x			0			x	Y		0			0		
1c. Developed materials for post-harvest training	0			0			0			0			0		
1c. Completed farmers' training in pre- and post harvest handling	0			0			x	Y		x			0		
1c. Evaluated influence of innovations on post-harvest losses	x			0			x	Y		x			0		
1d. Farmers/group members trained in research methods	0			0			0			0			0		
1d. Open field days conducted at selected trial sites	0			0			0			0			0		
1d. Farmer knowledge put into practice for field trial	0			0			x	Y		x			0		
1d. Trainee follow-up conducted	0			0			x	Y		x			0		
1d. Recommended research results incorporated into training	0			0			x	Y		x			0		
1d. Field days conducted	0			0			x	Y		x			0		
1d. Results applied to other bean producing districts	0			0			x	Y		x			0		
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
2a. Nutritional analysis of effects of agronomy on harvested beans	x			x			0			0			0		
2a. Analysis of effects of processing on nutrition quality	x			x			0			0			0		
2b. Processing protocol for an extruded bean snack developed	0			0			0			0			0		
2b. Nutritional and sensory characteristics of bean snack optimized	0			0			0			0			0		

2b. Effects of processing on nutritional quality determined	0			0			0			0			0		
2b. Bean flour for soups & porridges produced from extruded flour	x			0			0			0			0		
2b. Effect of bean consumption on human metabolism assessed	x			0			0			0			0		
2c. Protocol for producing bean flour up scaled and refined	0			0			0			0			0		
2c. Recipes using bean flour developed & evaluated in competition	0			0			0			0			0		
2c. Winning recipes promoted in communities	0			x			0			0			x		
2c. Protocol for bean flour-based product developed and optimized	x			x			0			0			x		
2c. Contribution of bean-based products to nutrient intake assessed	x			x			0			0			x		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
3a. Value chain and marketing analyses completed	0			0			0			0			0		
3a. Consumer requir. & market channels for bean flour identified	0			0			0			0			0		
3a. Successful producer marketing strategies identified	0			0			0			0			0		
3a. Market information system improved	x			x			x	Y		x			0		
3a. Farmers/farmer orgs. trained in improved bean marketing	x			x			x	Y		x			0		
3b. Consumer req. & market channels for bean products identified	0			0			0			0			0		
3b. Value of bean vars. and value-added prod. in markets identified	0			0			0			0			0		
3b. Consumer req. for the bean flour-based food determined	x			x			x	Y		x			0		
3b. Farmers & farmer orgs. trained in developing marketing plans	x			x			x	Y		x			0		
3c. Identification of successful marketing approaches	0			0			0			0			0		
3c. Producers trained on effective bean marketing	0			0			0			0			0		
3c. Producers trained on marketing for new beans products	x			x			x	Y		x			0		
3c. Processors/value chain trained to market beans, new products	x			x			x	Y		x			0		
Objective 4	*Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
Training 2 new M.S. (FST and AgEcon) at MAK initiated	0			0			0			0			0		
Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
Training 3 M.S. students at Makerere University completed	0			x			0			0			x		
Training 2 Ph.D. at Iowa State University ongoing	x			0			0			0			0		
Inter-organizational learning fostered	x			x			x	Y		x			x		
Preliminary results disseminated (conferences, publications, websites)	x			x			x	Y		x			x		

Name of the PI reporting on benchmarks by institution	R. Mazur	D. Nakimbigwe	M. Ugen	H.K. Musoke	H. Vasanthakaalam

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

Signature

Date

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

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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

	Iowa State			Makerere			NaCCRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Quality and Yields*														
1a. Meta-analysis report on effect of water & temp. stress on yields	0			0			0			0			0		
1a. Completed experiments on sensitivity of varieties to water stress	0			0			0			0			0		
1a. Documented impact of stress on seed nutrient composition	0			0			0			0			0		
1a. Increased quantities of seed for processing & nutritional studies	0			0			0			0			0		
1a. Manuscripts on physiological studies & meta-analysis completed	x			0			x			0			0		
1a. Collaborative studies initiated, selected stress tolerant varieties	x			0			x			0			0		
1b. Collected and analyzed 2009 yield data	0			0			0			0			0		
1b. Analyzed 2009 seed composition from field trials	0			0			0			0			0		
1b. Document impacts on quality from improved harvest & storage	0			0			0			0			0		
1b. Conducted 2010 trials using improved production practices	x			0			x			x	√		0		
1b. Confirmed yield and nutritional profile of priority varieties	x			0			x			0			0		
1b. Provided seed from field trials for analyses in Objective 2	x			0			x			0			0		
1b. Identified agro-ecological regions for using stress tolerance char.	x			0			x			0			0		
1c. Developed materials for post-harvest training	0			0			0			0			0		
1c. Completed farmers' training in pre- and post harvest handling	0			0			x			x	√		0		
1c. Evaluated influence of innovations on post-harvest losses	x			0			x			x	√		0		
1d. Farmers/group members trained in research methods	0			0			0			0			0		
1d. Open field days conducted at selected trial sites	0			0			0			0			0		
1d. Farmer knowledge put into practice for field trial	0			0			x			x	√		0		
1d. Trainee follow-up conducted	0			0			x			x	√		0		
1d. Recommended research results incorporated into training	0			0			x			x	√		0		
1d. Field days conducted	0			0			x			x	√		0		
1d. Results applied to other bean producing districts	0			0			x			x	√		0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Nutritional analysis of effects of agronomy on harvested beans	x			x			0			0			0		
2a. Analysis of effects of processing on nutrition quality	x			x			0			0			0		
2b. Processing protocol for an extruded bean snack developed	0			0			0			0			0		
2b. Nutritional and sensory characteristics of bean snack optimized	0			0			0			0			0		

2b. Effects of processing on nutritional quality determined	0			0			0			0			0		
2b. Bean flour for soups & porridges produced from extruded flour	x			0			0			0			0		
2b. Effect of bean consumption on human metabolism assessed	x			0			0			0			0		
2c. Protocol for producing bean flour up scaled and refined	0			0			0			0			0		
2c. Recipes using bean flour developed & evaluated in competition	0			0			0			0			0		
2c. Winning recipes promoted in communities	0			x			0			0			x		
2c. Protocol for bean flour-based product developed and optimized	x			x			0			0			x		
2c. Contribution of bean-based products to nutrient intake assessed	x			x			0			0			x		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
3a. Value chain and marketing analyses completed	0			0			0			0			0		
3a. Consumer requir. & market channels for bean flour identified	0			0			0			0			0		
3a. Successful producer marketing strategies identified	0			0			0			0			0		
3a. Market information system improved	x			x			x			x	√		0		
3a. Farmers/farmer orgs. trained in improved bean marketing	x			x			x			x	√		0		
3b. Consumer req. & market channels for bean products identified	0			0			0			0			0		
3b. Value of bean vars. and value-added prod. in markets identified	0			0			0			0			0		
3b. Consumer req. for the bean flour-based food determined	x			x			x			x	√		0		
3b. Farmers & farmer orgs. trained in developing marketing plans	x			x			x			x	√		0		
3c. Identification of successful marketing approaches	0			0			0			0			0		
3c. Producers trained on effective bean marketing	0			0			0			0			0		
3c. Producers trained on marketing for new beans products	x			x			x			x	√		0		
3c. Processors/value chain trained to market beans, new products	x			x			x			x	√		0		
Objective 4	*Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
Training 2 new M.S. (FST and AgEcon) at MAK initiated	0			0			0			0			0		
Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
Training 3 M.S. students at Makerere University completed	0			x			0			0			x		
Training 2 Ph.D. at Iowa State University ongoing	x			0			0			0			0		
Inter-organizational learning fostered	x			x			x			x	√		x		
Preliminary results disseminated (conferences, publications, websites)	x			x			x			x	√		x		

Name of the PI reporting on benchmarks by institution	R. Mazur	D. Nakimbigwe	M. Ugen	H.K. Musoke	H. Vasanthakaalam

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

Signature

Date: 29/9/2010

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

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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														
	Iowa State			Makerere			NaCCRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Quality and Yields*														
1a. Meta-analysis report on effect of water & temp. stress on yields	0			0			0			0			0		
1a. Completed experiments on sensitivity of varieties to water stress	0			0			0			0			0		
1a. Documented impact of stress on seed nutrient composition	0			0			0			0			0		
1a. Increased quantities of seed for processing & nutritional studies	0			0			0			0			0		
1a. Manuscripts on physiological studies & meta-analysis completed	x			0			x			0			0		
1a. Collaborative studies initiated, selected stress tolerant varieties	x			0			x			0			0		
1b. Collected and analyzed 2009 yield data	0			0			0			0			0		
1b. Analyzed 2009 seed composition from field trials	0			0			0			0			0		
1b. Document. impacts on quality from improved harvest & storage	0			0			0			0			0		
1b. Conducted 2010 trials using improved production practices	x			0			x			x			0		
1b. Confirmed yield and nutritional profile of priority varieties	x			0			x			0			0		
1b. Provided seed from field trials for analyses in Objective 2	x			0			x			0			0		
1b. Identified agro-ecological regions for using stress tolerance char.	x			0			x			0			0		
1c. Developed materials for post-harvest training	0			0			0			0			0		
1c. Completed farmers' training in pre- and post harvest handling	0			0			x			x			0		
1c. Evaluated influence of innovations on post-harvest losses	x			0			x			x			0		
1d. Farmers/group members trained in research methods	0			0			0			0			0		
1d. Open field days conducted at selected trial sites	0			0			0			0			0		
1d. Farmer knowledge put into practice for field trial	0			0			x			x			0		
1d. Trainee follow-up conducted	0			0			x			x			0		
1d. Recommended research results incorporated into training	0			0			x			x			0		
1d. Field days conducted	0			0			x			x			0		
1d. Results applied to other bean producing districts	0			0			x			x			0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Nutritional analysis of effects of agronomy on harvested beans	x			x			0			0			0		
2a. Analysis of effects of processing on nutrition quality	x			x			0			0			0		
2b. Processing protocol for an extruded bean snack developed	0			0			0			0			0		
2b. Nutritional and sensory characteristics of bean snack optimized	0			0			0			0			0		

2b. Effects of processing on nutritional quality determined	0			0			0			0			0		
2b. Bean flour for soups & porridges produced from extruded flour	x			0			0			0			0		
2b. Effect of bean consumption on human metabolism assessed	x			0			0			0			0		
2c. Protocol for producing bean flour up scaled and refined	0			0			0			0			0		
2c. Recipes using bean flour developed & evaluated in competition	0			0			0			0			0		
2c. Winning recipes promoted in communities	0			x			0			0			x	√	
2c. Protocol for bean flour-based product developed and optimized	x			x			0			0			x	√	
2c. Contribution of bean-based products to nutrient intake assessed	x			x			0			0			x	x	x
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
3a. Value chain and marketing analyses completed	0			0			0			0			0		
3a. Consumer requir. & market channels for bean flour identified	0			0			0			0			0		
3a. Successful producer marketing strategies identified	0			0			0			0			0		
3a. Market information system improved	x			x			x			x			0		
3a. Farmers/farmer orgs. trained in improved bean marketing	x			x			x			x			0		
3b. Consumer req. & market channels for bean products identified	0			0			0			0			0		
3b. Value of bean vars. and value-added prod. in markets identified	0			0			0			0			0		
3b. Consumer req. for the bean flour-based food determined	x			x			x			x			0		
3b. Farmers & farmer orgs. trained in developing marketing plans	x			x			x			x			0		
3c. Identification of successful marketing approaches	0			0			0			0			0		
3c. Producers trained on effective bean marketing	0			0			0			0			0		
3c. Producers trained on marketing for new beans products	x			x			x			x			0		
3c. Processors/value chain trained to market beans, new products	x			x			x			x			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
Training 2 new M.S. (FST and AgEcon) at MAK initiated	0			0			0			0			0		
Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
Training 3 M.S. students at Makerere University completed	0			x			0			0			x	x	x
Training 2 Ph.D. at Iowa State University ongoing	x			0			0			0			0		
Inter-organizational learning fostered	x			x			x			x			x	√	
Preliminary results disseminated (conferences, publications, websites)	x			x			x			x			x	√	
Name of the PI reporting on benchmarks by institution	R. Mazur			D. Nakimbigwe			M. Ugen			H.K. Musoke			H. Vasanthakaalam		

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

Hilda Vasanthakaalam (signature) 30/09/10

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
(October 1, 2009 – September 30, 2010)

PERFORMANCE INDICATORS
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	2010 Target (October 1 2009-Sept 30, 2010)	2010 Actual (October 1 2009-Sept 30, 2010)
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	2
Number of men	4	4
Short-term Training: Number of individuals who received short-term training		
Number of women	56	56
Number of men	11	11
Technologies and Policies		
Number of technologies and management practices under research	7	7
Number of technologies and management practices under field testing	4	4
Number of technologies and management practices made available for transfer	3	3
Number of policy studies undertaken	0	0
Beneficiaries:		
Number of rural households benefiting directly	67	67
Number of agricultural firms/enterprises benefiting	2	2
Number of producer and/or community-based organizations receiving technical assistance	14	14
Number of women organizations receiving technical assistance	14	14
Number of HC partner organizations/institutions benefiting	4	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	15	15
Public-Private Sector Partnerships		
Number of public-private sector partnerships formed as a result of USAID assistance	USAID added 09/09	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
Augostine Musoni, ISAR, Rwanda
Eduardo Peralta, INIAP, Ecuador

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

Abstract of Research Achievement and Impacts

The bean breeding program at MSU recently released a new black bean variety Zorro. The variety was the highest yielding black bean grown across six locations in statewide trials in Michigan in 2010. Zorro produced an average yield of 3tons per hectare and top yields exceeded 3.7 tons at two locations. 2010 was the first major production year for Zorro and it would appear to have exceeded expectations of growers in terms of yield, suitability for direct harvest and excellent uniform dry down when mature. In trials conducted by Dr. Abawi at Geneva NY, Zorro had the highest level of resistance to the root rot complex at that location. In 2010, the first vine cranberry bean variety Bellagio was released by MSU. The variety has improved plant structure, uniform maturity, excellent seed quality for canning and resistance to anthracnose and bean common mosaic virus. In statewide trials in 2010 it outperformed the commercial variety Chianti. The program continues to evaluate black, navy, red, pink, pinto, great northern and kidney lines for resistance to common bacterial blight, rust, white mold, virus and anthracnose; and drought tolerance. In 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 two new bean varieties were released to farmers in the Choto Valley. INIAP 481 Rojo del Valle is a large-seeded red mottled type and INIAP 482 AfroAndino is a small black-seeded variety released for canning industry. The varieties were released through the process of evaluation and participatory selection with members of the CIALs in the provinces of Carchi and Imbabura. The program expanded grower participatory variety selection to seven new CIALs in 2010 and continues to refine its non-conventional seed production in the Mira and Chota Valleys with specialized seed growers. Over 17 tons of basic seed of seven varieties was produced for distribution to growers in the region. The expansion of the Portillo red mottled variety into a broad area of the Intag Valley supports the substantial outreach component of the program and the interest and need for new bean varieties in the region. In Rwanda, the breeding dramatically expanded crossing program and successfully produced 24 ton of breeder seed that was distributed to NGO partners who multiplied over 100 tons of bean seed for distribution to farmers in small quantities. Seven climbing bean varieties -for mid to high altitude zones; three semi-climbers and four bush bean varieties-for low to mid altitude zones and one snap bean variety were officially released in 2010.

Project 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 valuable 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 should 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, 2009 - September 30, 2010

Objective 1: Develop through traditional breeding and marker-assisted selection (MAS) in 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. Continue to select parental breeding materials for crossing in Ecuador, Rwanda and U.S.
2. Identify select group of lines from Rwandan breeding for crossing with new introduced differential lines from Ecuador and CIAT.
3. Cross advanced lines back to resistance sources of bean common mosaic virus (BCMV) and angular leaf spot (ALS) to fix resistance which appears to lack stability in Rwanda.
4. Cross Rwandan sources of resistance for ALS, rust, anthracnose, Fusarium wilt and Pythium and major foliar pathogens into large seeded lines with contrasting colors. Confirm resistance of selected parental lines to target root pathogen(s) in a screenhouse/greenhouse test, if needed in Rwanda or at Cornell.
5. Utilize markers in early-generation selection for major disease resistant traits in Ecuador and conduct inheritance studies in the greenhouse for anthracnose in Yunguilla and rust resistance in JE.MA.
6. Initiate marker-assisted selection at one central lab (Ruhengeri) in Rwanda.

7. 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
8. Continue seed increase of most promising lines in all three countries
9. Expand on farm trials with advanced lines in Rwanda and Ecuador
10. Release four climbing beans and four bush bean varieties in three commercial types across agro-ecological zones in Rwanda; and a bush bean variety with broad disease resistance for production in Ecuador

Results, Achievements and Outputs of Research:

- The MSU breeding program released a new vine cranberry bean variety, Bellagio. The plant type is less decumbent than the current vine varieties, and its produces a large (55g) round seed with excellent canning quality. Bellagio is full-season variety with resistance to anthracnose and mosaic virus. The seed type would have commercial appeal in both Ecuador and Rwanda.
- The new black bean variety Zorro was the highest yielding bean grown across six locations in statewide trials in Michigan in 2010. Zorro produced an average yield of 3tons per hectare with top yields exceeded 3.7 tons at two locations. 2010 was the first major production year for Zorro and it would appear to have exceeded expectations of growers in terms of yield, suitability for direct harvest and excellent uniform dry down when mature. Performance and acceptance of new Santa Fe pinto and Fuji tebo bean in different production states in 2010 was encouraging. Approximately 3000 yield trial plots were harvested and 2600 single plant selections were made as part of the MSU breeding program activities in 2010.
- Research continues to develop a stable transformation system for common bean. Progress has been slow and the research is no longer a student project and has been fully assigned to the Plant Transformation Center.
- In Rwanda, 191 crosses multiple crosses were made to improve commercial and new varieties, mostly of the Andean types in diverse seed color types such as G2331 (Yellow) CAB 19 (Navy), Ngwinurare (Red kidney), MAC 9, MAC 44, MAC 49 (Calimas), RWR 1180, RWR 2245 (Red mottles), RWR 1668 (Dark red), CAB 2, Decelaya, MAC 28, RWV 2357, RWV 2070, Gasirida, G2333, RWK 10, UBR 96 and RWV 3006 among others. The full set of differential materials for angular leaf spot, anthracnose, bean rust and BCMV that were received from Ecuador, USA and Puerto Rico were maintained and were used in additional crosses to create new F_1 Andean recombinant populations during 2010 A. The harvested F_1 populations were evaluated and about 100 individual plant selections were made and were advanced for further screening at Rubona site during 2010 B. A total of 130 new crosses were made during 2010B in the Rubona screenhouse to generate 3- and 4-way crosses to incorporate anthracnose in the newly released climbing and bush varieties.
- Selection for micronutrient rich lines from advanced populations (F6 to F8) that were introduced from CIAT continued in 2009A. The parents for the breeding populations included: G14519 * SEL 1416; G 14519 * SEL 1457; G 14519 * CAB 19. All together 282 advanced lines were selected in the three mid or high altitude stations of Rubona (121 lines), Rwerere (107) and Musanze (54 lines). Of these 77 F8 or F9 homozygous lines were introduced into preliminary yield trials, while individual plant selections will be made among the remaining segregating populations in 2010B.

- In the past, the bean program has used the existing rich diversity of bean germplasm and land races in Rwanda in breeding and selection of new varieties such as Ngwinurare (climber) and Urugezi (bush). More recently, Gasilida and Mwirasi are among the landrace varieties that have been released by ISAR. As part of routine collections, 289 local bean accessions were collected across the country during 2009/2010. They were classified by growth habit, seed types as well as by region of adaptation. They were also sent to Waite Analytical Services in Australia for determination of micro-nutrients (Fe and Zn) content. They are being further evaluated for adaptive agronomic traits in different ecologies in the country.
- Under regional and international collaboration, more than 600 breeding or pure lines were received from partner research institutions, notably CIAT Colombia, Ecuador, Puerto Rico and MSU. They represented different market classes (navies, red kidney, red mottles, large white, carioca, zebra) or sources of different constraints (diseases and nutritional deficiencies). The lines were introduced in the breeding scheme under adaptation and yield trials or as donor parents to improve commercial cultivars (Table 1). CIAT also contributed more than 500 new lines, including NUA, NUV, MAC and MAB lines as well advanced breeding populations that were bred for high micronutrients content, BCMV or for adaptability to different agro-ecological regions. Evaluation and selection among the different nurseries is ongoing.
- Two newly released bush bean varieties of red-mottled and black seed types from the bean breeding program in Ecuador were introduced in the advanced yield trial at Nyagatare research station. Approximately 33 advanced lines bred for drought tolerance were received from CIAT for evaluation in drought environment sites at Karama and in Nyagatare this season.
- Following the traditional variety selection scheme, different promising advanced lines were selected from previous trials in 2009B after evaluation in the preliminary, intermediate, advanced and multi-location trials. These include bush and climbing beans in the low (1000 -1400 masl: Nyagatare, Karama and Ngoma), mid (1400 – 1700 m: Rubona, Muhanga, Nyamagabe and Ntendezi) and high altitude (1700 – 2300 masl: Rwerere and Musanze) stations and on-farm zones. 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 for eventual release to farmers.
- By building on the previous breeding work and selection and leveraged funding from the Alliance for a Green Revolution in Africa (AGRA), advanced multi-location yield trials and farmer participatory selection were expanded on a wider scale. The final selection and characterization resulted in the release of 15 new bush, semi climbing, climbing and snap bean varieties. The major achievement was the release of three new climbing and two semi-climbing bean varieties that were earlier maturing and heat tolerant and were adapted to the semi-arid conditions in Nyagatare and Bugesera regions of eastern Rwanda. They were selected from 56 and 41 entries that were introduced from CIAT, respectively. The new climbing varieties (MAC lines) matured earlier relative to the traditional climbers and had mean on-station yields of 3 to 4 tons per hectare and on-farm yields of 2.2-2.5 tons per hectare, ranging in yield from 141-198% over the local checks. The semi-climbers had potential yields of between 2-2.5 ton ha^{-1}, about one-and-half tons more than the local checks.

- The names and characteristics of the 15 new varieties officially released in Rwanda in 2010 are shown on table 1. These included seven climbing bean varieties for mid to high altitude zones; three semi-climbers and four bush bean varieties for low to mid altitude zones and one snap bean variety. The climbing beans MAC 9, MAC 49, MAC 44 are the first climbers developed for mid-low altitude zone and three semi-climbers SER16 and SER 30 are red-seeded, highly efficient early season lines with high levels of drought tolerance; the determinate types have excellent seed characteristics. The new varieties represent a diversity of seed color and with exception of SER lines are mainly from the Andean gene pool.
- In April 2010, the National Program in Ecuador initiated the release of two new bean varieties: red mottled INIAP 481 Rojo del Valle and black seeded variety INIAP 482 Afroandino in the Chota Valley. The varieties were released through the process of evaluation and participatory selection with members of the CIALs in Tumbatú (Carchi) and Juncal (Imbabura). The actual event coincided with the visit to Ecuador of PULSE CRSP scientists from the US, Africa and other LAC countries. A climbing bean type with a cargamento seed type for green shell was also released for the region of Pallatanga.
- The newest red mottled bush bean variety with type II growth habit originates as the breeding line TP6 with the pedigree (SEL1308/*Red Hawk//JeMa/3/*Paragachi). Crossing was initiated at MSU to introduce anthracnose resistance (*Co-4*^{2} gene) into red kidney seed types. In Ecuador the resistant line was further crossed to local varieties JeMa and backcrossed to Paragachi and the TP6 line was identified in 2004. From 2005-07 the line was evaluated at the Tumbaco research farm and was selected for resistance to rust, root rots, yield and seed quality; from 2007-08 the line was evaluated using participatory research in CIALs in the valleys of Chota y Mira (Imbabura y Carchi) where growers recognized its favorable plant vigor, yield and seed quality traits; seed multiplication was initiated in 2008 and in 2010 it was released as the improved variety INIAP-481 known as Rojo del Valle for production as a green shell or dry bean variety. The seed is red mottled with a longer kidney shaped seed. It carries intermediate resistance to rust (3.5 vs. 6.0=S) and high levels of resistance to root rot caused by (*F. oxysporum;* 1.8 vs 7.0=S) which is threatening the expansion of the new stress tolerant Portillo variety into specific production regions. The average yield of Rojo del Valle is 1.8 t/ha over 13 locations compared to 1.2 t/ha for the widely grown parental variety Paragachi.
- The variety INIAP 482 – Afroandino is a small seeded black bean that originates as the CIAT line A55. The line was introduced to Ecuador in 1998 and from 2005-08 was evaluated in Tumbaco for resistance to different root rot diseases (*F. solani* and *F. oxysporum*). In 2008 the line was evaluated by growers in CIALs and chosen for its adaptation, yield and seed quality. In 2010 it was released to growers as the first black bean variety released by INIAP for direct consumption or for use in the local canning industry. The variety is resistant to anthracnose, root rots (2.1 vs 6.1=S), and yield averaged 1.6 t/ha over seven locations compared to 1.3 t/ha for the local check.
- In Ecuador crosses were made using parents principally for rust, anthracnose, angular leaf spot-ALS, and Fusarium wilt caused by *Fusarium oxysporum.* Sources of resistance came from both gene pools that have been previously evaluated to confirm resistance. These include most of the anthracnose resistance genes from the

differential series, rust genes including Ur-11 and Ur-13 and sources for resistance to wilt in which the genes have not been characterized. In the second cycle these F1 were used to make 3-way crosses with commercial varieties like INIAP Concepción, INIAP Portilla, TRM1 y RMC 59. In the same cycle F1 from crosses for resistance to Fusarium wilt were selfed and single plant selections were made in the F2. Resistance sources included RMC 27, RMC 20 y TP6, and were combined with susceptible commercial varieties, Portilla, Concepción and INIAP Paragachi Andino. In addition 19 new single crosses were made with resistance sources for rust, ALS and anthracnose to genotypes with commercial seed types, red mottled solid reds, whites and pink mottles known as Uribe types. Crosses were also made to study the inheritance of rust and anthracnose in local varieties Je.Ma, Portillo and Yunguilla. The first materials with resistance to all three major diseases (rust, anthracnose and angular leaf spot) have been identified.

- Seed increases were initiated on the research farm at Tumbaco of promising lines RMA 26, RMC 59, (Yunguilla x POA 10)-3, ARME2 and Concepción x (G916 x Concepción)-1. Further increases were made in the Intag Valley of two lines Concepción*/G916-1 and ARME2 selected through participatory research program. Future increases of these lines are planned in the Intag Valley with the intention that they be released as new varieties in this production region. In June 2010 100 kg of seed of Portilla, 45 kg of INIAP Rocha and 20 kg of Paragachi Andino were planted with CIAL in Pallatanga (Chimborazo) to increase seed of these new varieties in this important production region.
- In the first cycle of 2009-2010, field studies were planted in six new CIALs to test new materials in different seed types, red mottled, White, yellow, red kidney and blacks. Selected of the best adapted materials was made with members of the CIALs. Selection parameters included plant vigor, yield and seed quality. Selection was continued for the same traits in the next growing cycle.

Objective 2: Develop inbred backcross lines 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. Evaluate specific populations at two sites for reaction to drought and non-stress in Rwanda
3. Advance other IBL populations with specific drought and root rot resistance traits that are under development.
4. Evaluate sub-set of best drought tolerant lines from thesis study of Louis Butare at two locations in Rwanda.
5. Complete characterization of 141 new local traditional lines (bush, climbers) collected from growers in Ecuador to determine level of drought tolerance under rainfed conditions in highlands.
6. Preliminary characterization and seed multiplication of 90 accessions (bush, climbers) collected in province of Bolivar, Ecuador.
7. Trials will be conducted for root rot resistance sources in Ecuador each season and

8. Validation studies will be conducted of markers linked to sources of root rot resistance and drought tolerance.
9. Identify field site for root rot evaluation (Pythium, Fusarium wilt and Macrophomina), and initiate screening of promising germplasm in Rwanda. Field identification will be accomplished by surveys or bioassay of soil samples with beans (known to be susceptible to target pathogens) in greenhouse/screenhouse tests.
10. Characterize germplasm for reaction to individual root pathogens at Cornell using selected promising germplasm for Rwanda and Ecuador.

Results, Achievements and Outputs of Research:

- During this year, 137 inter gene pool Recombinant Inbred Lines (RILs) from a cross between SEA 5 (Middle American gene pool) and CAL 96 (Andean gene pool) were sent to Rwanda for future field studies. The population was obtained from CIAT for QTL study of drought resistance in Rwanda and will be part of the doctoral studies of Gerardine Mukeshimana. This population will be evaluated under both irrigated and no irrigated conditions in Rwanda starting in early 2011. Currently, genotyping of the parental lines with SSR markers has been initiated. To date, 268 SSR primers were run on the parents SEA5 and CAL 96 of which 103 (39%) showed polymorphisms between the two parents.
- Preliminary and on-farm participatory trials evaluation and selection identified small red seeded SER 12, SER 13, SER 14, SER 16, and SER 30 lines were among the new bush types well adapated to the semi-arid conditions of Umutara and Bugesera zones of eastern Rwanda. Their potential yields range from 2.0 to 2.5 ton per ha. The small red seed types are associated with good taste and red broth color, important in mixed diets with tubers and cereals. The variety SER 16 was the most appreciated by both the male and female participating farmers, traders and consumers. It was released as ISAR-SCB-101, while SER 30 was released as ISAR-SCB-102 (Table 1).
- Greenhouse experiments at MSU were conducted by Gerardine Mukeshimana to identify bean lines with higher levels of drought tolerance. Eight cultivars will varying levels of drought tolerance were tested in the study. These included Blackhawk, Jaguar, Phantom, Zorro, TARS-SR05, L88-63, and B98311, and RAB651. Three experiments were conducted in 9-cm square plastic pots in the greenhouse where moisture is withheld. Since the root is constrained in this system, we were able to investigate shoot mechanisms underlying drought resistance in bean seedlings. Various variables including wilting, leaf abscission, maintenance of stem greenness, recovery after resuming irrigation, pod number yield, and biomass were recorded. For wilting, leaf abscission, and stem greenness traits, the cultivar Jaguar showed less wilting as well as less leaf senescence and stem greenness followed by Phantom in all cases. Cultivar B98311 which has a deep tap root that sustains it through intermittent droughts was the more susceptible in this study based on the above variables. The capacity of seedlings to set pods after the recovery from the drought was determined. Cultivars Jaguar, Phantom, and Blackhawk did not show any difference in pod number under both stress and no stress while Jaguar and TARS-SR05 did not show a significant loss of biomass under both treatments. It is hoped to better separate root and foliage responses to drought so that these can be combined into a single cultivar to further enhance tolerance to drought.

- An attempt to increase seed of the mapping population (CONCEPCIÓN * 2/RAB651) in Michigan was moderately successful in 2010, due to problems with photoperiodism. The population will be evaluated under moisture stress in Rwanda in 2011 to identify QTL for drought tolerance. Meanwhile, genotyping of the parental lines with SSR markers continues.
- Replicated field evaluation trials consisting of a total of 40 bean materials were established in the experimental bean root rot field at the Vegetable Research Farm of the NYSAES near Geneva, NY. Twenty six of the entries came from MSU, whereas the other 14 entries were selected from the 2009 bean evaluation trials conducted at the same location with bean germplasm provided by Drs. Porch, USDA/P.R. and Kelly, MSU; and the NY bean Breeding Program. Root rot development was only moderate due to the dry and warm weather conditions that prevailed during the early part of the 2010 season. However, the tested materials differed considerably in their reaction to root rot diseases that prevailed at this location, primarily those caused by *Fusarium solani* f. sp. *phaseoli*, *Pythium ultimum* and *Rhizoctonia solani*. Root rot severity rating ranged from 3.1 (Zorro) to 5.3 (Red Hawk) on a scale of 1 (no disease symptoms observed, healthy) to 9 (most severe symptoms with roots at a late stage of decay). Among the other bean materials with root rot severity score <4.0 were MSU breeding lines #P07863, R08516, S08419, B09175, and B09135. In addition, a severe epidemic development of common bacterial blight occurred naturally at this location. MSU line #B09135 exhibited an immune reaction (a rating of 1 on a 1 to 9 scale), whereas B09197, P07863, R09508, K08222, and N09056 were among the most tolerant (a rating score <3.0). In contrast, great northern breeding lines #G08263, G08256, G09320 were among the most susceptible (a rating > 7.0). Among the materials selected from the 2009 trial, the bean line code 16 (P.R. #TARS09-PR016) had the lowest root rot rating (a score of 3.3) and exhibited an immune reaction to CBB. Only a low incidence of Bean Yellow Mosaic Virus was observed in 2010, in contrast to the severe infection of several viruses that occurred in 2009 at the same location.
- Other activities include greenhouse test to characterize selected bean lines/germplasm for reaction to Cucumber Mosaic Virus (CMV). The work conducted collaboratively with Dr. Marc Fucks and a total of 15 lines were the most tolerant, as they exhibited mild mosaic symptoms and/or yellowing in comparison to the susceptible checks (CLRK and Hystyle). In addition, three greenhouse tests were conducted to determine the most effective inoculum pressure for assessing the reaction of promising bean germplasm against infections by *Rhizoctonia solani* (Rs). Pinto Zapata and Cornell’s 2114-12 have exhibited the highest tolerance to Rs in these tests. This work is on going with large number of promising lines of various seed types. Finally, we are currently testing a modification of a protocol for assessing the reaction of bean lines to infection by the Fusarium-wilt pathogen, *Fusarium oxysporum* f. sp. *phaseoli*. Two weeks after inoculation in an ongoing test, only Montcalm and BAT 477 showed a susceptible reaction, whereas all other materials included (Fanesquero Blanco, Paragachi, A 211, Black Turtle 03T-3092, Red Kanner, Pink Panther, Concepcion, Je.Ma. and Caprice) have exhibited no disease symptoms. This information will be provided to the program in Ecuador to assist them in their screening efforts of resistance to Fusarium wilt.

- Other research projects on beans being conducted by Dr. Abawi include the effect of reduced tillage (zone-till vs. plow-till) on dry bean yield and root rot severity; prioritizing cover crops for improving root health and yield of vegetables using beans as the bioassay crop. Average yield of beans was highest in the field with the highest soil health parameters and the lowest root rot severity ratings. The cover crop treatments also greatly affected root rot severity development and yield of beans, but varied among the four fields. However, yield of beans was lowest and root rot severity ratings were highest in plots with buckwheat as the cover crop. Root rot severity ratings were also high in plots planted to cover crops of red clover, forage radish and rapeseed in all fields. The cover crop treatments were re-established in the same plots in late August – early September 2010 for another cycle of evaluation in 2011.
- In Ecuador drought tolerance from the best Middle American sources L88-63 black and RAB651 red lines, was introgressed into six inbred backcross IBL F8 lines from this program. White, yellow (canario) and red mottled seed types were selected under conditions of terminal drought at the research farm in Tumbaco. In the same cycle 44 RILs with potential resistance to root rots were evaluated and 13 lines were selected for drought tolerance, yield and seed quality in red mottled types. In the second cycle (Jan-2010) the same lines were evaluated under terminal drought and seven high-yielding lines were identified with resistance to rust superior to Portillo and Concepcion check varieties.
- In the earlier cycle (Oct 2009-Jan 2010), a group of 123 F_2 and F_3 black-seeded types were planted as plant rows. At maturity 53 lines were selected for drought tolerance and yield. The lines were further evaluated with an addition 23 lines from Honduras for yield and drought tolerance and a total of 16 lines were selected. In the March-June 2010 cycle, 20 lines were evaluated for resistance to *F. oxysporum* at the Tumbaco station. Seven lines were resistance and 14 were susceptible in pathogen infested soil.
- Eighteen cranberry lines developed at MSU were evaluated for resistance to *F. solani* in the greenhouse at the Santa Catalina station. The lines were developed from inbred backcross population where Negro San Luis black bean was the donor parent. Only one line C03108 was resistant along with NSL parent and Negro Bola Pallatanga. This represents a major advance as the resistance was effectively moved from small-seeded black bean to larger seeded cranberry bean.

Objective 3: 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. The survey will be expanded to western production region. These surveys will be continued throughout 2009 and completed in 2010.
2. In Ecuador complete characterization of root rot isolates collected previously in both Northern and Southern production regions at Cornell and/or Ecuador, following discussion among collaborators during a visit in 2009.

3. Access potential for germplasm/root rot isolate interactions in greenhouse at Cornell.
4. Phenotypic evaluation of Rwandan germplasm for resistance to root rot(s); and local isolates of anthracnose, ALS and BCMV.
5. Continue the collection of isolates of anthracnose, and ALS in Rwanda and Ecuador from diverse agro-ecological zones for race typing
6. Initiate genetic characterization/race typing of rust, ALS and anthracnose isolates and maintain and increase seed of the differentials for anthracnose, ALS and rust in Rwanda; and initiate characterization of ALS in Ecuador. In addition, race characterization of Fusarium wilt pathogen and the aggressiveness of isolates of Macrophomina, Rhizoctonia, and F. solani will be conducted on selected bean germplasm.
7. In Rwanda, plan to document and summarize past studies on mapping and/or variability of Fusarium wilt, Pythium, ALS, anthracnose by CIAT/ISAR and MS theses since many of the studies are in French.
8. Continue to document and publish results of recent and on-going breeding activities in Rwanda.

Results, Achievements and Outputs of Research:

- Anthracnose was a problem in Michigan in 2010. Isolates were collected from growers' fields and all typed out as race 73. Adequate levels of resistance to this MA race are present in current cultivars, but 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, but it was more widespread and severe in 2010. The strain is similar to that collected over the last three seasons. The new strain characterized as race 22-2 defeats many of the current resistance genes deployed in MI. A similar race 20-3 was recently detected in North Dakota. Resistance has been identified in elite MSU black and navy bean germplasm and crossing has been initiated to transfer resistance. Given the persistence of this race an extensive screening of all MSU germplasm is being conducted in the greenhouse this winter.
- The collection of new samples of leaves, roots infected with major pathogens (angular leaf spot, bean rust and anthracnose) has been a continuous activity in Rwanda since 2009. This activity has been ongoing mainly in the east and southern Rwanda. Fresh and more extensive sample collection is expected in the current season and their characterization by conventional and molecular means is planned in collaboration with MSU and Cornell.
- Fusarium wilt is becoming increasingly serious disease in many bean production areas of Ecuador. In addition some of the most recently released varieties have proven to be susceptible to the disease in certain localities. The program initiated the collection of isolates of *Fusarium oxysporum* in the localities de Urcuquí, Pablo Arenas and Intag. Some of these isolates did not prove to be pathogenic so additional collections will be made in order to have a virulent isolate for greenhouse screening. Dr. Abawi is assisting the local pathologist with the process of isolate identification and screening methodologies, as field screening at Tumbaco is limited to specific region of the farm where the pathogen currently is localized.

- Four new races of anthracnose (293, 261, 391 and 389) from five samples collected in the localities of Caldera, Pallatanga, Urcuquí and the research farm in Tumbaco. Eleven monosporic isolates of ALS previously collected and stored back in 2004 were revived and lyophilized again for long term storage.
- Efforts were made to develop and standardize inoculation methods for screening for ALS using detached trifoliate leaves in Petri dish. Symptoms develop in 15 days after inoculation compared to delayed symptoms of 30 days on the intact plant. In order to standardize the protocol advanced lines with known resistance were inoculated to test the protocol. Additional work is needed to satisfactorily standardize the method which shows considerable promise for saving both time and resources.

Objective 4: Employ participatory plant breeding and agroecological methods to assist the breeding process in Ecuador and Rwanda to enhance productivity and market quality of beans under development.

Approaches and Methods:

1. Design and validate sustainable farming practices including integrated crop management systems for smallholder farmers in Rwanda. Prepare and distribute a report by the end of 2009 on the cropping system survey and literature review outputs from prior workplan, as a foundation for participatory on-farm bean cropping system assessment.
2. Compare and contrast advanced line selection practiced by breeders and farmers in mid-altitude and high agroecological regions in Rwanda
    - Plan genotype by environment farmer participatory assessment of advanced lines within intercrops and sole crops, start planning in October, 2009.
    - On-farm assessment at pilot basis start during main growing season of 2009 with baseline and set up of one set of station and on-farm trials for first season in 2010, expanded on-farm trials in September 2010
3. Evaluation of 12 tests with 10 CIALs each growing cycle in Ecuador.
4. Strengthen non-conventional seed production in Ecuador and both conventional and non-conventional seed production in Rwanda.
5. Release one bush bean and one climbing bean in Ecuador using farmer participatory approach.
6. Evaluate both in field and lab promising lines suited for canning (processing) in Ecuador.
7. Organize a visit of scientists from Rwanda to Ecuador to interchange experiences on population management, germplasm bank, evaluation of early generation materials at different stations; interchange of experience on farmer participatory and seed production for local use by small farmers and members of CIALs in Choto and Mira valleys.
8. Initiate interchange of experience in Rwanda on participatory methods and seed production for local community use with smallholder farmer members anticipated date August 2010. Training of trainers (extension, research technicians, NGO staff, expert farmers, seed company technicians) on seed and farming system production, and work with progressive farmers. This activity will be coordinated with root health workshop planned for late 2010.

Results, Achievements and Outputs of Research

- Several on-farm sites were planted to demonstrate the performance of improved varieties versus the local ones in Rwanda. In particular, trials were conducted on the effect of different combinations of fertilizers on yield of an improved variety, RWR 1668 and a local mixed variety (LM – Local Mixture) at nine locations Cyabayaga; Gakirage and Rukomo in the Nyagatare district where livestock farming is common. Farmers toured the sites and rated the performance of the varieties under the different treatments. Overall, combinations of organic (farm yard manure-FYM) and inorganic (NPK) amendments produced the best effects. Improved variety RWR 1668 had better yield than the check local variety across sites and fertilizer treatments.
- In each of the last two growing seasons at least 10 tons of breeder and pre-basic seed of old, pre-released and released bush or climbing bean varieties were produced on different research stations. In 2010B alone, 13.9 tons of seed was produced in seven stations. Climbing beans were mainly multiplied in the north and south of the country. While the bush beans dominated in numbers, there was deliberate effort to promote the new heat tolerant climbing bean varieties in the East. Seed was sold and distributed to farmers and farmer's cooperatives; NGOs such as ADRA and to RWASECO, IMBARAGA, DERN, COAMV, RADA partners for secondary seed multiplication and distribution to more farmers. Under this arrangement, more than 100 tons of basic and certified seed was produced by these partners and thousands of households were expected to be reached under the strategy of small seed packages (0.5 kg, 1.0 kg, 2kg, 5, 10, 50 kg) for distribution.
- Evaluation and participatory selection of bush bean germplasm with local CIALs continued in Ecuador. In the two growing cycles different colored breeding lines were evaluated in six new CIALs in the Salinas and Choto valleys. During the same two growing cycles at the end of 2009 and beginning of 2010, over 17 ton of seed of the following bush bean varieties, Portilla, Rojo del Valle, Rocha, Canario de Choto, Afroandino, Concepción, and Paragachi Andino was multiplied by eight specialized seed growers in CIALs in the Choto and Mira Valleys.
- In a new CIAL in the Mira Valley, four red kidney beans and six black bean varieties were planted with the intention of providing beans for industrial canning market. The farmers selected BRB 195 and DRK 105 red kidney types and three black bean lines G21212, L88-63 and Negro San Luis. These lines will continue to be tested to confirm their suitability to this region and their potential for the canning industry. This work is being conducted in the nutrition lab at Santa Catalina where preliminary canning tests are being conducted on the suitability of five red kidney, five black and two canario (yellow) lines for canning.
- In June 2010, 14 bean producers and members of the CIAL's of Urcuquí and Pablo arenas del Valle de Salinas visited the research farm at Tumbaco to see the research plots, and seed production lots of basic seed of new varieties.

<u>Objective 4</u>: 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) During May 2010, Gerardine was invited to attend a workshop at CIAT and she spent additional time at CIAT visiting scientists and becoming familiar with research programs. In July she attended a workshop on breeding for drought tolerance at Colorado State University. She is currently preparing for her comprehensive examination in December 2010. Upon the successful completion of that examination she will go to Rwanda in January 2011 to initiate field studies.
- 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. Krista Isaacs is in similar stage in her studies as Gerardine- preparing for her comprehensive examination. Since she secured a Fulbright Fellowship to work in Rwanda so she has been required to take a course and tutoring in Kinyarwanda language, which has been time consuming. Upon the successful completion of that examination she will go to Rwanda in January to initiate field studies based on findings from a prior visit to Rwanda in 2009 as part of pre-dissertation grant.
- Louis Butare returned from PhD training and assumed new leadership of the project in Rwanda. Augustine Musoni, the co-investigator in Rwanda attended two short course training workshops on Scientific Writing and Publications (July, 2010) and Statistical Analysis using R software package (October, 2010) under ASARECA support.

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 and again in 2010.

Networking and Linkages with Stakeholders

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

- The project also forged closer collaboration with Kigali Institute of Science and Technology (KIST). ISAR provided KIST with four additional newly released varieties for post harvest and processing studies under CRSP MSU/ISU collaboration. In the current October - December quarter, ISAR is providing additional 10 new varieties to assess the nutritional and culinary traits. This is intended to build synergy between the KIST lead PULSES CRSP ISU and the current project in integrating agronomic and market traits with the nutritional and quality attributes of new bean varieties released and being developed by ISAR.
- The program shared sets of elite bush and climbing bean lines including RWR 2244, BOA 5-7, RWK10, RWR 2340, RWR 2372, RWR 2091 and RWR3042 with the national bean research program in Burundi (ISABU). Two of these varieties: RWR2091 and RWR2244 were selected by local farmers.
- The project leaders in Rwanda (Louis Butare and Augustine Musoni) attended and gained valuable contacts at the Pulses CRSP Global Meeting that was held in Quito, Ecuador in April, 2010. In addition, Augustine Musoni attended the first AGRA General Meeting that was held in Bamako, Mali in October, 2009.
- Two seminars were organized in Bujumbura (April) and in Serena Hotel in Rwanda (June) bringing together all actors in the research, training (University of Rwanda) and seed chain (NGOs, seed companies, private) in Burundi and Rwanda, and in Rwanda respectively. Mutual action plan for seed production and dissemination were made and is currently being implemented by all the partners.
- Five posters and more than 500 brochures, technical notes were made and were used to disseminate information about varieties and integrated agronomic management practices. A technical booklet was written in English and translated into the local Kinyarwanda language for mass production and distribution to farmers. National, regional and international press was used to disseminate information about new varieties that were released in January, 2010. Radio, television broadcasts were also used.
- The program interacts with the following NGOs in Ecuador; PRODECI, PRODER, CRUZ ROJA, Agricultural Organizations; COPCAVIC, 10 CIALs, Grupo de Evaluadores de Frijol de Bolivar, Assoc. de Productores de Frejol de INTAG. Government Organizations; MAGAP, INIAP, Univ. Tecnia del Norte, and Univ. Catolica de Ibarra.
- The INIAP bean program hosted international PULSE CRSP meeting in Quito in April 2010 where scientists from the US, LAC and Africa participated. The group attended field day at El Bermejal in the Chota Valley and participated in the release of two new bean varieties, red mottled and black seeded types developed through the CRSP project.
- J. Kelly and G. Abawi participated in the PULSE CRSP meeting in Ecuador. Both Kelly and Abawi returned to Ecuador in June 2010 to visit new CIALs and trials in two new regions in the Salinas and Intag Valleys.

Leveraged Funds

- In addition to the government, bean breeding research funds are principally leveraged from AGRA, The Alliance for a Green Revolution in Africa. The Bill and Melinda

Gates Foundation (B&MGF) through CIAT funds the Bean Biofortification Project. Others are The Association for Strengthening Agriculture Research in East and Central Africa (ASARECA) and The Pan African Bean Research Alliance (PABRA). More prospects of funding research and dissemination are underway under AGRA, ASARECA, B&MGF and COMESA under institutional and regional projects arrangements.

- 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 in 2008 but due to the global recession, funding has been rescinded.

List of Publications

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

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

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

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

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

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

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

Professional Recognition, Awards and Accomplishments

Dr. Sieglinde Snapp was recognized as Fellow of the American Society of Agronomy – 2010.

Target Outputs

1. The development and release of locally adapted, acceptable and disease resistant bean cultivars for the major production regions in Rwanda, Ecuador and Michigan.
2. Increased sustainable productivity and profitability of bean production due to increased yield and reduced inputs.
3. Improved grower income and stability of bean production will contribute to better nutrition and health of farm families.
4. 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.
5. Identification of germplasm sources that are of benefit in the improvement of selected bean traits for the U.S. market.
6. Enhanced human resource development, gender equity and improved infrastructure capacity of participating institutions in Rwanda and Ecuador.

Tables Cited

Table 1. High yielding climbing and bush beans varieties released by ISAR bean program in January 2010.

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

CB = Climbing; SCB = Semiclimbing; BB = Bush; SB = Snap bean varieties

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period:September 1, 2009 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

Project Title: Combining Conventional, Molecular and Farmer Participatory Breeding Approaches to Improve Andean Beans

	Abbreviated name of institutions											
	MSU			Cornell			Ecuador			Rwanda		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	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	
Variety Release	x	x					x	x		x	x	
Objective 2												
Advanced Population development	x	x					x	x				
Test Populations in Rwanda										x	x	
Other population development	x	x					x	x			x	
Characterize CIAT resistance sources							x	x		x		x
Increase, characterize local germplasm							x	x			x	

Characterize germplasm to root pathogens	x	x		x	x		x	x		x		x
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			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	Louis Butare

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

James D. Kelly (signature) 10/1/2010

Signature **Date**

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

MSU:Trip to Rwanda was delayed to later in 2010, so no pathogen collections were made prior to 9/10.

Cornell: The trip to Rwanda was delayed, but the survey of root pathogens and the work on race characterization will be include on the agenda of the up-coming trip.

Ecuador: Due to changes in technical staff, work on markers assisted selection was not pursued. Less activity on root pathogens, new screening methods are being tested

Rwanda: ISAR is acquiring equipment to conduct marker assisted selection, work is expected to be initiated in 2011.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(April 1, 2008 – September 30, 2012)

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	2010 Target (Oct 1 2009-Sept 30, 2010)	2010 Actual		
Degree Training: Number of individuals who have received degree training				
Number of women	2	2		
Number of men	1	0		
Short-term Training: Number of individuals who have received short-term training				
Number of women	2	0		
Number of men	2	2		
Technologies and Policies				
Number of technologies and management practices under research	19	17		
Number of technologies and management practices under field testing	10	11		
Number of technologies and management practices made available for transfer	11	8		
Number of policy studies undertaken				
Beneficiaries				
Number of rural households benefiting directly	8000	10500		
Number of agricultural firms/enterprises benefiting	20	12		
Number of producer and/or community-based organizations receiving technical assistance	75	61		
Number of women organizations receiving technical assistance	13	21		
Number of HC partner organizations/institutions benefitir	38	30		
Developmental outcomes:				
Number of additional hectares under improved technologies or management practices	16000	18200		

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

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. MS student Chaves' visits to Luanda's market are pending his field research in 2011. Chaves' U. Vicosa advisor recommended more time for studies before he develops a thesis proposal. World Vision will provide price data for beans in the Planalto. A national parastatal marketing chain has been identified as a buyer of local beans with expansion potential. Two UAN students, who conducted surveys in 2 zones of Huambo Province to better understand smallholder production/marketing systems, completed their thesis--based on interviews with traders/farmers. The baseline document from the small holder survey with World Vision ProRenda project was finalized and results were presented to stakeholders & USAID. About 60% of households produce beans--almost none cultivate cowpeas. Beans are a major income source for farmers in the ProRenda target zones. Donovan conducted a class on agricultural policies, focusing on price policy for 35 UAN undergraduates/faculty.

Mozambique. Traders visited during the Windshield market information survey indicated higher use of cell phones, less waiting time for transit & demand for 24-hour bank machines. A preliminary bean/cowpea report was drafted, but will be revised to incorporate maps based on recent GIS training/price analysis. CRSP researchers were unable to bring together the stakeholders Task Force, but this is a key objective for 2011. The SABREN & PSU projects have been contacted about collaborating with MSU. The MS student's U Pretoria advisors requested delaying developing her research proposal until she completes research methods/econometrics courses. The 2002-2008 TIA (household) data are available. Combined with information from rapid appraisals & price data collected through the market information system (SIMA), the student will have access to an excellent data set. SIMA data continue to be collected weekly for beans & cowpeas.

Honduras. The project was refocused to produce third party certified fairtrade (FT) beans. Whole Foods Market prefers FT certification via IMO and agreed to buy 20 mt of beans for delivery in late 2011. Based on the results of ECOFRIJO trials (organic vs. conventional beans), CIALs from Yojoa Lake implemented organic fertilizer production. While the trial results varied, organic practices are a good option—given increasing input

costs & similar yields. Organic fertilizer was produced using compost and/or bokashi techniques. Practices to control diseases/insects are being used by these farmers. Previously, 2 farmer groups expressed interest in organic bean production. Both groups participated in training activities & the ECOFRIJOL trial, but during the current year we continued to interact only with the Yojoa Lake CIALs. Data were collected to estimate the supply-chain related costs for marketing beans. We determined that the farmer association is able to process the beans and a broker has agreed to provide export-related services.

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

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 opportunities 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.

<u>Angola.</u> 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, although 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 (small reds) to the US market.

Planned Project Activities for April 1, 2009 - September 30, 2010

Objective 1: Angola - This project component has 3sub-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: Summarize secondary data on bean/cowpea production and marketing, including the identification of gaps to guide future research. Visit key informants to identify information and data sources.

Objective 1.2: Identify production areas, marketing channels, and marketing margins/value chain diagnosis and capacity building. 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: Identify constraints, opportunities, and potential pilot interventions to improve competitiveness/Conduct smallholder survey.

Undertake a smallholder survey under the World Vision Smallholder Horticultural Value Chain Development project. The survey included 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: Summarize secondary data on bean/cowpea production and marketing, including the identification of gaps to guide future research. Market visits in Luanda for the major consumption market are pending Chavez's field research in 2011. World Vision will provide price data for common beans in the Planalto, but there is no price dataset for cowpeas in the country. The national parastatal marketing chain Nosso Supermercado has been identified as a buyer of local beans with expansion potential.

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

The MS thesis proposal of Chaves has yet to be developed for his program at the University of Vicosa. His advisors recommended greater time be allowed for studies before developing the thesis. While not ideal, we respect his professors' assessment in Brazil.

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

About 60 percent of the households in the zones under study produce common beans, but almost no households cultivate cowpeas, according to the survey. Common beans are a major income source for farmers in the ProRenda target zones. Women farmers tend to get higher prices for the beans that they sell, resulting in higher total revenues, even though they produced an average of only 112 kilograms, selling 75% of production compared to 314 kilograms produced among males, and 86% is sold. The basic results of the survey were also discussed with USAID colleagues when Donovan was in Luanda with Kiala.

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. Their research results are briefly discussed above. The CRSP funded their field research through funds to UAN. As an additional training activity during July 2010 travel to Angola, Donovan conducted a class on agricultural policies, focusing on price policy for 35 undergraduates and faculty at UAN in Chianga.

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: Capacity building with MS student undertaking econometric analysis of the determinants of market participation by producing households, including sex of household head as an explanatory variable.

Approaches and Methods:
Objective 2.1: Analyze spatial and temporal patterns of bean/cowpea production and marketing, using national survey data (TIA), disaggregated by gender. 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: 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. 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: Capacity building with MS student undertaking econometric analysis of the determinants of market participation by producing households, including sex of household head as an explanatory variable. 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: Analyze spatial and temporal patterns of bean/cowpea production and marketing, using national survey data (TIA), disaggregated by gender.

Key market traders were visited again during the Windshield survey of the market information system in 2010, but no special bean/cowpea section was added to the survey this time. The Windshield survey indicated higher use of cell phones by all traders, less waiting time for transit, and continued demand for 24-hour bank machines, compared to the 2008 survey.

Use of the Ministry of Agriculture TIA data has enabled researchers to have a secondary database across the years of survey which is representative down to the Provincial level. A preliminary bean/cowpea report has been drafted, but will be revised by SABREN collaborator Alda Tomo, incorporating maps based on a recent GIS training and price analysis. The SIMA price data analysis is included in the report, as the data are already compiled for the various markets. Both TIA and SIMA datasets are public access datasets and are available to bean and cowpea researchers upon request.

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

As has been noted before, stakeholders in Mozambique are more likely to organize around concrete substance, such as varietal release, market information, and policy decisionmaking. In 2009/2010, the Pulse CRSP researchers were not able to bring the stakeholders together. This objective, including the Task Force implementation, remains a key one for all the parties involved, and with the increasing emphasis on value chains, in part due to Pulse CRSP Value Chain training in 2009, the Bean/Cowpea Task Force will be convened in early 2011. The SABREN and Penn State Pulse projects have both been contacted about collaborating to move this forward, with the MSU project.

Objective 2.3: Capacity building with MS student undertaking econometric analysis of the determinants of market participation by producing households, including sex of household head as an explanatory variable

The MS student was delayed in her studies at the University of Pretoria, and is only now developing the analytical skills necessary to conduct the econometric analysis. As is the case of Chaves in Brazil, her advisors have requested that the development of the research proposal await her completion of the research methods and econometrics courses in early 2011. Donovan met with one of her research advisors in September 2010 and confirmed that they will be incorporating Mozambican bean/cowpeas research into her plan. The 2002-2008 TIA (household) data are available and combined with information from rapid appraisals and the price data collected through the market information system, SIMA, she will has an excellent set of data for her research. The SIMA data continue to be collected on a weekly basis in several relevant markets for common beans and cowpeas, and so the dataset evolves.

Objective 3: Honduras. This project component has 4 sub-objectives for this period. The sub-objectives in the current workplan are to: 3.1) put in place arrangements for exporting small-red beans from Honduras to US retailers, which are certified as organic and produced using sustainable production practices: 3.2) validate via field trails existing agronomic recommendations for growing organic small-red beans; 3.3) recruit interested smallholders and train the farmers to produce organic small-red beans that meet the grades and standards required by US retailers; 3.4) establish local market linkages required for small-scale small-red bean farmers to export organic/sustainably-produced beans to US markets.

Available evidence indicates that there is a demand for fair trade, organic small beans in the US. A recent study (DeVilla, Lara. 2008. "Assessing the Potential of Marketing air Trade Beans of Central American Origin in the United States". Unpublished MS. Thesis, Department of Agricultural Economics, Michigan State University, East Lansing, MI) found that there was considerable interest among US retailers (who market organic/ethical food product) in purchasing/selling fair trade organic small-red beans. Regarding the capacity of Honduran bean-farmers to supply the demand of this market, at meetings in 2008 and 2009, leaders and farmer-members of the cooperative ARSAGRO expressed strong interest in growing small-red beans for export to the US, which met USDA organic and Rainforest Alliance standards for sustainably produced/fair trade beans. Currently, approximately 500 members of this cooperative plants over 1,000 hectares of beans in the Primera season. Supplying the initially projected export quantity of 20 mt of small-red beans would require the participation of only 20-30 farmers.

Approaches and Methods: *Objective 3.1:* Put in place arrangements for exporting beans from Honduras to US retailers. Contact US retailers to confirm their interest in purchasing beans from Honduras, possibly visiting selected forms to negotiate purchase agreements

Objective 3.2: Validate via field trails organic bean production methods
Researchers at EAP will test methods that meet international standards for organic production via on-farm trials in collaboration with farmers. Organic fertilizers and amendments to enhance soil fertility and IPM practices will be included.

Objective 3.3: Recruit interested smallholders and train the farmers to produce organic beans. EAP researchers will recruit and train farmer groups (CIALs) and collaborating NGO interested in growing organic beans on organic bean production methods.

Objective 3.4: Establish local market linkages required for small-scale bean farmers to export organic/sustainably-produced beans to US markets. Researchers at EAP and MSU will contact market chain participants to finalize their roles in the project.

Results, Achievements and Outputs of Research: *Objective 3.1*: Put in place arrangements for exporting small-red beans from Honduras to US retailers, which are certified as organic and produced using sustainable production practices.

Due to the costs and difficulties in obtaining organic certification and insure that the farmers comply with organic standards, the project was refocused to produced third party certified fair trade beans.

Initially, the project planned to obtain fair trade certification through the FairTrade Labeling Organization (FLO), based in Germany. Several attempts were made to clarify several points, including if standards existed for beans and if FLO has established a fairtrade price for beans from Central America. Also, while FLO's representative for Central America promised several time to visit the farmer association in Honduras, he was unable to meet with the farmers.

During discussions with the bulk commodity buyer at Whole Foods Market (our target US retail market), we learned that Whole Food Markets preferred that we seek fairtrade certification through the IMO, rather than FLO. Subsequently we contacted IMO to obtain information on their certification process. IMO provided clear information on how to obtain certification and provided an invoice detailing the costs of certification. Thus, we will now obtain fair trade certification through IMO.

The bulk commodity buyer at Whole Food Markets' headquarters in Austin, TX has agreed to purchase 20 mt of fairtrade beans from the farmer association at the price that the farmers requested. The agreed to date of delivery is August 2011. Whole Food Market agreed to provide the farmers a formal purchase agreement by December 2010/January 2011. Typically, farmers plant their postrera bean crop in September and harvest it in December/January. However, due to extremely heavy rains, by the end of September farmers had not yet begun to plant their *postrera* crop. The heavy rains are expected to continue into October. Thus, farmers may not plant a *postrera* bean crop because if they plant late in the season, it is likely that the *postrera* rains will end before the crop matures—resulting in significant yield losses. Consequently, we are now planning to produce the beans for export to Whole Food Markets during *primera* 2011 (May-August).

Objective 3.2: validate via field trails existing agronomic recommendations for growing organic small-red beans.

Based on the results of ECO Frijol field trials comparing organic vs. conventional bean production conducted in 2009-10, several Local Farmer Research Committee (CIAL, in Spanish) from the Yojoa Lake have implemented organic fertilizer production in their communities. The results of these trials varied depending on 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 better yield resulting on increase of bean productivity. In those sites were farmers use some 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 increasing costs of fertilizers and pesticides and the similar productivity observed in organic plots. Farmers aware of the effect of the use of chemical products on the environment, and express a serious concern about it, and are in favor of the organic alternatives.

Most organic fertilizer are produced in the farm using the compost and/or bokashi techniques and including crop residues, chicken or cow manure, household garbage and other organic waste materials in their preparation. Organic fertilizers are manually applied in bands and incorporated before planting the seeds. Similar approaches are being used by CIAL in other regions where Zamorano conduct other collaborative bean research activities under the DGP-CRSP and other projects. Additional practices to control diseases and insects that affect the bean crop are also being used by these farmers. Some of these natural pesticides include the use of solutions prepared with extracts of hot pepper, onions, garlic, and the use of leaves or seeds extracts from neem, madreado (*Gliricidia sepium*), basil, mint, nettle, marigold and many other plants available and household materials such soap or detergent, ash and lime. The use of insect trap plants such as sunflower, eggplant and others, to facilitate the control of the bean pests that are attracted to these plants is also recommended.

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

Objective 3.3: recruit interested smallholders and train the farmers to produce organic small-red beans that meet the grades and standards required by US retailers.

In previous years, two farmer groups were identified as potential candidates to get involved in the production and export of bean produced under project assistance. Meetings were held with the leaders and farmer members of ARSAGRO--one of the largest bean farmer association in Honduras, based in Danli, El Paraiso. 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.

Two contrasting issues depending of the type of farmer group and its members were encountered last year with the farmer groups. 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 being implemented by some farmers. In contrast, farmers from the large organization ARSAGRO with better land and access to fertilizer and pesticides, were less interested in getting involved in organic farming of beans unless the process is facilitated by the project, which would require a larger investment of funds. Both groups have participated in training activities offered by the project and in conducting the organic bean ECOFRIJOL trial. During the current year, we have continued to interact only with the CIALs from the Yojoa Lake.

Objective 3.4: Identification of Private Sector Agents

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

<u>Objective 4</u>: Capacity Building

Angola: Short-term in-service training was conducted on data analysis using the household survey data. Chianga, Huambo, Angola, November 2009.

Mozambique: Follow up training on statistical analysis was conducted in Maputo, Mozambique, October 2009, and training of Simple GIS tools with survey data was conducted in Maputo, Mozambique, November 2009.

<u>Degree Training</u>:

Trainee #1

First and Other Given Names: Ana Lidia

Last Name: Gungulo

Citizenship: Mozambican

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: Dec 2011

Training Status: Active

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

Trainee #2

First and Other Given Names: Estevao

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: June 2011

Training Status: Active

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

Short Term Training

Training #1

Type of Training: Basic survey analysis using STATA

Description of training activity: The training will refresh participants' skills in using the national household surveys for data analysis.

Status of this activity as of September 2010? Completed

When did the Short Term Training occur?

Location of Short Term Training: Maputo, Mozambique

Who benefited from this Short Term Training Activity?: Analysts of the National Agricultural Research Institute (IIAM) and the Directorate of Economics of the Ministry of Agriculture

Number of Beneficiaries: 10

Training #2

Type of Training: Basic GIS tools with survey data

Description of training activity: The training will introduce participants to basic mapping skills in using the national household surveys

Status of Short Term Training Activity as of September 2010? Completed

Location: Maputo, Mozambique

When did the Short Term Training Activity occur?: April 2010

Who benefitted from this Short Term Training activity?: Analysts of the National Agricultural Research Institute (IIAM) and the Directorate of Economics of the Ministry of Agriculture

Number of Beneficiaries: 7

Training #3

Type of Training: Statistical analysis

Description of Training Activity: The training will refresh participants' skills in analyzing recent household surveys.

Status of Short Term Training Activity as of September 2010?

Location of Short Term Training: Huambo, Angola

When did this Training Activity occur?:

Who benefitted from this activity?: Students and faculty members of the Agricultural Sciences Faculty at the University of Agostinho Neto

Number of Beneficiaries: 8

Training #4
Type of Training Activity: Short practical learning by doing training.
Description of training activity: Training on construction of solar facilities for seed drying using local materials.
Status of this activity as of Sept 30, 2010: completed
When did the activity occur?: 24-25 April, 2010
Location: Rural Development Program, Zacapa, Santa Bárbara, Honduras
Duration: 24 days
Who benefited from this activity?: Farmers and technicians collaborating in the production of organic beans.
Number of Beneficiaries: 8
Males: 7 Females: 1

Training #5
Type of Training Activity: Short course offered by ECOPOL (Ecology and Population, A.C., México).
Description of training activity: Workshop on Sustainable agriculture on small scale: Bio-intensive cropping.
Status of this activity as of Sept 30, 2010: completed
When did the activity occur?: 13-15 September, 2010
Location: Zamorano, Honduras
Duration: 3 days
Who will benefit from this activity?: Farmers and technicians collaborating in the production of organic beans
Number of Beneficiaries: 3
Males: 3 Females: 0

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 for Donovan, Kiala and Bernsten. There have been continued problems ensuring the funding for the studies, due to coordination problems in South Africa. Combined with this is that the student's program has been delayed and he has not been available to assist with field work. Short-term training for UAN students has been delayed.

Note that Donovan and Kiala worked to coordinate travel with the UCR and UPR teams in June. Unfortunately those teams canceled their trips due to visa problems, but Donovan was able to travel and worked with Kiala and two students as well as giving a seminar and discussing the research with USAID staff in Luanda and meeting with DSA staff and FAO on market analysis and information system development. The potential INCER investment in market information systems has not developed. The research component of this project has had delays, since Kiala had substantial administrative burdens, Chaves remains in Brazil for graduate studies, and time allocation for travel for Donovan is limited. Her presence in the region does lower the costs of her travel to Angola.

Mozambique: Getting the MS student in Pretoria and ensuring the availability of funds for the program needed a strong continued effort on the part of the researchers and the Pulse CRSP administration. For CESE, that MS training is high priority and well appreciated. The research component of her studies has been delayed. Donovan's presence fulltime in Mozambique as a resident advisor with the MSU project at IIAM has beneficial, enabling the development of the draft working paper, which will be augmented by CESE researcher Alda Tomo, recently designated as a key bean/cowpea researcher in CESE, given the continued need for Gungulo to focus on her studies. The Value Chain training continues to have an impact, even though the research component has been delayed.

Honduras: Due to the heavy rains in Postrera 2010, the project has revised its target date for producing fairtrade beans for the US retailer (Whole Food Markets) until Primera (May—August) 2011—for delivery to Whole Food Markets in September 2011. Due to difficulties in getting organic certification, the project will only obtain third party fairtrade certification through IMO—which is acceptable to Whole Food Markets.

Networking and Linkages with Stakeholders

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

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

Among the private sector agents, only Nosso Super (supermarket chain) has been contacted and further work with other stakeholders is needed, including Shoprite (supermarket chain), Jumbo, Angolan Chamber of Commerce, and UNAC (farmers association).

Mozambique: As noted earlier, this is the area of greatest weakness in the project and will be a focus, as collaboration between SABREN and Pulse CRSP Pennsylvania State University projects develops. The Joint meeting with IIAM breeders and other stakeholders is scheduled for early 2011. Collaboration with the Pulse CRSP Pennsylvania State University project will enable MSU project to complement the Penn

State farmer level research, by evaluating the outputs markets in their research zones for the 2011 harvest period. SABREN is working simultaneously on seed systems diagnosis.

Leveraged Funds

Name of PI receiving leveraged funds**:** Cynthia Donovan
Description of leveraged Project: Angola household dataset and price data set completed with World Vision collaboration
Dollar Amount: $10,000 (estimate includes shared cost of data collection and analysis)
Funding Source: WV, Gates

Name of PI receiving leveraged funds: Cynthia Donovan
Description of leveraged Project: Mozambique data analysis funded jointly by USAID/MSU Food Security Project
Dollar Amount: at leaser $5,000 (estimate includes shared cost of data collection & analysis)
Funding
Source: MSU's Food Security Project (FSP)

Across the countries, we will be seeking funding to enable the sharing of experiences between the Central American research on advanced value chains and value chain development in Southern Africa.

Angola: The project will leverage Angolan government resources from the University of Agostinho Neto, Faculty of Agricultural Sciences. Production training and research at UAN is funded publicly, and the salaries and facilities of staff will provide a basis for the project operations. The Bean Program at IIA is also publicly funded and their participation has been sought in this training/research. MINADER has indicated strong interest in establishing market information services using public sector funding, and the project will be able to link with that work, as both the project and MINADER will use the rapid market appraisal methodology and results. World Vision development projects in the Planalto serve as a logical base for extension of project results as well as serving as the base for the household data collection effort.

Mozambique: Public sector funding contributes substantially to the development of this research and training program. That funding provides the salaries and facilities for the CESE staff members, including the HC-PI in Mozambique. In addition, MINAG funds funds the Bean Program of IIAM. The National Directorate of Economics and the provincial MINAG offices support both the national household surveys (TIA) and the market data collection of the Agricultural Market Information System (SIMA), through public sector funding.

Honduras: EAP, a private university supports the project by salary support for the HC-PI's participation in the project.

Contribution of Project to Target USAID Performance Indicators

The attached form demonstrated the strong linkage between projective objectives and those of USAID, particularly the IEHA goals under pillars 1, 2 and 4.

It should be noted that Mozambique is a priority country for IEHA and the USAID mission strategy in Mozambique is closely aligned with IEHA, focusing on increased rural incomes through productivity growth and market access. While not an IEHA country, Angola's mission strategy also includes many of the same features for smallholder agriculture market development.

The current proposal is aligned with IEHA goals and focuses on IEHA pillars 1, 2 and 4 Although Mozambique has not yet inaugurated its CAADP process the current proposal addresses CAADP pillars 2, 3 and 4. The research undertaken will also be relevant to the COMESA regional food staples trade program since Malawi, as well as other potential neighboring trade partners are COMESA member countries.

Contribution to Gender Equity Goal

Angola: The MS student is a male. 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). The seminar on price policy involved the set of undergraduate students at UAN (25 men and 10 women students). Note that the gender composition on the seminar depended strictly on the composition of the UAN student body, not on Pulse CRSP selection of students.

Mozambique: The MS trainee is a woman, Ana Lidia Gungulo. The Bean/cowpea report includes a gender component in the analysis.

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2009 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

Project Title: *Expanding Pulse Supply and Demand in Africa & Latin Americs: Constraints & New Strateg*

	Abbreviated name of institutions											
	MSU			Univ. Agos. Neto			IIAM			EAP		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1: Angola												
Objective 1, Identification of information/data sources												
Revised document summarizing both earlier and new secondary information on agricultural production and markets in Angola, focusing on beans and cowpeas												
Objective 2. Value chain diagnosis and capacity building												
Value chain diagnostic: Revised report, based on smallholder survey results and additional research with private sector												
UAN Thesis: Farmer constraints and opportunities												
UAN Thesis: Smallholder production systems with beans and potatoes												
MS Thesis proposal (delayed from previous period)	X		X									
Objective 3. Identification of constraints and opportunities												
Draft articles from each of the two theses from UAN				X		X						
Article on smallholder marketing	X											
Outreach with NGO on smallholder marketing results				X	X							
Objective II: Mozambique												
Objective 1. Taskforce development and temporal and spatial analysis												
Mapping of spatial analysis from TIA												
Final summary report on markets and price analysis (SIMA data)												
Synthesis Paper on spatial and temporal analysis of production							X	X				
Policy brief on production and marketing	X		X									
Objective 2. Identification of constraints and opportunities												
Presentation of the diagnostic results to stakeholders												
Establishment of a bean/cowpea task force (delayed pending market appraisal report)												
Joint meeting with IIAM breeders on the market results and consumer preferences to identify potential interventions with production												
Final working paper (for objectives 2.1and 2.2)	X		X									
Final policy brief (for objective 2.2)	X		X									
Objective 3. Capacity building												
Draft MS thesis proposal	X		X									
Objective III. Honduras												
Objective 1. Put in Place Arrangemts for exporting beans from Honduras to the US												
Confirm US retailers' interest in importing beans from Honduras												
Negotiate purchase agreements with US retailers	X	X										
Finalize arrangements for exporting bean to the US	X	X										
Objective 2. Validate via on-farms trials organic bean production methods												
Conduct organic bean production field trials during postrera (Oct-Dec) 2009 season												
Report on results of organic bean production field trials from postrera 2009.												
Conduct organic bean production field trials during primera 2010 season										X	X	
Publish results of set of organic bean production field trials for 2009 & 2010 season										X	X	
Objective 3. Recruit interested smallholders & train farmers to produce organic beans that meet the grades/standards required by US retailers												
Recruit farmers/groups/NGOs interested in growing organic beans												
Train farmers and technicians on organic bean production methods												
Train farmers on requirements for third-party certification												
Initiate organic bean production for the US market (postrera)										X		X
Objective 4. Establish local market linkages required for small-scale farmers to export organic/sustainably-produced beans to US markets												
Finalize process for third-parties to certify farms as organic/sustainable practices												
Finalize agreements with farmers to produce specific quantities of beans												
Finalize agreement with Honduran processor/exporter (Rojitos) to export										X		X
Objective IV. Institution Building												
Angola												
One MS student in Ag Econ at Univ Federal of Vicosa, completing first year												
One MS student in Ag Econ at Univ Federal of Vicosa, completing MS coursework				X								
One in service training in data analysis												
Mozambique												
One MS student in Ag Econ at Univ. of Pretoria, completing first year												
One MS student in Ag Econ at Univ. of Pretoria, coursework for MS degree							X					

One in-service in the basics of GIS												
One in service training in data analysis												
Honduras												
Train farmers and technicians on organic bean production methods												
Train farmers on requirements for third-party certification												
Name of the PI reporting on benchmarks by institution	R. Bernsten			D. Kiala C. Donovan			F. Mazozue, C. Donovan			J.C. Rosas, R. Berensten		
Name of the U.S. Lead PI submitting this Report to the MO	Richard H. Bernsten											

Richard H. Bernsten 10/8/2010
Signature **Date**

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

Explanations Regarding "Semi-Annual Indicators of Progress (Benchmarks") for period 5/1/10-9/30/10

Angola

Objective 2: MS Thesis proposal (delayed from previous period): The student continues to progress in his program, but his professors at the University of Vicosa have requested that he delay the thesis proposal until he completes more coursework.

Objective 3: Draft articles from each of the two theses from UAN: The quality of the theses were not satisfactory for writing articles as written. Kiala will be working with one student who has the promising document to create an article. This student wishes to continue his education and has an incentive to invest in the article.

Mozambique

Objective 1: Synthesis Paper on spatial and temporal analysis of production; a draft version has been prepared but is not complete and will need substantial addition work. The MS student at University of Pretoria has been focused on her studies and unable to contribute to this work, so collaboration with PABRA researcher Alda Tomo will enable this work to be wrapped up. Policy brief on production and marketing: Policy brief is an output from the paper indicated above, so will be completed after the paper.

Objective 2: Final working paper: Delayed due to lack of staff time for field work. Collaboration with the PSU project and PABRA will move this work forward in the next two quarters. Final policy brief: Delayed until working paper completed

Objective 3: MS Thesis proposal: The student continues to progress in his program, but her professors at the University of Pretoria have requested that she delay the thesis proposal until she completes more coursework.

Honduras

Objective 1: The bulk commodity buyer at Whole Food Markets' headquarters in Austin, TX has agreed to purchase 20 mt of fairtrade beans from the farmer association at the price that the farmers requested. The agreed to date of delivery is August 2011. Whole Food Market agreed to provide the farmers a formal purchase agreement by December 2010/January 2011.

Objective 2:

Typically, farmers plant their postrera bean crop in September and harvest it in December/January. However, due to extremely heavy rains, by the end of September farmers had not yet begun to plant their *postrera* crop. The heavy rains are expected to continue for several weeks. Thus, farmers may not plant a *postrera* bean crop because if they plant late in the season, it is likely that the *postrera* rains will end before the crop matures—resulting in significant yield losses. Consequently, we are now planning to produce the beans for export to Whole Food Markets during *primera* 2011 (May-August).

Objective 4: We have determined that the farmer association is able to process (clean, polish) the beans themselves and have contacted a broker who has agreed to provide export-related services (e.g., transporting a container to the village, transporting the packed container to Puerto Cortez, fumigating the shipment, completing US customs paperwork, making sea transport arrangements with a export/shipping company) and ship the beans directly to Whole Food Markets. Thus, the project doesn't require Rojitos' processing/exporting services.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2009 – September 30, 2010)

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

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

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	1
Number of men	1	1
Short-term Training: Number of individuals who received short-term training		
Number of women	15	15
Number of men	37	20
Technologies and Policies		
Number of technologies and management practices under research	0	1
Number of technologies and management practices under field testing	8	8
Number of technologies and management practices made available for transfer	4	4
Number of policy studies undertaken	2	1
Beneficiaries:		
Number of rural households benefiting directly	20	25
Number of agricultural firms/enterprises benefiting	2	0
Number of producer and/or community-based organizations receiving technical assistance	9	15
Number of women organizations receiving technical assistance	1	2
Number of HC partner organizations/institutions benefiting	5	7
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	100	100

Comment: In Honduras, the technologies and management practices under testing and made available for transfer will be the production and use of organic fertilizers (bokashi, compost, others) and biological products for disease and pest control)

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

Juan Carlos Rosas, EAP, Honduras
Celestina Jochua, IIAM, Mozambique
Soares Xerinda, IIAM, Mozambique
Magalhaes Miguel, IIAM, Mozambique
Jill Findeis, Penn State, USA
Kathleen Brown, Penn State, USA

Abstract of Research Achievements and Impacts

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

Project 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, 2009 - September 30, 2010

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. We will engage both male and female farmers in these activities with the goal of equitable representation of the local community.

Results, Achievements and Outputs of Research:

EAP/Honduras: During the past years three inbred-backcross populations were developed by crossing the small red cultivar Amadeus 77 (the most utilized improved cultivar in Central America in the last five years), used as recurrent parent and the lines L88-13, L88- and L88-63, selected for root traits associated with better adaptation to low fertility and drought conditions by PSU researchers, used as donor parents. Two hundred seventy five IB lines (two backcrosses and three selfing generations), were screened twice during 2009-10 under field conditions for agronomic adaptation, seed yield and commercial seed characteristics, in a low N and P field plot with no fertilizer application. On these field trials, the IB lines were characterized for their growth habit, days to flowering and maturity, disease reaction and grain yield; seed samples were evaluated for seed color (1-9 scale), shape and size (100 seeds wt) in seed lab facilities.

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

IIAM/Mozambique: *Activity 1.1 Phenotyping bean root traits*

Hundred and sixty-five (165) bean genotypes from the bean core collection obtained at CIAT were evaluated in the laboratory with the following objectives: to access the phenotypic diversity of root traits of common bean, to select bean genotypes with root traits adapted to low phosphorus soils and drought, and to identify sources of nutrient and drought efficiency. The experiment was planted in a randomized complete block design with 4 replications. Seeds were surface sterilized with 10% commercial blench before scarified and placed in brown germination paper moisturized with 0.5 mM CaSO4. The germination paper was then rolled and placed in a beaker with 0.5 mM CaSO4 solution. The beakers were placed in a dark incubator at 28 °C for three to four days. The beakers were then placed in a plant culture room at 26 ^{o}C in the laboratory for 4 days with 12 hours of light. The roots were harvested 8 days after planting and preserved in 50% alcohol for late measurement of root hair traits. The number of basal root whorl and basal root were evaluated at the harvest.

The root hair length and density were measured on a representative basal root. Pictures were taken using microscope and camera Nikon at 40x and root hair length and density were measured using Image J.

Preliminary data showed variation in basal whorl number (Figure 1), basal root number (Figure 2), and root hair length (Figure 3). Significant differences were found among genotypes in basal whorl number and basal root number and root hair length at 1% level of significance. The average whorl number varied from 1 to 4, and the average number of basal roots varied from 4 to 14. The root hair lengths varied from 0.196 to 0.779 mm (Figure 3). Figure 6 shows an example of bean roots with short/few and long/dense root hairs.

In addition, a positive correlation was observed between whorl number and basal root number evaluated in 8 day old bean seedlings (R^2 = 0.91) (Figure 4). The correlation was significant at 1%. This relationship indicates that genotypes with more whorls has potential of having more basal roots and therefore will acquire more phosphorus in the up soil (shallow roots).

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

Activity 1.2: Screening for low Phosphorus and drought tolerance
Several genotypes are being evaluated in the laboratory to identify genotypes with root traits suitable for phosphorus and drought stresses.

1) About 600 F4 lines from crosses developed in phase 1 are being screened for root hair traits in the laboratory at PSU. The data is being collected for statistical analyses.

2) In addition, root traits of 150 genotypes from the bean core collection were evaluated in the field in Pennsylvania under low phosphorus conditions. The experiment was planted in a randomized complete block design with 4 replications. The ob127jective of

the study was to identify sources of tolerance for low phosphorus for future use in bean breeding programs. The traits evaluated in the field included number, length, branching and diameter of adventitious and basal roots; length, branching and diameter of primary root; basal root whorl number, basal root angle, rot root, nodulation and shoot dry biomass. Additional data is being evaluated in the laboratory. Preliminary data showed high variation in adventitious, basal and primary root traits. We expect to select several genotypes with root traits suitable for soils with low levels of phosphorus. We are still analyzing the data.

Activity 1.3: Field trial with selected genotypes
A trial was installed in June in Chokwe under drought stress with the objective of identifying common bean genotypes with better yield under drought stress. Twenty genotypes were planted in a randomized complete block design with 4 replications. All replications were planted under terminal drought stress (irrigation until flowering) and under normal irrigation. Phenological observations such as days to flowering, maturity including yield performance will be collected. The data is being collected in Chokwe Research Station.

Activity 1.4: Trait synergism
Breeders and farmers need integrated phenotypes composed of positive traits working together to enhance crop performance in target agroecosystems. Interactions among root traits are poorly understood. This activity tests the hypothesis of positive synergism between two key root traits - root hair length and density (RHLD) and basal root growth angle (BRGA).

This research was conducted in the field at Rock Springs, PA in 2009. The same experiment was repeated in 2010 at Sussundenga research station in Mozambique. In this experiment, 86 recombinant inbred lines developed from the cross between DOR364 and G19833 was screened and evaluated for root traits, after which four root categories were identified. The four categories included: category A- three RILs with long root hairs and shallow basal roots; category B- three RILs with long root hairs and deep basal roots; category C- three RILs with short root hairs and shallow basal roots; and category D- three RILs with short root hairs and deep basal roots.

Below are genotypes grouped per root category:
Category A: RILs 13, 38, 53.
Category B: RILs 32, 36, 66.
Category A: RILs 52, 64, 79.
Category A: RILs 19, 27, 47.

The experiment was conducted at Sussundenga research station in Mozambique. A split-plot design was used, with Phosphorus treatment as main plot and genotype as the sub-plot. Each treatment had 4 replications with 3 genotypes per root category. Each treatment consisted of a plot with three rows of two meters long; with the spacing of 60 cm. 21 seeds were planted in each row, with spacing of 10 centimeters within the row (60 cm x 10 cm spacing). Planting date was February 2, 2010. Data collection was performed at 14, 21 and 28 days after planting (DAP). Collected data included: Root hairs, Root growth Angle, root distribution, shoot dry weight, leaf dry weight, P content, Relative leaf surface area, number of adventitious roots.

The results from the experiment indicate strong synergism between root traits in common bean. Genotypes exhibiting more than one root trait associated with phosphorus uptake efficiency show better performance than the sum of the root traits occurring separately (Fig 6). Data on other parameters also confirm the superiority of the genotypes with the combination of the studied root traits. The results show the importance of the combination of several root traits in the same genotype a characteristic that with a potential benefit for crop performance in low nutrient soils.

PSU/USA

Activity 1.5: QTL Analysis of Basal Root Whorl Number (BRWN)

Basal Root Whorl Number (BRWN) plays an important role in determining basal root distribution in soil profile. Genotypes with increased BRWN have roots distributed in such way that it maximizes the soil volume being exploited by the plant. BRWN among bean cultivars ranges from 1 to 4, sometimes 5, and each whorl typically forms 4 basal roots. The objective of this study was to perform a quantitative trait loci (QTL) analysis for BRWN using two populations of recombinant inbred lines (RILs) developed from the following set of parents: DOR364 x G19833 and G2333 x G198339.

This study was conducted in 2008 and 2010. Phenotypic data from the genotype screening in 2008 was used to perform the first QTL analysis. Phenotypic data from the genotype screening in 2009 was used to perform the second QTL analysis. Phenotypic data on the number of basal root whorls and number of basal roots was obtained from the seedlings 3 days after imbibition. QTL analysis for basal root whorl number and total basal root number was performed using composite interval mapping, where 20 QTL were detected on 6 of the 11 linkage groups.

In the first QTL analysis we found that approximately 25% of the variation for BRWN in DOR364 x G19833 was controlled by one QTL and over 58% of the variation for BRWN in G2333 x G19839 RIL populations were controlled another single QTL in chromosome *B7*. In addition, we found the that more than 14% of the variation for number of basal roots in DOR 364 x G19833 population was controlled by a single QTL, and more than 61% of the variations for number of basal roots in G2333 x G19839 RIL population was controlled by a another single QTL in linkage group B7. The results from the second QTL analysis were consistent with previous results. In the G2333 x G19839 population, most of the genes associated with BRWN were found in same region in both analysis. In addition, few genes were associated with this root trait. This high proportion of variance explained by relatively few QTL suggests that this trait can be used as a criterion for selection of plant materials with phosphorus acquisition efficiency.

Activity 1.6 structural-functional modeling of value of root cortical aerenchyma (RCA) for P acquisition in common bean

The geometric simulation model *SimRoot* was used to test the hypothesis that root cortical aerenchyma (RCA) is a useful trait for bean growth in low P soil by reducing the metabolic costs of soil exploration. 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). Preliminary data was reported last year- this year we published an article about this (Postma, JA, JP Lynch. Theoretical evidence for the functional benefit of root cortical aerenchyma in soils with low phosphorus availability. Annals of Botany, in press). This trait has never before been considered in bean breeding programs, but these results suggest that it is worth further evaluation.

Activity 1.7 root phenotyping under stress
Fifteen genotypes were screened under drought and low soil fertility, and phenotyped for a number of root traits. The traits included basal root whorl number, basal root number, basal root growth angle root hairs, adventious roots, and root length. It was observed that most of the genotypes had 2 BRWN and some few had 3 whorls. The genotypes, which had 3 whorls, had higher yield and high shoot biomass weight compared to genotypes, which had 1 whorl. Genotypes with more adventious root had higher P content in shoots. Genotypes VTT 924/19-8-1, SER 79 and SER 16 showed a combination of several root traits like higher basal root whorl number, more root hairs and more adventious roots. Tiocanela 75 had higher mean tap root length. The controls (Malawi commercial varieties) like nasaka and UBR 92 had low yield and low shoot biomass. These genotypes have both 2 sometimes 1 whorl and a mean of 6 basal root number and they have low number of adventitious roots.

Objective 2: 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, runoff water, 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 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

Activity 2.1 Evaluation of the effect of P efficient bean genotypes on soil erosion

Water erosion is an overwhelming problem in high rainfall uplands. The major bean growing areas in Mozambique are located in uplands with high annual rainfall (>1000 mm $year^{-1}$) and predominant slopes of 4 to 15%. Most soils are Oxisols with low phosphorus (P) availability and high P-fixing capacity. P-efficient, shallow rooted beans can grow fast and attain higher biomass accumulation providing better soil surface cover in low P poor soils. The study was conducted in Lichinga Agriculture Research Station to evaluate the effect of P-efficient bean genotypes on alleviation of water erosion. The site has average annual rainfall of 1161 mm, with 996 mm falling in 4 months (December to March). Soil test Olsen P was 8 mg kg^{-1}, pH was 4.9 and SOM was 1.6%. We hypothesized that P-efficient genotypes will reduce interrill (raindrop splash and overland flow) erosion as compared to P-inefficient (deeper rooted) bean genotypes. The treatments included two P-efficient genotypes (L88-14 and L88-57), 2 P-inefficient genotypes (L88-30 and L88-43) which are RILs from L88 population, and bare soil. The four genotypes were planted in 1.6 m by 2.0 m lysimeters delimitated with metal sheets pounded to the soil 10-15 cm deep to form the micro-basins (runoff plots). The fifth plot was left as bare soil control. At the down end of each lysimeter were installed 2 containers with 25 L for collection of runoff water. The lysimeters were installed in contour lines which were the blocks in 6% slope terrain. The treatments were randomly placed within a block and replicated 5 times. Runoff water was measured and water samples were collected in 8 natural rainfall events. P-efficient beans had consistently and significantly ($p<0.001$) lower volumes of runoff water as compared to P-inefficient genotypes in the eight rainstorms with runoff. The total runoff in the 8 events in plots with P-efficient lysimeters: 186.5 L for L88-14 and 165.5 L for L88-57, significantly lower volumes as compared to the volumes obtained in the plots planted to P-inefficient genotypes (245.4 L for L88-30 plots, and 247 L for L88-43 plots) (Fig. 8). The bare soil control plots had the highest runoff volume of 287.8 L. On average the P-efficient genotype category had significantly less runoff (146 L) than the P-inefficient genotypes (246.2 L) per plot. The coefficient of variation in the 8 runoff events ranged from 6.7 to 14.4%. We conclude that bean genotypes with shallow roots are effective in reducing water erosion caused by high intensity erosive rainfalls that are abundant in bean growing areas of Mozambique. Other data on sediment and phosphorus associated to runoff water are still being analyzed and were not included for this report.

Activity 2.2 Evaluation of the utility of local rock P with P efficient bean genotypes
This activity will resume in 2011. In 2010 only took place preparatory activities. The PI of this activity is currently at Penn State University, continuing PhD studies.

Activity 2.3 Evaluation of synergy of water conserving soil management with drought tolerant genotypes
An experiment was conducted in Chokwe research Station from May 21st to September 15th 2010. The experiment consisted of three moisture techniques treatments (No mulch, mulch at 3 ton ha-1 of dry crop residues, or micro-basins) as main plots, and four genotypes in sub-plots. The genotypes were two P-efficient (Lic-04-1-3 and Lic-04-2-3) and two draught tolerant (Tio Canela, and BAT 477) selected from previous draught tolerance screening trials of the breeding component. The analysis of variance of yield data shows no significant ($p=0.6$) difference among moisture conservation techniques. There was significant ($p=0.008$) difference among the four genotypes, but no significant interaction of genotype x moisture techniques (Figure 9). The micro-basins' mean yield was 1596 kg ha-1, followed by 1548 for plots with no mulch, and 1491 kg ha-1 for plots in which was applied mulch. The results of this year are negatively influenced by an unusual wet year. Normally, in the months the trial was conducted in no rainfall, but this year 125 mm of precipitation well distributed, which interfered with the irrigation schedule set for the trial. This left the plots with mulch with excess moisture, which is not desirable for better bean growth. The two P-efficient Lichinga lines had the highest and similar yields (1682 kg ha-1 for Lic-04-2-3 and 1658 for Lic-04-1-3), which differ significantly from Tio Canela with 1294 kg ha-1. The genotype BAT 477 had intermediate grain yield (1544 kg ha-1) which did not differ significantly from both Lichinga lines and Tio Canela. The grain yield results of the four genotypes under the three moisture conservation techniques are presented in the figure 1, below.

<u>PSU/USA</u>
Activity 2.4 Evaluation of the effect of root traits in maize/bean intercrops
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.

A trial was conducted at Rock Springs Research Farm, near Penn State University, from June 11 to October 14th 2010. The experiment had 2 phosphorus levels (low P and high P), and in each P level four genotypes (P-efficient: L88-14 and L88-57; P-inefficient: L88-30 and L88-43) in monocrops of beans, and the same genotypes intercropped with maize. The maize and beans were planted 76 cm spacing between rows; the maize plants were 30 cm apart in the row, and the bean plants were 10 cm apart in the row. In the intercrop plots maize plant had 2 bean plants 5 cm apart in each sides of the row, and 3 bean plants were between two maize plants. Maize was also planted as monocrop at the same spacing. An additional intercrop plot was included but with bean plants 10 cm apart of the maize plant. Root cores were taken at flowering of beans and at maize tasseling; and root crowns were taken at flowering of maize to evaluate root competition effects. The root data include root length, root length density, and root angles. Aboveground measurements include: plant biomass, number of pods, weight of pods, cobs, grain weight; plant height, base shoot diameter. Samples and data processing is not complete yet, it will be presented in the next report.

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

Approaches and Methods: The Phase I activities for Objective 3 include baseline farm household surveys identifying 1) barriers to adoption and diffusion, 2) constraints to achieving potential income and nutrition impacts, and 3) bean attributes preferred by households in the four study areas designated for this project: Angonia, Gurue, Lichinga and Sussundenga. The Mozambique Vulnerable Soil Vulnerable Household (VSVH) Survey was designed to provide answers to these questions via face-to-face interviews of men and women from households randomly sampled across 8 village sites in Angonia (2 villages), Gurue (2 villages), Lichinga (2 villages) and Sussundenga (2 villages). Male and female surveys were designed, with one adult male and one adult female surveyed in each household, with the recognition that not all households would include both a male and a female. The protocol included pretesting of the survey and a 2-day training of all personnel prior to fieldwork. In each village, permission of the traditional chief or municipal chief, or both, was sought prior to work with the village

A total of four instruments comprise the VSVH: 1) Male Core Survey, 2) Female Core Survey, 3) Household Profile Survey, and 4) Agricultural Plot Survey. The VSVH survey instruments include questions to establish agricultural practices, barriers to adoption and diffusion, bean attribute preferences, as well as questions related to social/economic networks, including supply chains. The VSVH Survey also included questions related to intra-household decision-making regarding agricultural technologies, since both men and women farmers are involved in deciding whether or not to adopt improved varieties. Finally, the surveys provide data on ownership or use of cell phones and other technologies for potential dissemination of information about new low-phosphorous bean cultivars and for accessing supply chains for legume marketing. To gain a historical assessment of change taking place in the villages, including changes in agricultural practices and perceived changes in soil quality, a fifth instrument was designed to be administered to a key leader in the village. This survey is qualitative in nature.

Local communities for the baseline research were chosen such that two (paired) communities were selected in each of the four regions. In each region, one site was selected to serve as a control site, with the other paired site designated as an intervention site – ie., where new low-phosphorous (low-P) bean varieties will be introduced using different seed dissemination and diffusion approaches (e.g., small seed packets, promotional campaigns, etc.). The baseline surveys serve to guide design of the quasi-experimental new low-P bean interventions to be conducted at the sites under Phase II.

High-print-quality Google maps are also used, to establish local networks (of diffferent types) and also to establish locations of markets, prevalence of processing options, and other similar village-level infrastructure that could serve to improve villager livelihoods. The maps were developed for each study village, showing local-level features, including all households, as well as the larger landscape. Based on the Google maps, a random sample of households was selected for each of the 8 village sites, to ensure representativeness of households in the baseline data. This ensures that we are able to represent an accurate cross-section of impacts of the technology across villages where it will be introduced.

Results, Achievements and Outputs of Research: Ex ante surveys in 4 regions of Mozambique were completed in the previous reporting period, and were coded in the current period for all regions: Angonia, Lichinga, Gurue and Sussundenga. Data are from the Target, Plot and Profile Surveys. Data include (as examples): 1. preferences for specific common bean attributes, by male and female farmers at the field research sites; 2. access to improved seed varieties by male and female farmers; 3. access to information distribution networks relevant to seed adoption and diffusion (e.g., posters, radio, mobile phones). The data provide useful information for common bean seed preferences based on a broad representation of farmer households across the villages; these will be supplemented in Phase II with PVS activities at the sites.

Data also include network data to conduct analyses of diffusion of bean seeds through trader networks, through seed sharing networks operative at the village level, and through the design and greater use of information networks that can be adapted to the needs of local farmers. From the coded data, network matrixes were developed for those economic and social networks being analyzed as part of the Phase II project. Network matrixes are for male and female farmers within households; overall household network matrixes will be developed in the next reporting period, utilizing male and female data.

Finally, in the current reporting period, Google Pro maps showing all household compounds located in the field research sites were developed for the Lichinga and Angonia sites. Maps are now being completed for the Sussundenga and Gurue sites.

Preliminary descriptive results (Angonia) indicate the following:

Attributes

1. Bean attributes most likely to be ranked as very important based on male farmer preferences include (in order of response %, for responses 60% or above): marketability to traders found in village, marketability to traders coming directly to home/farm, lower fertilizer requirements, drought tolerance, potential for intercropping with maize, and potential for intercropping with other crops. (highest to lowest ranked attributes for those attributes above 60%)
2. Bean attributes most likely to be ranked as very important based on female farmer preferences (in addition to cooking time) include drought tolerance and marketability to traders coming directly to home/farm (as opposed to marketability to traders they find in the village, which was not highly ranked in importance). (highest to lowest ranked attributes for those attributes above 60%)
3. Statistically significant differences between male and female responses were established for traders in the village (male>female), lower fertilizer requirements (male>female).
4. Tests using aggregated 'very important' and 'important' responses (creation of single category) indicate that males may be more attracted to a bean with good leaves on the plant than females. No difference between male/female rankings for preferences for varieties with drought tolerance, few insect pests, tolerance to plant diseases, and that contribute to soil fertility.

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

Access to improved seed varieties:

1. Access to improved seed – through traders/markets, extension workers, farmer organizations, friend and kin networks both inside and outside villages, NGOs – is limited for both men and women.
2. Women are most likely to receive improved seed from (in order of response, and limited to responses > 10%): traders/in market, extension workers, kin networks in village, friend network in village.
3. Men are most likely to receive improved seed from (in order of response, and limited to responses > 10%): extension workers, traders/in market, relative networks in village, relative networks outside village, friend networks in village.
4. NGOs are not found to be active in seed distribution in this region, although some women (approximately 1 in 10) respond that they have received improved seed from NGOs. Very few men or women have received improved seed from friend networks outside the village or from farmer organizations. But relatively few respondents in the sample belong to farmer associations in this region.
5. Small percentages of men and women reported receiving free bean seed in the past.
6. Females report that not having good bean seed is a problem or large problem for their households; 60% of men do not consider this a problem, resulting in significant differences between men and women in perceptions of ‘good bean seed’ availability. Analysis with the other village samples is underway to better understand this result. Given differences in preferences for different attributes, what is considered as ‘good’ seed differ by gender.

Information access and seed diffusion channels

Preliminary results indicate that men and women are as likely to have received free seed in small packets in the past (may or may not include beans). Some men and some women have received loans to purchase seeds and others have received seed vouchers, but there is no statistical difference by gender. The full sample will allow analysis with a larger sample.

In general, male (%yes) response to questions regarding recalling having seen, heard, or seen information on better seeds is higher than that reported by women, although male-female differences are not statistically significant. This result may be in part a function of small sample size; analysis using the greater number of observations afforded by the full sample (all sites) could provide a better understanding of these results.

Males report being more likely to have participated in a seed trial, or recall (surprisingly) having seen a poster promoting better seeds. In both cases, male-female differences are statistically significant.

In this region, NGOs are not observed as being particularly active in providing information to farmers.

In addition to the questions above, the ex ante surveys provide information on bean production, home consumption of beans, bean income receipt, and other indicators relevant to assessing the impacts of introducing phosphorous-efficient beans for farmer use. In addition, this research provides a better understanding of the barriers that men and women farmers face in finding out about new technologies that could benefit them and in securing seed that are consistent with their preferences. Phase II research will provide an assessment of actual seed choice, and experiences in using the new seed, when made available.

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 then identified Samuel Camilo from IIAM as a potential trainee. Samuel is now at Penn State taking intensive English instruction. It is hoped that he can pass the TOEFL in December 2010, allowing him to begin his MS study in the Spring of 2011.

During FY 10, one undergraduate student finished his research project and two others started their projects at Zamorano using methods and techniques for testing bean germplasm under low fertility and drought conditions adopted from PSU and CIAT. Two technicians from INTA (the agricultural research institute from Nicaragua), Sergio Cuadras and Noel Duarte, were trained on the use of the soil cylinder technique and

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

Drought and low fertility tolerant small red bean lines developed in previous years were incorporated to the bean network of nurseries and trials which are distributed on a yearly basis by Zamorano to the collaborators from the National Bean Programs of Central America and Haiti. Some of the lines are being validated under on-farm conditions in Honduras, Nicaragua and El Salvador. In addition, some nurseries that included advanced lines developed by the project were distributed to farmer organizations and NGO involved in participatory plant breeding in the Mesoamerican region (project supported by the Development Fund from Norway). Drought and low fertility tolerant lines have been released at local level for some of these farmer groups participating in PPB activities in Honduras and El Salvador. Although these lines has not been released at national or regional level, they are being used locally by farmers for their greater adaptation to low input conditions commonly present in most bean production regions of Central America.

Representatives of the socioeconomic team met with USAID personnel at Maputo in August 2010 (useful for other section of report, as I recall). We are building linkages to faciliate low-P seed availability information diffusion via cell phones.

This represents a crossover linkage with the MSU socioeconomic Phase II project. Our team met with Anabela Mabota when there (she is now works with mobile techs at USAID Maputo office), and Cynthia Donovan and I discussed next steps for further collaboration on mobile techs, price information, and seed information. Of interest to both projects: trader networks.

The socioeconomic team is starting to work more closely with CIAT in East Africa (Jean Claude R., Louise S.), and will be collaborating with them on 1) design of diffusion research, and 2) potential for social certification policy and schemes.

We have hired five technicians positioned at our research sites in Mozambique (Gurue, Lichinga, Angonia, Chokwe and Sussundenga), that will be directly involved into the activities of our projects. In Angonia and Gurue, the hiring was made in collaboration with our on-site collaborators, such as Angonia District Directorate of Agriculture (extension services), which not only suggested the candidate, but also identified a house for accommodation. In Gurue, the identification of the candidate was made in collaboration with the World Vision International, and CLUSA. Clusa housed the technician at its training facilities in Lioma for sometime, before the technician was able to identify his independent accommodation in the village of Gurue. The networking and linkages with stakeholders is going to be more strong in incoming years (starting from 2011), when we will be disseminating our P-efficient seeds through the planned small bags distribution strategy, to the farmers in the villages to be recommended by the socio-economic team.

Leveraged Funds

P.I.s: JC Rosas
Title: Participatory plant breeding
Amount: $250,000
Agency: Norwegian Development Fund

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

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

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

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

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

Tables/Figures Cited in the Report

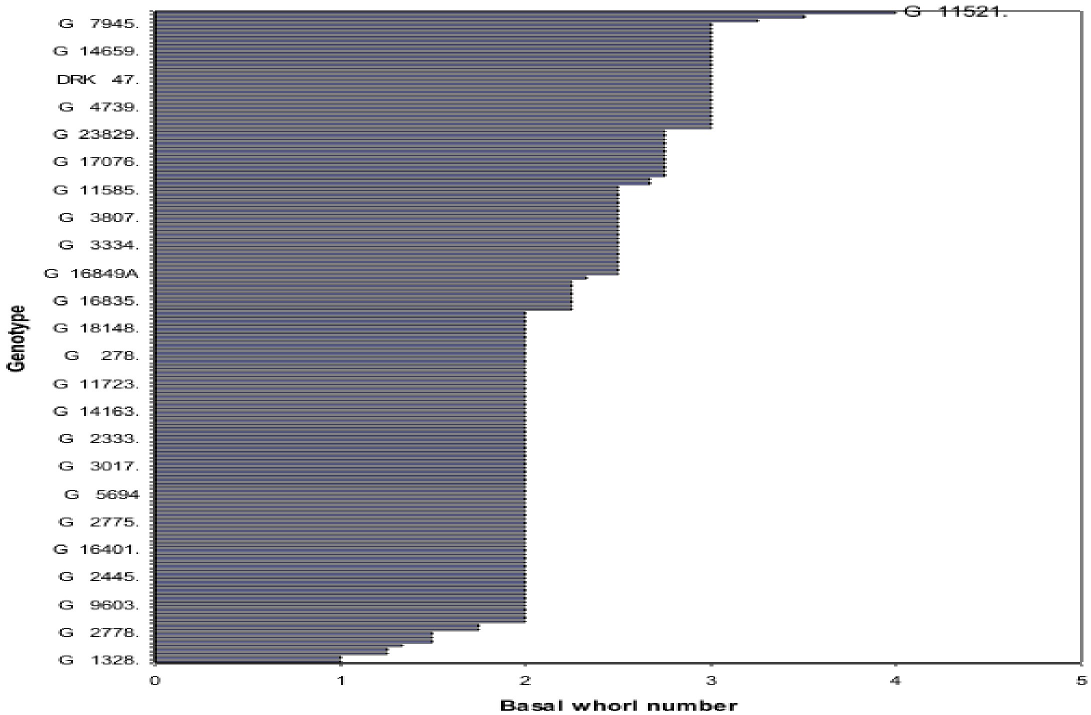


Figure 1: Variation in basal root whorl number in 165 genotypes from the common bean core collection. The values are average of 4 replications. Differences among genotypes were significant at 1%.

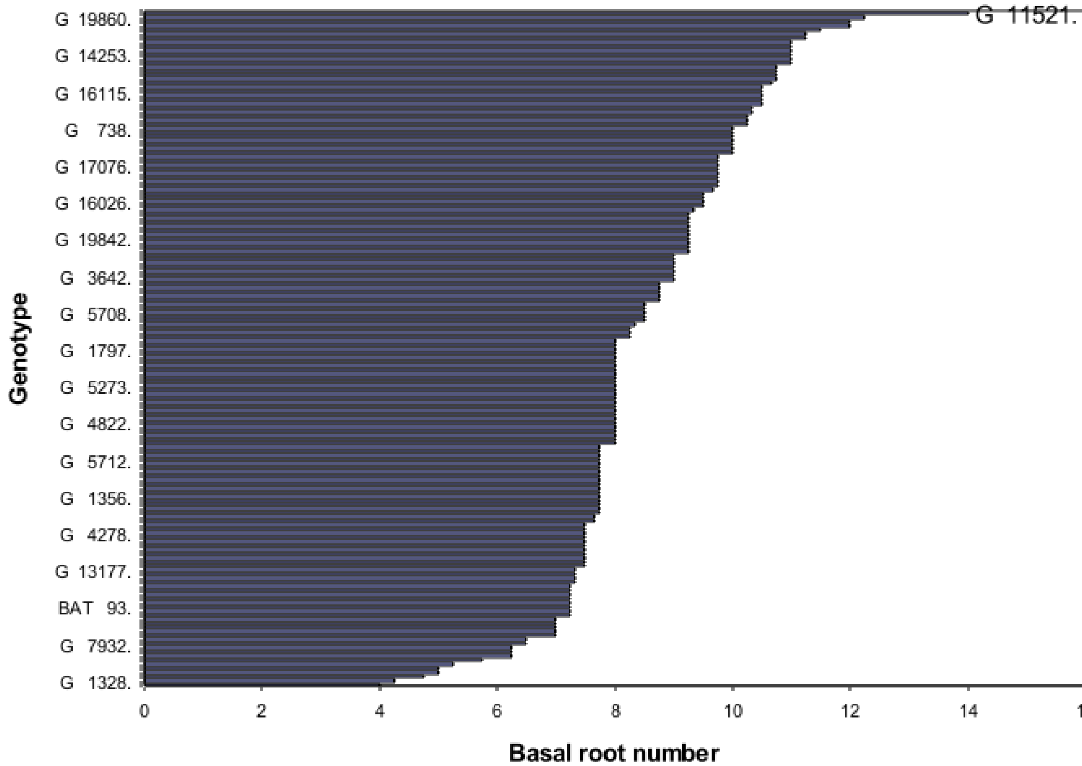


Figure 2: Variation in basal root number in 165 genotypes from the common bean core collection. The values are average of 4 replications. Differences among genotypes were significant at 1%.

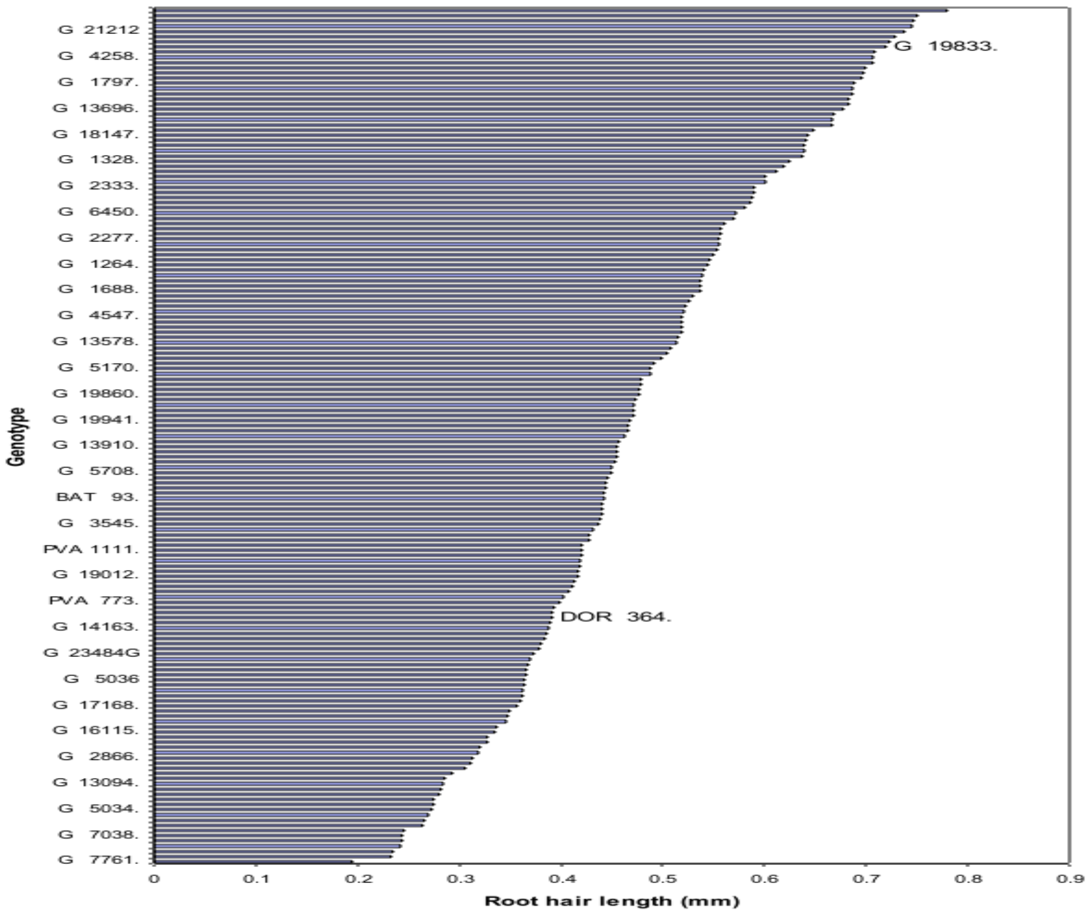


Figure 3: Root hair length variation in 165 genotypes from the common bean core collection. The values are average of 4 replications. Differences among genotypes were significant at 1%.

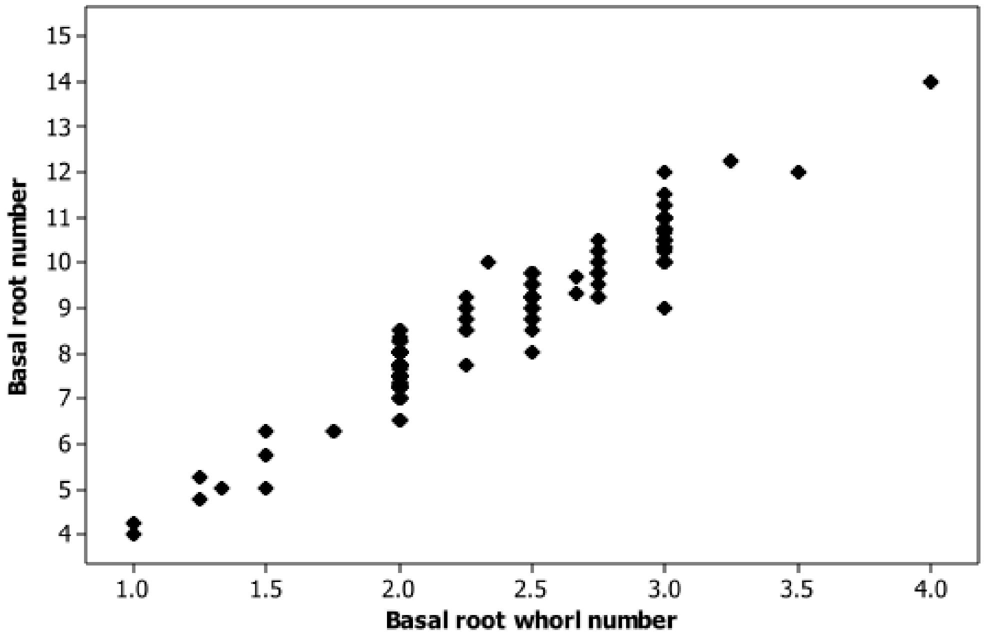
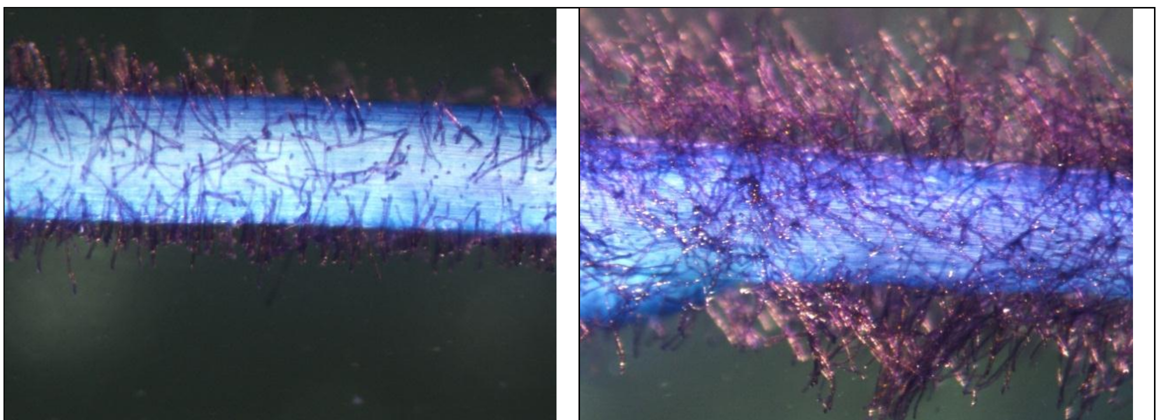


Figure 4: Relationship between basal root whorl number and basal root number measured in 165 bean genotypes. The correlation was significant at 1% (Coefficient of determination R^2 = 0.91). The values are average of replications.



a) Genotype with short and few root hairs	b) Genotype with long and dense root hairs

Figure 5: Illustration of common bean basal root of a genotype with few and short root hairs (a), and genotype with long and dense root hairs (b). The photos were taken at 40x magnification in 8 day old seedlings.

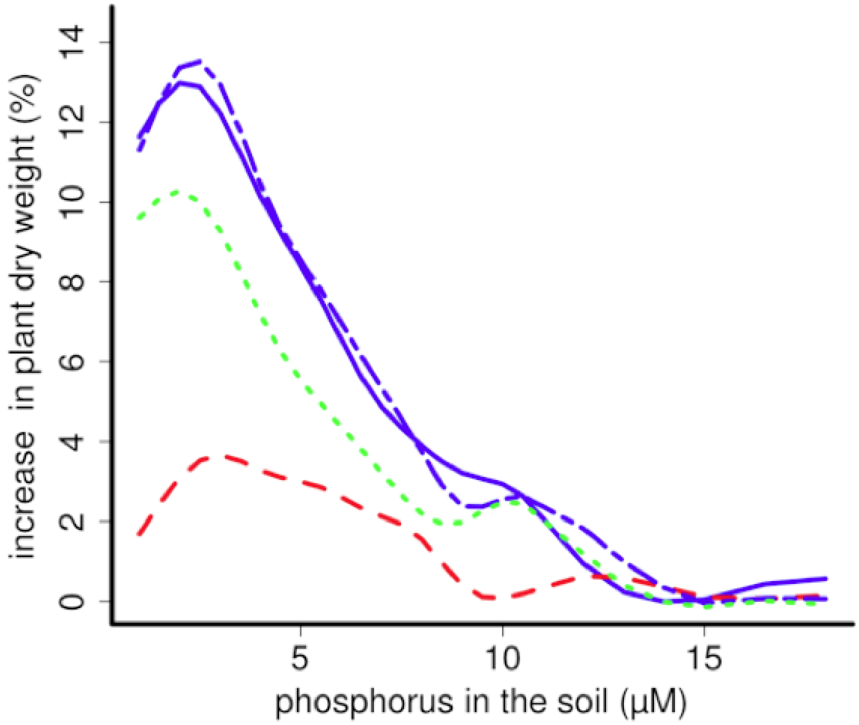


Fig 6. Expected benefit of RCA for growth of common bean to 40 days after germination as a function of soil P status.

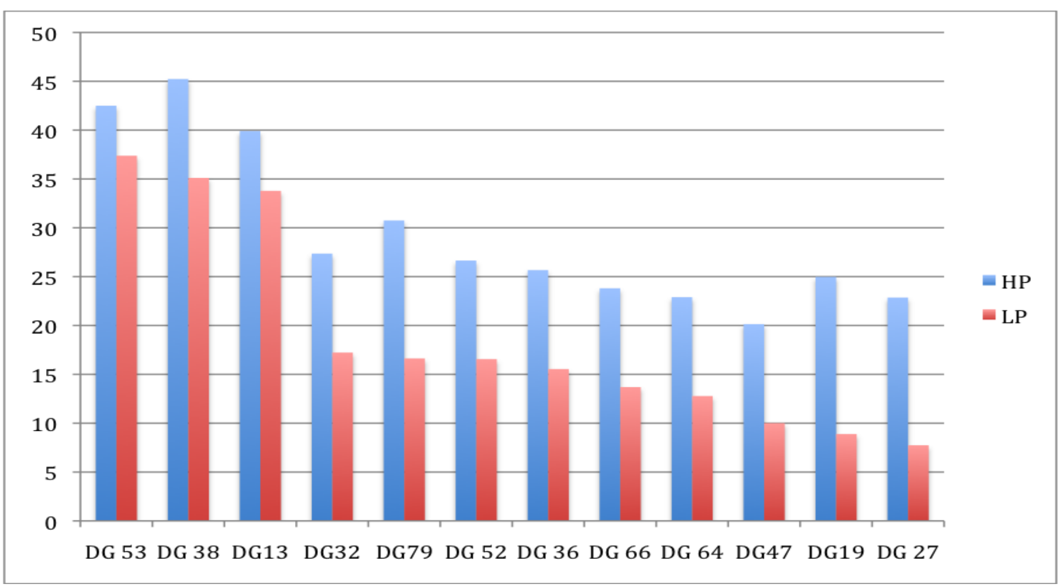


Figure 7. Shoot dry weight of 12 genotypes contrasting for root traits (Root hairs and basal root growth angle), grown under High P and low P treatments. The first 3 genotypes in graph (53, 38 and 13) have shallow roots and long root hairs. They showed significantly greater shoot dry weight compared to other genotypes from other root categories (see text above).

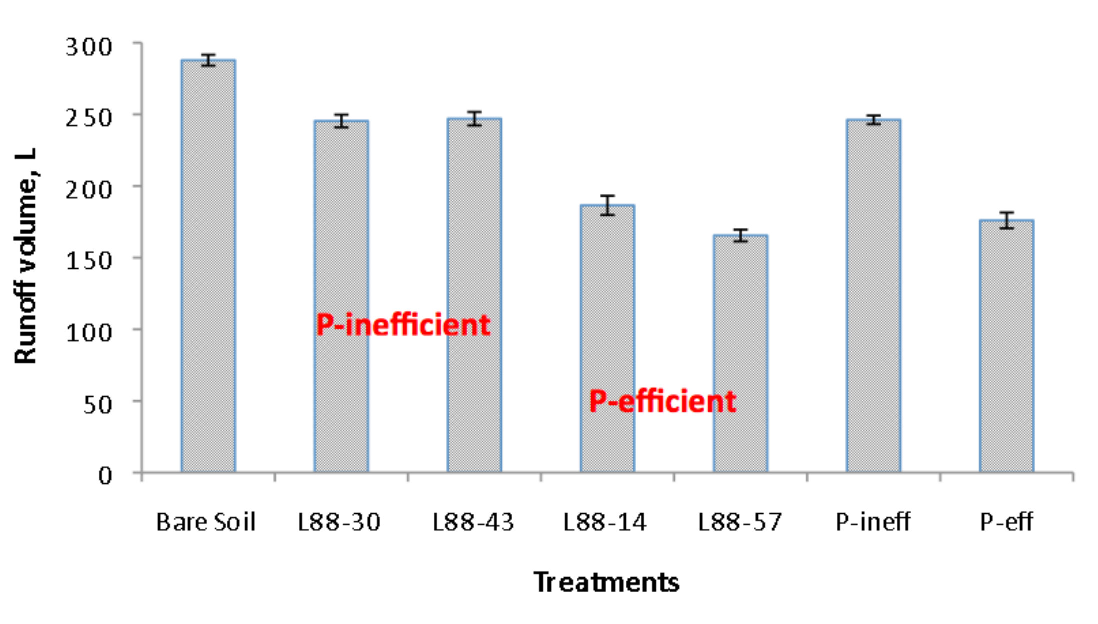


Fig. 8: P-efficient Common bean (Phaseolus vulgaris, L.) genotypes effects on runoff erosion in lysimeters installed in Lichinga in 2009.

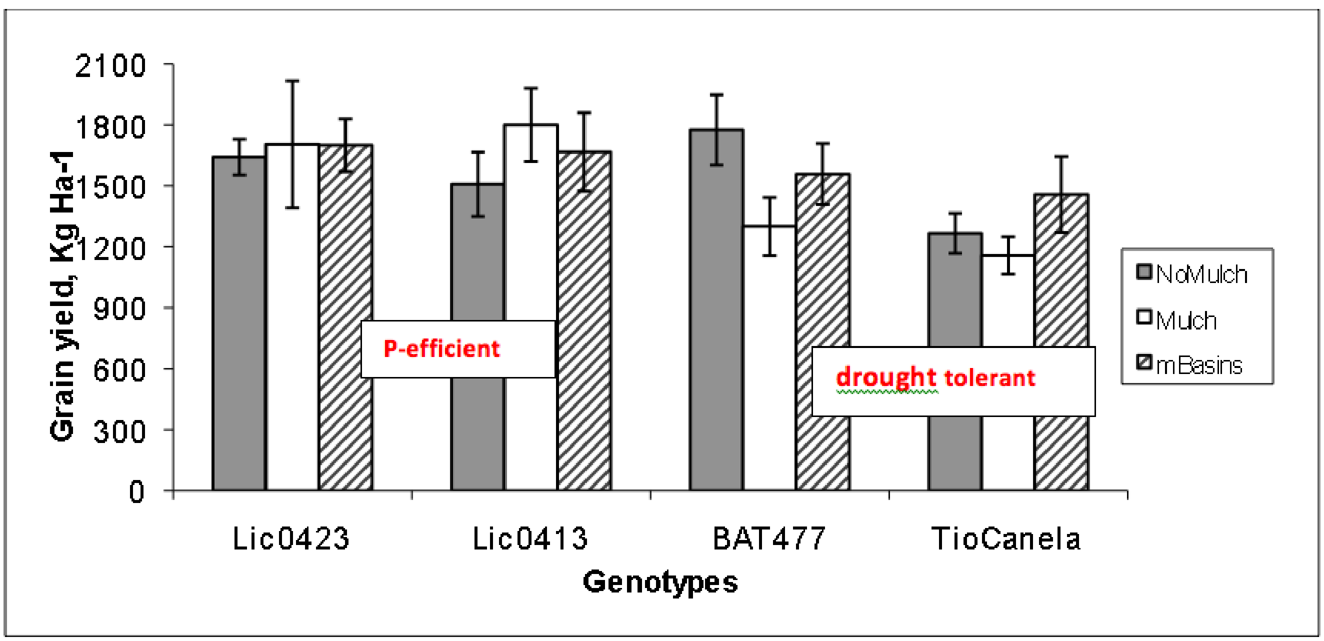


Fig. 9: Effects of moisture conservation techniques on yield of P-efficient and drought tolerant genotypes in Chokwe in 2010. Results of this year are not showing any consistent moisture techniques effects due to unusual wet season.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2009 – September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the M

Project Title: *Improving Bean Production in Drought-prone, Low Fertility Soils of Africa and Latin*

	Abbreviated name of ins									
	EAP			IIAM			PSU			
	Target	Achieved		Target	Achieved		Target	Achieved		Target
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10
	(Tick mark the Yes or No column for identified benchmarks by instit									
Objective 1										
Phenotype root traits	x	X		x	X		0			0
Screen for drought/low P tolerance	x	X		x	X		0			0
Introgress root traits for drought/low P	x	X		0			0			0
Field trial with selected genotypes	x	X		x	X		0			0
0	0			0			0			0
0	0			0			0			0
0	0			0			0			0
Objective 2										
analyze erosion study results Lichinga	0			0			0			0
establish soil moisture plots Chokwe	0			x	X		0			0
Conduct greenhouse studies w RP (co	0			x		X	0			0
Field evaluation of RP	0			x		X	0			0
Identification of genotypes w best resp	0			x	X		0			0
Intercropping study	0			0			0			0
0	0			0			0			0
Objective 3										
Code face-to-face surveys	0			0			0			0
Clean coded data set	0			0			0			0
Transcribe historical survey	0			0			0			0
Conduct network analyses	0			X	X		X	X		0
Analyze data	0			X	X		X	X		0
Draft survey report 1	0			X	X		X	X		0
Objective 4										
Training of Central American technicia	x	X		0			x		X	0
Application of root phenotyping metho	x	X		0			0			0
Recruit IIAM student/English training	0			0			0			0
MS student coursework	0			0			x	X		0
MS student research	0			0			x		X	0
Maintenance of Internet Access in Cho	0			x	X		0			0
web resource root methods	0			0			x	X		0
Name of the PI reporting on benchmarks by institution	J.C. Rosas			M. Miguel			J. Lynch			

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

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
(October 1, 2009 – September 30, 2010)

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

Project Title:
Lead U.S. PI and University:
Host Country(s):

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	1
Number of men	1	1
Short-term Training: Number of individuals who received short-term training		
Number of women	1	0
Number of men	1	2
Technologies and Policies		
Number of technologies and management practices under research	13	13
Number of technologies and management practices under field testing	8	7
Number of technologies and management practices made available for transfer	5	4
Number of policy studies undertaken	3	3
Beneficiaries:		
Number of rural households benefiting directly	630	1850
Number of agricultural firms/enterprises benefiting	280	284
Number of producer and/or community-based organizations receiving technical assistance	5 organizations	8
Number of women organizations receiving technical assistance	1	1
Number of HC partner organizations/institutions benefiting	3	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	1225	1120

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 was available for 2009 planting. The 2009 crop was sold by several warehouses as a premium export class and the production acreage increased in 2010. Plant Variety Protection (PVP) for CB50 was granted in early 2010. Elite novel dry grain 'all-white' cowpea line evaluations in four on-station trials for grain quality, yield, disease and insect resistance were positive in 2009 and 2010 and a release is being processed. In Burkina Faso, 3 new varieties are in the release process following strong farmer preference in multi-location trials. In Senegal, 30 Foundation Seed was produced to complete release of line ISRA-2065 with thrips and aphid resistance. Advanced multi-location yield trials were conducted in the 3 seasons (2008 – 2010) in Burkina Faso, Senegal and California on a about 150 lines for release selection based on grain quality, yield, and disease and insect resistance. Progenies of 40 crosses for developing new breeding lines were tested in Burkina Faso, Senegal and California to combine high yield, grain quality, and abiotic and biotic stress resistance traits. Most crosses were advanced to F4-F5 stage in 2010. Under the seed production and delivery systems objective, the following was achieved: In Burkina Faso, Breeder Seed of 9 improved varieties (>200 kg/entry) was grown in Pobe-Mengao, Foundation Seed of 4 varieties was produced at Saria and Pobe-Mengao, and 15 MT of Foundation Seed of 4 varieties from off-season production was sold to Certified Seed producers. 85 lead farmers were trained as Certified Seed producers. In Senegal, 3 ha each of Melakh and Yacine Foundation Seed was produced at Bambey to supply EWA NGO seed producer network. 44 ha each of Melakh and Yacine Certified Seed was produced by farmers in 2009, much produced in the Mekhe and Merina areas where women and men farmer groups were trained in seed production. Certified Seed production and training focused on farmer organizations. A student from Angola completed the first year of degree training in cowpea germplasm and breeding and will aid in Angola seed production and distribution system assessment. Multi-location trials of diverse cowpea lines were completed in Angola.

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. Genomics and modern breeding methods will be used to improve cowpea for yield limiting constraints, with leveraging of genomic resources developed under a complementary cowpea project.

<u>Increasing Cowpea Productivity.</u> 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 5-10 times greater. Drought, poor soil fertility, insect pests and diseases are major constraints. Cowpea varieties that yield more without purchased inputs especially benefit poor farmers, many being women who lack access to the most productive lands. Productivity is central to increasing rural incomes 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. 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.

<u>Increasing Marketing with Improved Varieties</u>: New cowpea varieties must have features desired by consumers and farmers, including grain appearance, desirable cooking and processing qualities 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 (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 new cowpea products based on the 'sweet' trait; sweeter and milder taste could help broaden cowpea consumption in the US, Africa and elsewhere.

<u>Increasing Seed Supply of Improved Varieties:</u> 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. Experience with improved common bean indicates rural African farmers will buy seed when available, indicating a probable market for cowpea seed.

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, now largely self-sustaining) but 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.

Training and Capacity Building: The research project provides an excellent framework for training current and new African scientists and capacity building for Host Country Institutions.

Planned Project Activities for April 1, 2009 - September 30, 2010

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 are being followed to achieve our research objective. We are completing final testing and release protocols of lines developed under the previous Bean/Cowpea CRSP and other germplasm in the development 'pipeline', and initiating new short- and long-term breeding strategies to develop high-yielding improved varieties.

Final Testing and Release of Varieties

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

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 one on-station trial location (Bambey) and at 6 on-farm sites in the Mékhé and Louga areas. The trials are designed with 4 replications and each plot 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.

In Angola, cowpea field evaluations will be conducted at two locations, with the aim of identifying candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal and/or Burkina Faso) and IITA varieties. Seed has been sent to Angola from UCR for the next season plantings, and Angola seed has been produced of local landraces for the comparative plantings. We anticipate plantings in both 2009 and 2010 will be needed to provide necessary field evaluation data. One or more of these candidates will become the first varieties to be formally produced under the project.

At UCR for 07-11-572 and 03-11-747 (or a related 'sister line'), a 'fast-track' release protocol is being followed to accommodate the needs of potential licensees for these varieties to be made available as quickly as possible. This is possible 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.

Short-Term Breeding Strategy

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. The varieties being improved by this approach are given in Table 2.

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. In the second workplan period (FY10), 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.

Longer Term Breeding Strategy

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 are using a 'two-stream' recurrent selection approach. One stream includes the six possible biparental crosses between highly drought tolerant lines SuVita 2, 58-57, TN88-63, and IT93K-503-1. The original plan was based on using seedling screens for drought tolerance up to the F3 generation. We modified this by screening the F2 and F3 generations under drought in the field at Coachella, CA. We are now testing the effectiveness of this approach by conducting a replicated trial with 16 experimental selections and 8 drought tolerant African lines under drought as described later in the results section. 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 SNP-based 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): 'CB50' was released by the University of California, Riverside in May 2008 as California Blackeye 50 (CB50). Approval of the Plant Variety Protection (PVP) was granted in early 2010 (PVP Application No. 200800395). A variety registration article was published in June 2009 in the Journal of Plant Registrations (Ehlers, J.D., B.L. Sanden, C.A. Frate, and P.A. Roberts. 2009. Registration of 'California Blackeye No. 50 Cowpea'. *Journal of Plant Registrations* 3: 236–240). CB50 has been designated as US Plant Introduction (PI) 655235 by the NCGRP. CB50 was 'genetically fingerprinted' at 1536 positions using the Illumina GoldenGate Assay. This fingerprinting will help in the enforcement of PVP infringement cases, and in future breeding activities. Approximately 18,000 lbs of Certified Seed of CB50 was planted on about 400 acres in the 2009 season, along with several hundred acres planted with 'field run/farmer-saved' seed for a total of more than 900 acres. Acreage expanded even more in 2010. Reports from warehouses concerning the productively and grain quality suggest that CB50 continues to show yields that are competitive with CB46, but higher grain quality that achieves a price premium. We continue to monitor the production of Foundation Seed of CB50 by the California Foundation Seed Program at UC Davis. J. Ehlers communicates regularly with FSP manager Richard O'Malley and visited the Foundation Seed field at UC Davis on Sept. 20, 2010, just prior to harvest to give advice on harvest procedures.

Selecting superior blackeye breeding lines from early and advanced generation nurseries: Improved breeding lines have been developed from ten F_2 populations derived from crosses between promising breeding lines and CB46 or CB27 (e.g. CB46 x CB50, etc). Single pod F_3 bulks were made from these ten populations at Shafter in 2005. These were advanced one generation by planting in late August at the Coachella Valley Agricultural Research Station in 2005 and 64 selections were made. At Shafter in 2006 the 64 F_4 lines were evaluated for agronomic and grain quality characteristics. Nineteen lines were judged to be outstanding and a single pod bulk of the selected rows was taken. The selected bulks were then planted in eight-row plots at Coachella in the fall of 2006 and 300 total F_5 lines were harvested. These were planted at Riverside and Shafter REC in May 2007 and visually evaluated for yield potential and grain quality. About 200 selections were made based on visual assessment of grain yield and quality. These were planted at Shafter in 2008, and 100 selections made. In 2009, these advanced lines were evaluated in two-row plots with two replications. Bulks were composited from selected lines by harvesting a single pod from each of 20 plants in the plot. In the fall 2009, ten seeds from each bulk were planted in the greenhouse to multiply 10 pure sub-lines of each of the selections. The sublines were planted at UC Kearney Center near Fresno, CA in 2010 in replicated two-row plots and seed of the most promising 20 lines harvested to provide sufficient seed for multiple row, replicated trials in 2011. At the same time, the selected sublines were used as parents in a crossing scheme to generate 26 new F1's as described below (Table 3). These were advanced in the greenhouse during Spring 2010 and the F2 seed harvested and then planted at Kearney. Approximately 100 single plant selections were made from these F2s.

Conducting line selection from third backcross/selection cycle progenies for development of a Fusarium wilt resistant version of CB5 (CB5-FWR): CB5 is an old, dependable-yielding blackeye variety with desirable large grain size. Unfortunately, the variety is susceptible to both race 3 and race 4 of Fusarium wilt. Susceptibility to Fusarium wilt was the main impetus for the development and adoption of CB46, which has strong resistance to race 3. Growers asked that a Fusarium wilt resistant version of CB5 be developed, so we are employing a backcrossing procedure to transfer the Fusarium wilt resistance in CB27 (resistant to both races 3 and 4) to CB5. In 2008, four highly resistant plants from this set were selected for inbreeding and line development. In 2009, seed of 30 lines from these selections was increased in the greenhouse and used for further greenhouse tests of resistance and for agronomic testing in the field in 2010. These were planted in a nursery at Kearney in 2010, and seed of 6 lines bulked for replicated tests that are planned for 2011. Genetic markers are now available for Fusarium wilt resistance (see comment below about advances in modern breeding made by our sister project which has developed modern breeding techniques in blackeyes). We will be able to verify which lines carry Fusarium wilt resistance using a DNA-based test, followed by confirmatory greenhouse tests of selected lines.

Developing lygus and aphid resistant blackeyes: In 2008 we conducted a large lygus bug resistance trial at Kearney having 30 entries, including CB27, CB46, and CB50. The entries were selected based on their performance in trials in 2007 that had either both protected (insecticide – Temik) and unprotected treatments or an unprotected treatment). In 2009 eleven lines were selected for inclusion into replicated trials with protected and unprotected treatments with three check entries, CB46, CB5, and CB50. Early (mid-May) and late (late June) planted trials were conducted. Unfortunately lygus pressure in the late-planted trial was insufficient for separation of resistance levels among the entries. In the early planted trial, three lines, 07kn-42, 07kn-46 and 07kn-74 had high unprotected yields in both 2008 and 2009, although they were not significantly higher in yield than CB46 in the 2009 trial (Table 4). They also had lower percent loss in yield than CB46, with average losses between 9 and 13% compared to 24% yield loss for CB46. 07kn-42 and 07kn-46 have extremely large seed, with an average individual seed weight of 0.279 mg under *protected* conditions, which was slightly larger even than CB50. In 2008 these lines also had high individual seed weights of 0.278 and 0.270 for 07kn-42 and 07kn-46, respectively, compared to CB46 individual seed weight of 0.216. We are quite sure the good yield performance under unprotected conditions is not due to escape from lygus pressure, since these lines all flowered and matured at the same time as CB46. Line 04kly-23 also exhibited low loss in yield due to lygus. However this line, matures several days earlier than CB46 and has a very compact growth habit and thus it is difficult to separate effects of escape from lygus infestation and true resistance to the pest. These lines appear to have yield potential equivalent to CB46 under protected conditions. This is important as yield potential is a difficult trait to breed for, so it will be significant if we have developed large-seeded, high yield potential lines with resistance to lygus. In 2010, 07KN-42, 07KN-46, 07KN-74 and 07KN-98 were re-tested at Kearney in a similar trial having protected and unprotected treatments. These trials (Figures 1 and 2) were just recently harvested and the data not yet analyzed. In addition, a trial with only unprotected plots and having 10 new experimental entries was conducted at Kearney.

Although the grain quality of 07kn-42 and 07kn-46 is not up to commercial blackeye standards, these lines both have very large seed (Table 4) which will simplify breeding large-seeded blackeyes when they are used as parents in crosses with blackeyes that are planned to be made in late 2010. Thus it will be relatively easy to now finish development of lygus resistant blackeyes by focusing on grain appearance and skin quality, while maintaining yield potential and lygus resistance.

Figure 1. CRSP lygus bug resistance trial with protected and unprotected plots at Kearney in 2010.

Figure 2. Lygus resistance trial with 10 experimental lines and two checks being grown without insect protection. Note center 4-row plot of standard variety CB46 exhibiting few pods due to lygus bug damage to flower buds.

All-white and dry-green grain classes: Tests of the yield potential of the 'all-white' 07-11-572 advanced line in 2008 and 2009 at two locations determined that it has grain yields equivalent to CB46. Tests conducted in 2010 comparing the yields of this line are expected to show similar results. 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 is new and unique in California, 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. In 2010, another green selection, 07-11-350 was compared to blackeyes. We are awaiting the harvest grain weights but expect them to show that 07-11-350 is also lower yielding than the standard blackeye variety 'CB46'. Thus a need was recognized to make additional crosses between 'green' breeding lines and between green lines and blackeyes. Twenty-nine crosses were made between California Blackeyes and 'green' breeding lines, advanced and the F2 planted at Kearney for selection of desirable grain quality (Table 5).

For this 'dry green' market class further testing of new breeding lines developed from previous crosses will be done to identify more promising materials before release is considered. Now 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 4).

In Burkina Faso (INERA): Field evaluations for final yield testing to support release of new varieties IT98K-205-8, KVx421-2J and Melakh were made during the 2008 and 2009 seasons. These are improved varieties obtained from the previous Bean/Cowpea CRSP collaborative activities (Table 1). 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 confirmed their good performance and farmer preference. The three 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 in 2008 and 2009. The positive responses to these evaluations indicated that cowpea farmers are ready to adopt these new varieties. Since the new varieties were preferred by the farmers in 2009, INERA proceeded to release them instead of making another on-farm test in 2010. Foundation Seeds have been bought by seed producers to produce Certified Seed for large production in 2011.

In Senegal (ISRA): The breeding line ISRA-2065 was developed under the previous Bean/Cowpea CRSP from a cross between the high-yielding CRSP cultivar 'Mouride' and aphid and thrips resistant local landrace accession '58-77', with the objective of developing a cultivar with the yield and stability of Mouride but with resistance to aphids and thrips (Table 1). 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, Nioro 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 again in the 2010 main season with larger plots (2500 m^2) on a total of 30 farms. These trials constitute the final activity for an official release which will happen during this coming off-season. The PADER project is multiplying 3 ha of ISRA-2065 seeds for use in the coming season.

In Angola (IIA): Cowpea field evaluations were conducted at three locations (Benguela, Cela, Malange), with the aim of identifying candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal and/or Burkina Faso) and IITA varieties. Seed of the IITA and CRSP lines for these field plantings was sent to Angola from UCR. Seed of some of the Angola local landraces for the comparative plantings was produced by Antonio David at UPR and shipped to IIA. This included 26 lines, of which half were initial selections, providing two lines per landrace. Results of the 2010 plantings are being evaluated. Ten local lines from Mazoso and Huambo were also included. The lines were assessed for growth type, disease incidence, seed type and agronomic characters, plus yield. Some Aschochyta blight disease occurred again in the recent trials, but not as severe as in the 2008-2009 trials. Thus we have initial data for making decisions on the best lines to test over additional locations in Angola. All the tested Angola lines were SNP-genotyped using the Illumina GoldenGate Assay. These data will be used by the CRSP student Antonio David in his diversity analysis of Angolan cowpea, as a comparative study with the core IITA/CRSP germplasm lines. We anticipate plantings in both 2009 and 2010 will be needed to provide necessary field evaluation data. One or more of these candidates will become the first varieties to be formally produced under the project.

<u>Advanced yield trials:</u>
In Burkina Faso (INERA): Two advanced yield trials were conducted at Saria and Pobe Mengao in 2008, 2009 and 2010. 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 and 2009 trial data allowed selection of the best performing lines and these were harvested at the two sites in 2009. The best performing lines were planned to be re-tested in the 2010 season. Five candidate best performing lines were selected as potential varieties (KVx 908-3P2, KVx 907-2P2, KVx 912-22P1, KVx 912-1P1 and IT 98K-1111-1) and were grown in replicated yield trials at Pobe and Saria in the 2010 main season in order to choose the best two varieties that will be evaluated on-farm in 2011 season. The yield and quality data from 2010 are being processed.

In Senegal (ISRA): Two advanced yield trials were conducted at the Bambey, ISRA field station in 2010. 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 26 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 in 2009 and 2010. 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.

Figure 3. Large-scale strip trial at Shafter in 2010 with new experimental entry P-87, CB50, CB46 and CB5. Each of the replicated plots is 12 rows wide x 300 feet long.

In California: Evaluation of three 'new' advanced blackeye breeding lines for grain yield and quality, and agronomic characteristics was conducted at two locations in 2009 and 2010 (Figure 3): A set of five advanced blackeye lines were identified as potential blackeye cowpea varieties for the US. These were reduced to three candidate lines following trials conducted in 2008 (see Table 6). In 2009, replicated trials comparing yields and grain quality of CB46, CB50 and three 'new' blackeye breeding lines were conducted under early-planted double-flush and late-planted single-flush production systems. The experimental design for all four trials was a Latin Square with 6 replications. At Shafter, trials were planted on May 13 and June 24 for the early and late-planted trials, and cut on Sept. 2. At Kearney the trials were planted on May 20 and June 25 for the early- and late-planted trials, and cut on Sept. 24. Unfortunately, the second planting at Shafter was inadvertently destroyed shortly before harvest by a custom harvesting operation that mistakenly went into the experimental area. Threshed grain samples from all harvested plots were cleaned and the clean seed weighed. Seed size (100 seed weight) was determined from counts of 100 random seeds from each plot sample. The three advanced lines (P-87, P-191, and P-203) have now been tested a total of 4 years. Yield data over the four years and two locations suggested that only P-87 should be tested as a varietal candidate in larger-scale trials. P-87 had greater average yield than CB46 over the four years of tests at Kearney, yielding 42.6 cwt/ac compared to 40.5 cwt/ac for CB46. P-87 yields were greater than CB46 in three of the four years at Kearney. One interesting and consistent observation we have made in trials conducted from 2007-2009 is that seed-coat 'checking' or splitting of P-87 was consistently less compared to CB46 in each test, averaging 9% vs 18% 'splits' for CB46. After analyzing the results of the trials conducted in 2009, one variety (P-87) was selected for more comprehensive evaluation in 2010. P-87 was included in a large-scale replicated strip plot trial at Shafter and an advanced trial at Kearney. The trials are being harvested in late October.

Crosses for developing new breeding lines:

In Burkina Faso (INERA): Dr. Drabo made all the planned crosses, and these are summarized in Table 7. The F1 generation seed of each cross was advanced to F5 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 8. For introgressing Striga resistance, Yacine was crossed with a more recent line (IT90K-76) instead of Suvita 2. Advanced lines from Melakh and Montiero derived genotypes with large seeds were tested 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, IT90K-77, IT90K-76, IT97K-499-39, IT81D-994, and IT82D-849, and with IT93K-503-1 and 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.

For Angola (IIA): In order to 'jump-start' the Angola cowpea breeding program, selected F1 hybrids were produced at UCR using a diverse range of elite lines (Table 9). The F1's were grown in the greenhouse during Spring 2010, and the F2s planted either at Riverside or Coachella, CA. F2 populations involving parents that are day neutral were planted in July at Riverside, while crosses involving late or photoperiod sensitive parents were planted in mid-August at Coachella (Figure 4), which provides the combination of short day-lengths and high temperatures needed for flowering and pod development of photoperiod sensitive cowpea lines.

Figure 4. The F_2 'Angola' cowpea breeding nursery at Coachella, CA, Oct, 2010.

In California: The planned crosses were made at UC Riverside during the summer of 2008 for use in the recurrent back-crossing program (Table 10). 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 to assess seed size and quality, and several promising lines were selected and re-evaluated in field plots in 2009. In 2010, the most promising selection was included in replicated trials at Kearney locations and plots have been harvested for yield and grain quality determinations but not yet analyzed. 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 11). 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 Coachella 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. Sixteen promising lines were identified based primarily on seed yield under drought and these were used to formulate a replicated terminal drought tolerance trial planted at Coachella in mid-August 2010. This trial was irrigated until flower bud formation, and then irrigation was stopped. In addition to the 16 experimental CRSP lines, 9 drought tolerant African lines were included in the trial. This trial will be harvested in November 2010. 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 7, 8, and 10.

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., 2009d). We have begun to implement MABC since 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. Some genotyping through the platform was conducted in late 2009 and early 2010 to aid in progeny selection.

Promising pigeonpea cultivar for the US: A limited amount of work conducted on selecting high-yielding pigeonpea for the US has been ongoing at UCR for the last ten years. Under the current Dry Pulse CRSP, this work can be brought under this project. Pigeonpea is an important pulse crop grown in the tropics and subtropics lying between 30°S and 30°N. It occupies 6.5 percent of the world's total pulses area and contributes 5.7 percent to the total pulses production. The crop has its origin in India, and spread to many places around the world, but particularly Africa and the Caribbean. Most pigeonpea varieties cannot be grown in California because they require season lengths of 150 or more warm and frost-free days. UCR-GA1 is an early-maturing pigeonpea variety adapted to summer production of fresh pods for shelling and dry grain in the Central Valley of California. UCR-GA1 begins flowering in approximately 75 days from sowing in a typical season in the southern San Joaquin Valley, and is ready for harvest 130 - 140 days after sowing. The grain color is silver and weighs about 12 grams per 100 seeds. UCR-GA1 is an early-maturing pigeonpea selection derived from an F_5 breeding line of the cross of GA-1/PR-147 supplied by Dr. Sharad Pathak at the University of Georgia in 2003. This line was planted out in the field at UCR in 2004 and single plants selected for early maturity, high podset and large grain with white/silver grain color. Single-plant selection was conducted for 5 additional seasons in nurseries conducted at Shafter and Kearney, CA, for earliness, grain yield and quality. Currently a 2010 replicated trial of 7 related selections is being conducted at Kearney and we anticipate bulking seed from the best selection to comprise the Foundation Seed of this variety.

Objective 2: 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 7 MT of Foundation Seed on 5 ha planting. This will address the estimated 5 % 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 Tougan (Sourou Province). A total of 40 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 2 ha of Melakh, 2 ha of Yacine and 1 ha of ISRA-2065 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 (Touba Toul, Thilmakha, Mekhe districts) and also in the Louga region with the Millennium objectives project and the RESOPP, a farmers organization previously supported by EWA. 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 had planned 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. However, the planting failed due to severe Ascochyta infection. Therefore, a repeat of this effort in a different location will be made in the 2010 seasons.

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. Breeder seeds produced last season allow us to grow 15 ha of Foundation Seed with the CRSP funds and 145 ha of Foundation Seed by INERA funds during the current reporting period. The varieties were IT98K-205-8, Melakh, KVX421-2J, KVX414-22-2, Gorom Local, KVx 61-1, KVx 745-11P, KVx 396-4-5-2D and KVx 396-4-4. The quantity of seed produced will allow a doubling of the quantity of Certified Seed in 2011. Dr. Drabo's team trained 45 farmers at Tougan and 40 farmers at Saria during the current reporting period.

In Senegal: 2 ha each of Melakh and Yacine and 1 ha of ISRA-2065 Foundation Seed was produced at the ISRA Bambey station. It is expected that at least 100 kg of each variety will be made available to the NGO. This network has several women seed producers as members. In the Thilmakha area, Foundation Seeds were distributed to two farmers for production of 1 ha of Melakh and 1 ha of Yacine Certified Seeds during the 2010 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 10 ha of Melakh and Yacine each. In UGPM, the group is comprised of about 5000 members of whom 61% are women. At Touba Toul, a locality near Bambey, 20 ha of Melakh and Yacine Certified Seeds were produced by a farmers' organization (Central D'achat) which purchase inputs in bulk for its 3056 members, for whom 55% are women. With the closing of the EWA activities in the Louga area, we supplied 8 ha of Certified Seed production to the farmers' cooperative RESOPP. Additionally 11 ha of Melakh and Yacine seeds were produced by the Millennium Village Project which has 1343 members comprised of women and men. Training of farmers during the 2009 and 2010 seasons for seed production consisted of field selection, removal of off-types and diseased plants, and both harvest and post-harvest handling. Double bags will be provided to farmers for storage.

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 and Dr. Porch who visited Angola in 2009 for similar assessments of the bean breeding and seed distribution setup. We have a site visit to Angola planned for late 2010 and are confident that our interactions with the new Angola trainee Antonio David focusing on cowpea in the MS program at UPR will help develop new approaches with target cowpea varieties.

Objective 3: Capacity Building

Develop a cowpea breeding program in Angola and strengthen existing breeding programs in Senegal and Burkina Faso through targeted training.

Approaches and Methods: A cowpea breeding program in Angola will be developed and the existing cowpea breeding programs in Burkina Faso and Senegal will be strengthened through targeted training of existing and new cowpea program personnel, and the development and provision of user-friendly manual-format and web-based cowpea breeding guidelines. The Host Country partners provide a spectrum of opportunities and needs for developing and strengthening cowpea breeding programs. They are representative of neighboring cowpea producing countries in this sub-Saharan production area. Therefore, training activities and outputs can be 'regionalized' to attain broader impact, for example in Ghana, Mali, Niger, Nigeria, and Zambia. We have partnered with Burkina Faso and Senegal cowpea breeding programs for many years. The programs in these countries are relatively mature, particularly in Senegal, and have benefited from staffing with senior cowpea breeders and other scientists working on agronomic, pest and disease problems, coupled with recognition and support from their national institutions (INERA and ISRA). In contrast, Angola represents a cowpea producer with excellent production, marketing and consumption potential, but requiring considerable aid to develop a viable national cowpea breeding program. The Pulse CRSP can make significant positive impact toward this goal, by taking advantage of the interest and experience of key scientific personnel, led by HC PI Dr. Antonio Chicapa Dovala. Dr. Dovala has long-term experience working with legume crops, with focus on plant pathology problems, and initial exchanges of cowpea germplasm have started with the UC Riverside program. The targeted training will comprise the following components:

Degree (MS and PhD level) training for two African scientists will be undertaken with the goal of developing the next generation of cowpea breeders. The project team is aware of some potential trainee candidates but individuals have not yet been selected. One trainee (Antonio David) has been identified from Angola, where a new cowpea breeder will fully complement the plans to develop a new cowpea breeding program. This trainee will complete the MS course in plant breeding at the U. Puerto Rico, in collaboration with Dr. James Beaver.

In countries with established senior cowpea breeders such as Burkina Faso, Senegal, and Nigeria, PhD student training now would anticipate gaps arising as senior breeders reach retirement. Degree training for one PhD student will be conducted at the University of California Riverside in the Plant Biology or Plant Pathology graduate program. Research topic and guidance will be overseen by the UCR PIs and encompass Objective 1 activities for marker-assisted cowpea breeding focused on abiotic and biotic stress resistance traits. Two candidate trainees (Penda Sarr, Senegal and Arsenio Ndeve, Mozambique) were brought to UCR during Fall 2009 –Spring 2010) for intensive English language training, in preparation for their TOEFL and GRE tests for Graduate Program entrance at UCR.

Training current cowpea breeders in the development and application of DNA-based markers for MAS in the cowpea breeding programs will be embedded in the research effort under Objective 1. Cowpea breeders are being trained in marker application utilizing their own breeding populations generated by the high x high crosses and recurrent back-crossing for existing variety improvement made within the programs. This is focused on the Senegal and Burkina Faso programs. ‘Shuttle’ screening of progenies with trait markers and yield QTL between UC Riverside and the Host Countries has been initiated, with joint interpretation of data sets and progeny selections as a hands-on MAS and MARS experience. The markers were chosen from the cowpea SNP development and SNP genotyping (using Goldengate Ilumina assay) done at UC Riverside. Markers linked to traits including drought tolerance and *Macrophomina* resistance identified under Objective 1 are being used for genotyping.

Development of a practical guide to cowpea breeding is in the draft stage, with the original target of having an in-field assessment by breeders and trainees during the West Africa 2010 growing season, followed by final modification and publication. The guide emphasizes primary target constraints to cowpea yield in Africa and incorporate application of DNA marker technology to breeding. We plan to publish the guidelines in hard-copy manual format that can be taken to the field, greenhouse or lab, and a web-based version of the same document that can have a broad distribution and be easily accessed as a teaching/training resource. The aim is to have the cowpea breeding guide available for all cowpea breeding programs in Africa and elsewhere. The key elements of the guide cover maintenance and storage of cowpea germplasm, selecting parents, making crosses and selfing for breeding line development, field and greenhouse grow-out and selection, major trait phenotypes (agronomic characters, pest, disease and abiotic stress symptoms and resistance), application of molecular markers for traits for MAS, and requirements for candidate variety testing and new variety release protocols. In the current draft, we are extending the scope to include our initial experiences and recommendations for using the high-throughput SNP marker genotyping technology which has come online this summer. We plan to finalize the Guide during the FY11 to provide a high quality product with the cutting edge technology application included.

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 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: $40,000
Indirect cost: None
U.S. or HC Institution to receive CRSP funding for training activity: UC-Riverside.

PhD Student 2:
First and Other Given Names Marti
Last Name Pottorff
Citizenship USA
Gender: Female
Degree Program for training: PhD
Program Areas or Discipline: Plant Breeding/Genetics/Plant Pathology
Host Country Institution to Benefit from Training
University to provide training: UC-Riverside
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? No.

Supervising CRSP PI: PA Roberts
Start Date October, 2008
Projected Completion Date March 2011
Type of CRSP Support (full, partial or indirect) parial/indirect
If providing Indirect Support, identify source(s)s of leveraged funds: UC-Riverside GSR funds; GCP project funded to UC-R
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost:
Indirect cost: $10,000
U.S. or HC Institution to receive CRSP funding for training activity: University of California - Riverside

PhD Student 3:
First and Other Given Names: TBD
Last Name TBD
Citizenship African country
Gender: Female
Degree Program for training: PhD
Program Areas or Discipline: Plant Breeding/Genetics/Plant Pathology
Host Country Institution to Benefit from Training TBD
University to provide training: UC-Riverside
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 January 2011
Projected Completion Date October 2012
Type of CRSP Support (full, partial or indirect) Partial
If providing Indirect Support, identify source(s)s of leveraged funds: UC-Riverside GSR funds; GCP project funded to UC-R
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $21,045
Indirect cost:
U.S. or HC Institution to receive CRSP funding for training activity: University of California – Riverside

Vehicles were purchased for the HC projects in Angola and Burkina Faso) (I. Drabo, INERA and A. Chicapa, IIA) in support of field-based research and training and seed systems dissemination.

Explanation for Changes
Under Objective 1 - Varietal identification and release (IIA): While the field evaluations of promising cowpea lines are continuing, additional data in different growing areas is required to support a formal release. In part this has been impacted by disease problems in some of the field trials.

Under Objective 3 - Training: PhD Training (Breeding-HPR): Difficulty was encountered in identifying an appropriate African student for this program, due to English language inadequacy. Two African student candidates have come to UC Riverside for intensive English language training; both are currently taking TOEFL and GRE exams with the goal of having at least one of them enroll in the UCR graduate program in the winter quarter of this academic year.

Under Objective 3 - Training: Breeding Guide: We have drafted a Breeding Guide, but have extended its scope to include our initial experiences and recommendations for using the high-throughput SNP marker genotyping technology which has come online this summer. We plan to finalize the Guide during the FY11 to provide a high quality product with the cutting edge technology application included.

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, and Dr. Barry Pittendrigh of the Dry Pulse CRSP project with cowpea lines for his insect management project. We are also working with Dr. Jim Beaver at the University of Puerto Rico on training a CRSP student from Angola. Under the CGIAR-GCP funded project Tropical Legumes 1, we are leading the cowpea improvement Objective and interact with a large international network of tropical legumes researchers.

In Burkina Faso, we had been working with AFRICARE, a NGO financed by USAID to ensure food security. The collaborative work aimed to develop new Striga resistant varieties adapted to intercropping. A collaboration with LVIA, a NGO financed by the EU and Italy, which aimed to train farmers for cowpea Certified Seed production and conservation, was also developed. However, during the current period, both AFRICARE and LVIA have ceased activities in Burkina Faso. With Association FERT, a French NGO whose aim is to improve cowpea production in the northern part of the country, we have continued on-farm tests of improved varieties and 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 addition, collaboration was started with a Seed Producer Association named Venegre and one seed entrepreneur named Famille Kabre.

In Senegal, collaboration was established with the extension service ANCAR in the Kaolack and Thiès regions and with the PADER project of EWA in the southern region of Sedhiou, for Certified Seed production of the advanced breeding line ISRA-2065. The Millennium project and ANCAR-Thiès were involved in seed production in the Louga, Mekhe and Touba Toul regions. In 2009, The Kirkhouse Trust started supporting activities on marker-assisted backcrossing for Striga resistance, by providing $20,000 annually for 3 years.

Leveraged Funds

Other resources leveraged from current and future funded complementary cowpea research projects include the following:

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, long-term 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) was approved for a 4-year extension of funded research (Phase 2, May 2010 – April 2014). 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), Senegal (PI N. Cisse), and IITA (PI, C. Fatokun and O. Boukar). This project funded at nearly $1.9M (Phase 1) and $2.8M (Phase 2) is developing and applying 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 for 2010 and 2011 was approved 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.

<u>INERA leveraged funds:</u> 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 $22,420 from GCP commissioned project for cowpea drought resistance. A new cowpea seed systems project started in 2010 with funding ($36,000) from the Japanese Government in collaboration with IITA (IITA/ AVEC-BF Project).

<u>ISRA leveraged funds:</u> The Kirkhouse Trust has started supporting from June 2009 activities on marker assisted backcrossing for Striga resistance; $20,000 will be provided annually for 3 years.

List of Scholarly Activities and Accomplishments

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

Das, S., D.A. DeMason, J.D. Ehlers, T.J. Close, and P.A. Roberts. 2010. Transcriptional profiling of root-knot nematode induced feeding sites in cowpea (*Vigna unguiculata* L. Walp.) using a soybean genome array. *BMC Genomics* 2010, **11:**480. doi:10.1186/1471 2164-11-480.

Ehlers, J. D., B.L. Sanden, C.A. Frate, A.E. Hall, and P.A. Roberts. 2009. Registration of 'California Blackeye 50' Cowpea. *Journal of Crop Registrations* 3:236-240.

Muchero, W., J.D. Ehlers, T.J. Close, and P.A. Roberts. 2009a. Mapping QTL for drought stress-induced premature senescence and maturity in cowpea (*Vigna unguiculata* (L.) Walp). *Theoretical and Applied Genetics* 118:849-863.

Muchero, W., J.D. Ehlers, and P.A. Roberts. 2009b. Restriction fragment length polymorphism-based candidate gene mapping for seedling drought tolerance in cowpea (*Vigna unguiculata* L. Walp.). *Theoretical and Applied Genetics* 120**:**509-518.

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* 25:47-56.

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.

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

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* 41:120-127.

Tonessia C., M. Wade, N. Cissé and S. Aké. 2009. Caractérisation de Striga gesnerioides (Willd.) Vatke du Sénégal: réactions de plusieurs cultivars de niébé (*Vigna unguiculata* (L.) Walp.). Journal of Applied Biosciences 24:1462-1476.

California Blackeye 50 (CB50). Approval of the Plant Variety Protection (PVP) was granted in early 2010 (PVP Application No. 200800395). A variety registration article was published in 2009 in the Journal of Plant Registrations. CB50 has been designated as US Plant Introduction (PI) 655235 by the NCGRP.

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

Contribution to Gender Equity Goal

Among the target beneficiaries of the project work, the activities in Burkina Faso and Senegal resulted in 23 producer/community based organizations being recipients of technical assistance during the report period, which are comprised of women and men. In addition, 17 Host Country partner organizations/institutions in Burkina Faso and Senegal benefitted from the seed systems technology. More specifically, five women organizations received technical assistance in Senegal and Burkina Faso. Also short-term training of 25 women and 24 men was accomplished. The technical assistance was focused on seed system processes under Objective 2, for growing, harvest handling and storing cowpea planting seed (Certified Seed production). This activity was further supported with Supplemental funds for “Technology Dissemination”.

Progress Report on Activities Funded Through Supplemental Funds

1. Technology Dissemination Supplement:
   ISRA Senegal: In Senegal, the availability of Foundation Seed is a bottleneck for adequate supply of seed to farmers. Additional Foundation Seed was planned to be produced of three varieties (Melakh, Yacine, ISRA-2065) to supply new Certified Seed to growers. 1 T of Melakh and Yacine and 200 kg of ISRA-2065 Foundation Seeds were produced during the off-season (March – May 2010) under irrigation to complement the Foundation Seed obtained during the rainy season of 2009. The project team worked with the National Extension Service (ANCAR) and 80 farmer organizations at 4 locations (Thilmakha, Touba Toul, Mekhe, Louga), where farmers (100 – 200) were trained in seed production, harvest and post-harvest handling. ISRA focused in particular on Mekhe, a federation with 70 member farmer organizations, with the capacity to supply communities with cowpea seed sold through their storage facilities and in local markets. It was estimated that 50-60 T of Certified Seeds would be produced. Seed will be packaged in 4 Kg bags from a government processing unit in Diourbel near Bambey. At least 50 ha of Melakh and Yacine were grown initially for Certified Seed, with the goal of scaling up in the second and third years. The target of 100 ha was not met because of shortage of

seeds due to additional needs of ISRA seed unit for a special government program. During the 2010 growing season 2-3 T of Foundation Seed was produced at the ISRA Bambey Research Station. Support was provided to the RESOPP and Millennium objectives project to expand its cowpea seed production.

INERA, Burkina Faso: In Burkina Faso, during the three-year project Breeder Seed of seven improved cowpea varieties (e.g., IT98K-205-8, Melakh, KVX421-2J, KVX414-22-2, KVX442-3-25, KVX775-33-2, Gorom Local) will be produced in off-season plantings at Bazega, Bagre and (or) Di under irrigation. In 2010 the varieties KVX414-22-2, KVX442-3-25, and KVX775-33-2 were replaced by KVx 908-3P2, KVx 907-2P2, KVx 912-22P1, KVx 912-1P1 and IT 98K-1111-1. This adjustment was based on farmer preferences and previous seed development. During FY 10, 1 ha of Breeder Seed production was planted at Bagre in February 10 and grown under irrigation. This yield about 700 kg of Breeder Seed of the best 4 varieties. This supported Foundation Seed production on the INERA station sites (Saria, Pobe, and Kamboinse) during the main 2010 cowpea production season. Also at Di, 4 ha of Foundation Seed was produced under irrigation from February to May, 2010, using Breeder Seed produced during the 2009 main production season. This planting yielded about 4 T of Foundation Seeds. The Foundation Seed produced will be fed into the supply for Certified Seed producers. These off-season seed production activities were used to train seed producers on the protocols of quality seed production, seed conservation and seed marketing. Theory and practical training was conducted at three locations (Tougan, Pissila, and Donsin), during the period April – May, 2010. This activity trained 120 farmers, of which at least 30 were women. The 120 trained farmers were guided in producing Certified Seed of the INERA improved cowpea varieties. Each farmer planted 0.5 ha (total of 840 kg of Breeder seeds) starting at the end of June 2010 in several villages of three provinces (Souro, Oubritenga, and Sanmatenga). This activity is estimated to generate 40 T of Certified Seed produced on a total area of 60 ha. Two visits by the INERA national cowpea research team were made to each farmer’s field during the June-September production season to provide updates on practical training and advice.

A meeting of cowpea scientists and breeders was held in April 2010 in Ouagadougou (with Dr. Baoua, INRAN) to deliver planting seed of improved Senegal and Burkina Faso cowpea varieties and to discuss protocols for field testing. Varieties from Senegal and Burkina Faso were tested in Niger and Mali during the main 2010 growing season. A preliminary yield trial with 8 lines of Senegal and Burkina Faso was send to Mali and Niger for the 2010 tests, but we could not travel in Mali. The trials were also conducted in Senegal and Burkina. The two best performing varieties will be chosen for Mali and Niger expansion in following years using the Breeder to Foundation to Certified Seed production pipeline.

2. Capacity Building Supplement:
   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, A supplement of $3,500 was approved in September, 2009 for one technician from ISRA's cowpea breeding program to be trained at the regional pathology laboratory of Aghymet in Niger under the supervision of Dr. Mbaye Ndiaye. Ngor Diagne was trained in techniques to collect, prepare, and conserve infected plant samples for the identification of fungal (Macrophomina), bacterial and viral diseases of cowpea, and for inoculation of cowpea genotypes to be phenotyped for resistance and susceptibility.
2. INERA, Burkina Faso: A supplement of $39,000 for the purchase of a vehicle implementation of INERA's cowpea breeding program and to serve the needs of stakeholders of cowpea value chains in Burkina Faso was approved in September, 2009. The vehicle was purchased in July, 2010, and has been used during the cowpea main growing season in 2010.
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. Purchase of the vehicle was made in September 2010, and is thus available for the next cowpea season (starting November 2010). A supplement of $10,000 for purchase of an environment controlled incubator shaker cabinet and a dissecting microscope plus associated miscellaneous supplies for the Plant Pathology Lab to serve both the cowpea and bean Angola projects under the Pulse CRSP was approved in September, 2009, and the purchase is pending.

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, IT90K-76, IT82D-849
Mouride	ISRA	Large grain	Montiero derived line
Melakh	ISRA	Striga resistance	IT97K-499-39, IT81D-994
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 between advanced blackeye breeding lines and blackeye cultivars that were made, advanced, and the F2 planted at Kearney in 2010.

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

Table 4. Entry, grain yield, % grain damage due to lygus, and individual seed weight of CB46, CB50 and CB27, and 11 lygus resistant lines grown under unprotected (Unpro) and protected (Pro) conditions in a replicated trial at Kearney in 2009. Unprotected yield rank data from 2008 also included for comparison.

	Grain Yield				**Damaged Seeds**		
	2008	**2009**			**2009**		
Entry	**Unpro**	**Unpro**	**Pro**	**Loss**	**Unpro**	**Pro**	**Seed weight**
	Yield Rank	**cwt/ac**		**%**	**%**	**%**	**gm**
07kn-42	1	28.1	31.0	9	21	1	0.279
04kly-23	5	26.9	29.9	10	22	3	0.209
07kn-74	3	26.6	29.5	10	27	3	0.223
07kn-46	2	25.9	30.1	13	28	5	0.279
07kn-98	7	24.1	27.9	13	29	3	0.180
04kly-131	9	24.7	28.9	15	18	2	0.219
CB27	Not tested	27.7	34.2	16	31	3	0.217
07kn-59	4	26.6	29.2	23	31	4	0.234
07kn-103	6	24.4	32.5	24	30	7	0.227
CB46	12	23.9	31.9	24	21	3	0.214
07kn-81	11	22.3	29.0	26	31	2	0.199
04kly-2	10	18.9	26.0	27	24	4	0.205
CB50	NT	25.1	34.9	28	25	3	0.265
04kly-152	8	21.8	31.3	30	26	26	0.225
Trial Mean		24.8	30.5	19	26	3	0.227
LSD(0.05)		7	6.9	19	12	2	0.020
CV(%)		20	15.9	65	32	30	6

Planted May 20, 2009; hand harvested August 23 (95 days).

Table 5. Crosses made between promising persistent green blackeye breeding lines and CB46, CB27 and 524B during late 2009 to develop blackeyes with improved yield and seed quality. The F1's of these crosses were grown in the greenhouse to produce F2 seed that was planted in a nursery at Kearney in 2010.

Green	2009-012	08-11-49 x 07-11-351
Green	2009-013	08-11-70-1 x 08-11-154
Green	2009-015	08-11-153 x 08-11-110
Green	2009-016	08-11-187-3 x 08-11-65
Green	2009-017	CB46 x 07-11-350
Green	2009-018	CB46 x 08-11-70-1
Green	2009-019	CB46 x 08-11-91
Green	2009-020	CB46 x 08-11-187-2
Green	2009-021	07-11-350 x CB46
white	2009-022	CB50 x 07-11-557-1-25
Green	2009-023	CB50 x 08-11-49
Green	2009-024	CB50 x 08-11-60-2
Green	2009-025	CB50 x 08-11-70-1
Green	2009-026	CB50 x 08-11-132
Green	2009-027	CB50 x 08-11-140
Green	2009-028	CB50 x 08-11-186
Green	2009-029	08-11-70-1 x CB50
Green	2009-030	08-11-78 x CB50
Green	2009-031	08-11-103 x CB50
Green	2009-032	08-11-106 x CB50
Green	2009-033	08-11-187-3 x CB50
Green BC1	2009-035	CB50 x 02053F1
Green BC1	2009-036	02053F1 x 07-11-350
Green BC1	2009-037	02053F1 x 02082F1
Green	2009-038	CB46 x G747-1
Green	2009-039	G749-1-1 x CB46
Green	2009-040	CB50 x G749-1
BExBE	2009-042	CB50 x CB5
BExVeg	2009-049	CB50 x 08-11-MASPE

Table 6. Source, pedigree, days to maturity, nematode and Fusarium wilt resistance of CB5, CB46, CB50, and three new blackeye breeding lines that were tested in small plot evaluations at Kearney and Shafter in 2009.

Entry	**Source**	**Pedigree**	**Fusarium Resistance**		**Days to Maturity**	**Nematode Res.****
			Race 3	**Race 4**		
CB5	Variety	Calif. BE/Iron	S	S	85	Rk
CB46	Variety	CB5/PI166146// CB5	R	S	80	Rk
CB50	03-Sh-50	CB46/98-8-622-2	R	R	85	Rk+
P-87	04-Sh-79-1	UCR 541/CB27	R	R	80	Rk
P-191	04-Sh-255-2	UCD9259/96-11-522	R	R	84	Rk+
P-201	04-Sh-262-1	UCD9259/96-11-522	R	R	84	Rk+

**Rk* confers strong and moderate resistance to *M. incognita* and *M. javanica* root-knot nematodes, respectively, while Rk+ confers strong resistance to both nematodes.

Table 7: 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 8. 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), IT82D-849	ISRA	Striga
Mouride	Montiero derived line	ISRA	Large grain
Melakh	IT97K-499-39, IT81D-994	ISRA	Striga resistance
Melakh	UCR 03-11-747	ISRA	Green grain

Table 9. Crosses made as part of a shuttle breeding program to help 'jump start' the cowpea breeding program in Angola. The F2 of these populations is currently being grown at Riverside (Field 15) or Coachella (CVARS) as indicated in the table.

Cross No.	**Pedigree**	**F2 Nursery Location**
2010-007	IT89KD-288 x 524B	CVARS
2010-008	IT95M-190 x 524B	CVARS
2010-011	CB27 x IT86D-1010-27	CVARS
2010-012	CB27 x IT97K-499-35-1-1	CVARS
2010-017	IT00K-1263 x TVu 3310	CVARS
2010-018	IT89KD-288 x IT00K-1263	CVARS
2010-023	IT84S-2246 x IT93K-503-1	CVARS
2010-032	IT95K-1491 x Suvita 2	CVARS
2010-035	IT89KD-288 x IT83D-442	CVARS
2010-051	IT97K-499-35 x IT93K-503-1	CVARS
2010-052	Suvita 2 x IT93K-503-1	CVARS
2010-056	IT97K-499-39 x UCR 246	CVARS
2010-057	Suvita 2 x IT97K-499-35	CVARS
2010-061	IT95M-190 x Kvx 525	CVARS
2010-062	IT00K-901-6 x TVu 113	CVARS
2010-063	IT97K-207-15 x Mouride	CVARS
2010-009	IT97K-499-39 x 524B	CVARS, Field 15
2010-004	524B x IT97K-499-35-1-1	Field 15
2010-010	CB27 x IT82E-18	Field 15
2010-027	IT84S-2246 x Mouride	Field 15
2010-031	IT95K-1491 x Mouride	Field 15

Table 10. California blackeye lines being improved by introgression of specific traits using backcrossing at UCR, indicating status following advancement in 2008 - 2010.

Recurrent Parent Line	Trait donor (non-recurrent) parent	Trait being introgressed	Current Generation (October 2009)
CB5	CB27	Fusarium wilt	BC3F7
CB46	UCR 03-11-747	Green grain	BC4F9
CB46	IT84S-2049	Root-knot nematodes	BC6F8
CB46	Montiero (Brazil)	Large grain size	BC4F8
CB46	Bambey 21(Senegal)	All-white grain	BC4F9
CB46	IT97K-556-6 & UCR 779	Aphid resistance	BC2F5
CB46	IT93K-2046	Lygus resistance	BC4F5

Table 11. Crosses made and advanced to F4-F5 generation that will provide progenies for selection of drought and pest tolerant cultivars.

Cross	Type	Current Status (October 2010)
SuVita2/Mouride	Elite Drought Tol. x Elite Drought Tol.	F4 – F5 in field at CVARS now
IT93K-503-1/IT84S-2246	Elite Drought Tol. x Elite Drought Tol.	F5 at CVARS
Mouride /IT84S-2246	Elite Drought Tol. x Elite Drought Tol.	F5 at CVARS
IT97K-499-39/IT93K-503-1	Elite Drought Tol. x Elite Drought Tol.	F4 – F5 in CVARS now
IT97K-503-1/IT97K-556-6	Elite Drought Tol. x Elite Drought Tol.	F4 – F5 in field at CVARS now
Mouride/Apagbaala	Elite Drought x Elite Heat Tolerant	F4 – F5 in field at CVARS now
KVx61-1/Mouride	Elite x Elite Drought Tolerant	F4 – F5 in field at CVARS now
IT93K-503-1/UCR 779	Elite Drought Tolerant x Drought Tolerant and aphid resistant landrace	F4 – F5 in field at CVARS now
Apagbaala/IT82E-18	Elite Heat Tolerant x Elite	F4 – F5 in field at CVARS now
IT97K-819-45/Ein El Ghazal	Elite x Elite Drought Tolerant	F4 – F5 in field at CVARS now
Ein El Ghazal/KVx544-6-151	Elite Drought Tolerant x Elite	F4 – F5 in field at CVARS now
IT98K-558-1/Mouride	Elite x Elite Drought Tolerant	F4 – F5 in field at CVARS now
Apagbaala/IT98K-558-1	Elite Heat Tolerant x Elite	F4 – F5 in field at CVARS now
IT95K-1479/Mouride	Elite x Elite Drought Tolerant	F4 – F5 in field at CVARS now

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

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Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2009 – September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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

	Abbreviated name of institutions																	
	UCR			ISRA			INERA			IIA			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Varietal identification and release	x	x		x	x		x	x		x		x	0			0		
Germplasm seed increases	x	x		x	x		x	x		0			0			0		
Germplasm screening	x	x		x	x		x	x		x	x		0			0		
Varietal candidate screening - Ango	0			0			0			x	x		0			0		
Advance and test BC2F2 pops	0			x	x		x	x		0			0			0		
Advance/test elite F3-F5 Pops	x	x		x	x		x	x		0			0			0		
SNP genotyping	x	x		0			0			0			0			0		
Objective 2																		
Breeder's seed production	x	x		x	x		x	x		x	x		0			0		
Foundation Seed Production	0			x	x		x	x		0			0			0		
Certified Seed producer training	0			x	x		x	x		0			0			0		
Assess seed system needs - Angola	x	x		0			0			x	x		0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 3																		
MS Training (Breeding) Angola/UPR	x	x		0			0			x	x		0			0		
PhD Training (Breeding -HPR)	x		x	0			0			0			0			0		
Training in MASD with SNP markers	x	x		x	x		x	x		x	x		0			0		
Breeding Guide	x		x	0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 4																		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
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0	0			0			0			0			0			0		
0	0			0			0			0			0			0		

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]
Signature

#####
Date

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

Dry Grain Pulses CRSP
<u>Report on the Achievement of "Semi-Annual Indicators of Progress"</u>
(For the Period: April 1, 2010 – September 30, 2010)
Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the US.

The following provides explanation for the non-achievement of benchmark indicators:

Under Objective 1 Varietal identification and release (IIA):

While the field evaluations of promising cowpea lines are continuing, additional data in different growing areas is required to support a formal release. In part this has been impacted by disease problems in some of the field trials.

Under Objective 3 Training: PhD Training (Breeding-HPR):

Difficulty was encountered in identifying an appropriate African student for this program, due to English language inadequacy. Two African student candidates have come to UC Riverside for intensive English language training; both are currently taking TOEFL and GRE exams with the goal of having at least one of them enroll in the UCR graduate program in the winter quarter of this academic year.

Under Objective 3 Training: Breeding Guide:

We have drafted a Breeding Guide, but have extended its scope to include our initial experiences and recommendations for using the high-throughput SNP marker genotyping technology which has come online this summer. We plan to finalize the Guide during the FY11 to provide a high quality product with the cutting edge technology application included.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2009 -- September 30, 2010)

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

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

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	1
Number of men	1	1
Short-term Training: Number of individuals who received short-term training		
Number of women	26	25
Number of men	22	24
Technologies and Policies		
Number of technologies and management practices under research	13	20
Number of technologies and management practices under field testing	13	11
Number of technologies and management practices made available for transfer	4	7
Number of policy studies undertaken		
Beneficiaries:		
Number of rural households benefiting directly	9,000	>22,000
Number of agricultural firms/enterprises benefiting	19	7
Number of producer and/or community-based organizations receiving technical assistance	35	23
Number of women organizations receiving technical assistance	14	5
Number of HC partner organizations/institutions benefiting	24	17
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	35,000	>30,000

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

In order to better define the insect populations our group is developing a new paradigm for pest control, an integration of genomics tools for making integrated pest management decisions; an approach we have termed “Integrated Pest Management Omics” (IPM-Omics) (Pittendrigh *et al*., 2008; Gassmann *et al*., 2009). We have created the necessary molecular tools to understand population dynamics and movement patterns of the legume pod borer (*Maruca vitrata*) and are currently creating these tools for the other major pests of cowpea. These molecular tools have and will be used in conjunction with traditional field studies to define from where the pest populations are originating during the dry season. This information is extremely important in order to best determine where to release the biological control agents we now have in hand. *We have also performed field studies on the effectiveness of bio-control agents on the control of insect pest populations and increasing yield in the cowpea crop; the results have been highly positive.*

Lastly, we are developing educational deployment strategies that will position us to deploy pest control strategies on a large-scale and potentially in a highly cost-effective manner. We are spearheading (1) cell-phone ready animations that can be used to train people in pest control strategies (which have been shared with two other DGPCRSP projects) and (2) an online peer review system for host county collaborators to share these educational materials, (3) in addition to developing working relationships with other organizations (e.g., Peace Corps) that will allow us to scale-up "on-the-ground" farmer education of IPM-based pest control strategies.

Project Problem Statement and Justification

Arguably, the greatest biotic constraints on cowpea (*Vigna uguiculata* [L.] Walp.) production are insect pests. There is currently a dire need for deployment of pest control strategies that can have the greatest positive impact on improving the livelihoods of those that produce and consume cowpeas. In following project report we outline that the most logical long-term options for control of pests of cowpea will be – a mixture of the use of biological control agents, cultural practices, bio-pesticides, and classic host plant resistance.

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 and cultural practices will certainly help in the control of a few of the pest species of cowpea, and are actively being pursued, however, they need to be complemented 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, it may still be some time before such varieties are in the hands of farmers. Physical approaches for insect control have been developed and are currently being deployed for the control of bruchids in stored cowpeas and many host-country scientists have continued to promote the successful use of local plant extracts (e.g., neem), in conjunction with host plant resistance traits, to suppress pest populations. Although these approaches can be used to suppress the pest populations, they require development of educational materials that can be easily deployed in order to be used by a large number of farmers in a given region or regions. Additionally, bio-control agents have the advantage that some can simply be released and "do their job" (suppress pest populations over the long-term) without further human intervention, while others can be turned into "cottage industries" (*e.g*., viral sprays). These aforementioned approaches represent immediate, tangible, and cost-effective pest control solutions that can be placed in the hands of farmers for the control of insects that attack cowpeas in the field.

Our HC scientists and their institutions have had major successes with the use of biological control agents for pests of other crops (*e.g*., cassava and millet) and have other practical control methods that they have both tested in the field and have used in farmer field schools with positive outcomes. We now have numerous biological control agents against pests of cowpeas, and educational materials for promotion of "other" pest control strategies (*e.g.*, cultural practices and plant extract sprays), ready for release and testing on a pilot-scale to "set the stage" for a large-scale deployment effort.

One of the challenges of releasing bio-control agents has been 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: (1) to combine surveys of pest populations with genomic analysis tools to determine where best to release bio-control agents for *M. vitrata* to maximize the control of this pest; (2) to develop the necessary expertise to extend these IPM-omics strategies to all other insect pests of cowpea; and (3) to develop the necessary capacity and institutional infrastructure, as well as farmer training, for the strategic release of biological control agents for the pests of cowpeas in 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, 2009 - September 30, 2010

Objective 1: *Light Trapping of M. vitrata and Molecular Markers*
In order to deploy a bio-control agent release program (and to set the stage for a viral spray program) for *M. vitrata* we need to gain insights into when and where *M. vitrata* is occurring in our host countries. This activity will build both (i) institutional infrastructures to monitor *M. vitrata* (ii) as well as a better understanding of the problems of this pest within the host countries. Although our efforts are not specifically focused on *Bt* cowpea, this work has laid the basis for the development of an IRM plan for *Bt* cowpea, as well as providing the basis for other IPM-based pest control strategies (when and where bio-control agents should be deployed at a regional level for the suppression of *M. vitrata* populations).

Approaches and Methods: Light trapping continued to occur over the past 12 months, in keeping with the previous 18 months, at the existing locations: (i) in Niger the current locations are Maradi, Kornaka, and Gaya; (ii) in Nigeria the existing locations are Zaria, Kadawa, and Minjbir; and, (iii) in Burkina Faso the existing locations are Farako-ba, Kamboinsé, Fada N'Gourma and Dori. Adults were monitored and collected from the light traps on a daily basis. Adults were sent to UIUC through a courier service for molecular analyses at UIUC.

Molecular analysis of the *M. vitrata* populations occurred at UIUC using microsatellite and single nucleotide polymorphism.

Results, Achievements and Outputs of Research:

Summary of our findings: Our field and molecular data currently support the hypothesis that *M. vitrata* move in a northerly pattern from an endemic zone during the wet season, surviving in the southern endemic zone during the dry season. However, we have observed the endemic zone in Burkina Faso to be farther north than previously expected (*M.vitrata* is endemic in Bobo-Dioulasso; Ba *et al*., 2009). Also, our molecular data suggests a fairly direct south to north movement pattern of *M. vitrata* in the rainy season.

Implications for pest control strategy**:** Thus, for the release of bio-control agents that will establish in the *M. vitrata*, and suppress the populations in large-scale over the long-term, bio-control agents will need to be released in Southern Burkina Faso (in the Bobo-Dioulasso area), as well as Northern Ghana, Togo, and Benin. Additionally, we have also demonstrated that *M. vitrata* is an important pest of cowpea in Southern to mid-Burkina Faso, but not at all in northern Burkina Faso (thrips are the major pest in the north). Thus, control efforts for this pest, including bio-control releases and viral sprays, should be concentrated in the South and mid-part of the country.

Details of Efforts over FY10: We have both (i) a large collection of *M. vitrata* from throughout Burkina Faso, Niger, and Northern Nigeria and (ii) have been and are continuing to be used in molecular analysis of the populations.

This activity has allowed us to (i) build institutional infrastructures to monitor *M. 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; Gassman et al., 2009). Our initial experiments, with light trapping and scouting data, have resulted in a recent publication (Ba at el. 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. This has provided important base-line information for our "Technology Dissemination Project" to deploy biological control agents for the control of cowpea pests (see Objective 5).

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 are as follows:*

1. To date, development of microsatellites for studying Lepidopteran insects has proven 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 are now completing our characterization of *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. Over the past year they have been using 454 and bioinformatics approaches to study the population dynamics of European corn borer (*Ostrinia nubilalis*), a major pest of corn in the mid-West. <u>This represents an important outcome of our project that will directly benefit U.S. agriculture.</u> A manuscript using this approach is now being prepared for submission to a peer-reviewed journal.
2. We have used 454 sequencing technology to (a) sequence the complete mitochondrial genome of *M. vitrata*, (b) determine the exact locations in the mitochondrial genome that will and will not vary from insects found around the world and (c) which genes vary locally and regionally (in West Africa) and across the planet (Margam *et al*., 2010). 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 technologies 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 IITA 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 on 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, Kang, Ba, Dabire, Tamò, Jackai, 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. Analysis of the data from this model will be completed by December 2010. Dr. Pittendrigh is currently paying for a research-assistantship (from UIUC funds) for the graduate student, Jungkoo Kang, to complete this model.
7. All of the molecular tools we have developed, along with their applications for insect control, can now be applied to the other pest insects that attack cowpea. This past year we began the effort of applying these tools to the sequencing of two of the bio-control agents (*Apanteles taragamae* and *Ceranisus femoratus*) that we will release. This same molecular marker information will be used to demonstrate (i) that successful bio-control agents came from our release populations and will (ii) ultimately determine if there are specific molecular markers associated with successful bio-control agents that have been released (in order to help identify populations of bio-control agents that may be most successful in a bio-control release program). We have also collected large numbers of insects from all the other pest species to perform sequencing of these populations in FY11 in order to perform the same type of studies as we have done with *M. vitrata*. Thus, we now have the capacity to extend (in FY11 and FY12) 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 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(3): 109-113. (from CRSP support)

Gassmann, A.J., Onstad D. W. 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., Sun L., Gaffney P., 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 C., Tamò M., Pittendrigh B. R. and L. L. Murdock. 2009. Geographical variation revealed by molecular barcoding of the legume pod borer, *Maruca vitrata* (Lepidoptera: Pyraloidea: Crambidae). Molecular Biology Reports. Online First Release.

Margam V. M., Coates B., Ba N.M., Dabire-Binso C., Baoua I., Tamò M. Ishiyaku M. F. and B. R. Pittendrigh. 2009. *Maruca vitrata* Fabricius (lepidoptera: pyraloidea: crambidae) mitochondrial genome. Submitted to PLoS One.

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., Kang J., Ba N. M., Dabire C., Tamo M., Jackai, L. and 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: *Insect Pests on Cultivated Cowpeas*

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. We will also test the impact of viral and neem sprays on cultivated cowpea crops to determine if these approaches can be used to (1) reduce pest attack and (2) increase yield.

The major pests of cowpea in the field in West Africa include: the legume pod borer, *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. These are the pests we have studied in this objective.

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 was completed in the first six months of the FY10 budget period. Based on these experimental plans we studied the presence and detailed life-history of the five major pests of cowpea (in the field and where necessary in the laboratory). This was achieved through the use of randomized complete block design experiments using multiple lines of cowpea and alternative host plants. We will also test viral sprays (against *M. vitrata*) and neem sprays (against all the pests) on the cowpea crops (on both susceptible and pest tolerant lines of cowpea). In Burkina Faso, Dr. Dabire will has one graduate student 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. The data are currently being tabulated. They will be shared with the group and analyzed.

Results, Achievements and Outputs of Research:

<u>Summary of our findings:</u>

1) Major pest problems by region have been defined and we now have three seasons of base-line data on the pest levels of insect populations on cowpeas in test plots.
2) Viral sprays dramatically reduced *M. vitrata* populations and increased yield in the test plots (26-34% increased levels of yield) (Also – see Objective 5).
3) Neem sprays were effective in decreasing pest populations, increasing yield, and neem sprays coupled with host plant resistant strains were the most effective in reducing the pest populations.

<u>Implications for pest control strategy</u>:

1) We have defined which regions on which we should focus the deployment of specific bio-control agents (to control specific pest species). These biocontrol agents are the ones that can be released for establishment in the region for long-term suppression of pest populations.
2) Viral sprays represent a new option for the control of *M. vitrata* (Also – see Objective 5).
3) Neem sprays were effective, especially in combination with host plant resistant varieties, and have been used to train farmers in farmer field schools.

<u>Details of Efforts over FY10</u>:

We have performed the above experiments over the past three field-seasons (summer of 2008, 2009, and 2010). 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 the details of 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, with the final season of data being collected in 2010.

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

However, other important trends have emerged that will be helpful for us in future insect control efforts (a repeat of previous FY experiments). 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 the regions where there is little need for such control measures for specific insect pests. For example, in Burkina Faso the major pest insects in the south are *M. vitrata* and pod sucking bugs, which are serious constraints for cowpea production, with aphids being the third most important pest (however, still of economic importance). In central Burkina Faso, thrips and pod sucking bugs are the most important pests, with *M. vitrata* being the third most important pest (however, still of economic importance). In Northern Burkina Faso, only thrips are a major pest problem and *M. vitrata* are a rare occurrence (and not of economic importance). Thus, local IPM strategies will need to be focused on the most important local pests to have the maximum amount of impact.

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); we repeated these field experiments in the summer of 2010 with similar results. 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 the development of genomics tools to understand the nature of these pest populations and thereby make informed decisions, on the best places and times, to release biological control agents.

Manuscript in Progress

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

Objective 3: *Survey Wild Alternative host plants (in and off season)*

This activity will provide the basis for a better understanding of the problems of pest insects of cowpeas within the host countries both during the growing season and when the cowpea is not in season. This will help us to determine where the pest populations are occurring when the cowpea is not being grown.

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). Insects that were observed will be collected for use in sequencing efforts to generate the necessary polymorphisms that will be used to study the insect populations and the movement patterns.

Results, Achievements and Outputs of Research:

Summary of our findings:

1) Identification of important wild alternative hosts.
2) Collection of insects necessary for genomics work in FY11

Implications for pest control strategy:

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

Details of Efforts over FY10:

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 giving the best locations where biological control agents for *M. vitrata* need to be released in order to achieve the greatest potential impact on *M. vitrata* populations that affect 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 farther 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 border (e.g., northern Benin, Ghana and Togo). Release of biocontrol 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.

For both pod-sucking bug species (e.g., in Burkina Faso) there are at least six local wild alternatives that support these populations during the dry season: *Cajanus cajan* (L.) Mills, *Crotalaria retusa* L., *Rhynchosia memnonia* (Del.) DC; *R. minima* and *R. orthobothrya*. Thrips, *Megalurothrips sjostedti* Trybom developed in the off-season on several wild Fabaceae including, *Pterocarpus santalinoïdes*, *Pterocarpus erinaceus*, *Lonchocarpus laxifloris*, *Piliostigma reticulata*, *Piliostigma thoninguii*, *Sesbania pachycarpa*, *Tephrosia bracteolata*, *Cajanus cajan*, *Phaseolus vulgarus* and other plants from Mimosaceae, Ceasalpinaceae and Bixaceae families. Cowpea aphids, *Aphis craccivora* Fab are hosted by peanuts, *Arachis hypogea*, and vegetables during the dry season.

We will continue these scouting efforts in the upcoming year (FY11) 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.

In FY11 and FY12 we will also continue 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 biocontrol 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. Submitted.

Objective 4: *Development of Infrastructure for Release of Information to Extension Services, NGOs, and to Cowpea Farmers as well as Short-term and Long-Term Training.* The goal of this component of our program is to develop a long-term capacity for the large-scale release of IPM strategies for Mali, Burkina Faso, Niger, and northern Nigeria. This includes (1) an institutional human resources infrastructure building; (2) partnerships with collaborative groups that will help us deploy these approaches on a larger scale; and, (3) educational tools and resources for training host country scientists, extension educators, and farmers in the most effective pest control strategies.

In order to achieve these objectives we have:

1) Performed scientist (all of the collaborators have experienced cross-training), graduate student (8 graduate students), and intra- and inter-institutional technician training (within and between institution training, including within institution day-long workshops to train technicians) (described in section XII);
2) IITA has developed eight videos necessary for technician and scientist training on the pests of cowpeas, including identification of the pests in the field, as well as rearing of the pests and their bio-control agents (useful for training groups beyond our current CRSP program) (described in section XII);;
3) Trained host country scientist and technicians in highly cost-effective strategies of rearing of *M. vitrata* and production of bio-control agents for release (part of one of the videos) (partially described in section XII););
4) Partnered with other organizations to deliver pest control strategies into the hands of farmers (*e.g.*, Peace Corp in Niger to perform FFSs for pest control strategies for cowpea; in discussions with CORAF for further deployment partnerships);
5) Developed an online information sharing system of pest control strategies that will be used by our project [Sustainable Development Virtual Knowledge interface (SusDeViKI); http://beta.matrida.biz/Default.aspx; http://news.illinois.edu/news/10/0519sustainable.html; http://www.news.illinois.edu/videos.html?webSiteID=vmGiOUsYPk2IJcKSvIjqAA&videoID=hiv7aZOt3keKL1jKnkqx3w; Bello *et al*., 2010] to share extension materials both within our group and to the rest of the world (partnership with UIUC Business school to make this economically sustainable in the long-term);
6) In response to feedback from host country collaborators on the outcomes of successful pest control strategies (based on cultural practices), we have begun the process of developing a series of animations (in local languages), which can be and have been deployed using cell phones. We have developed videos for hermetic sealing of cowpeas for storage, solar treating of cowpeas, and proper preparation and use of Neem sprays. The first two videos have been released in the beginning of FY11 and have been translated into multiple local languages (please see https://sib.illinois.edu/pittendrigh/projects/cowpea/extension/videos/for an incomplete

list of the total language videos). This cost-effective way to produce such material (with easy voice-overs in new languages) has resulted in the development of a UIUC-based fledgling group called "Scientific Animations Without Borders" which will also be producing videos for other development and socially related projects and programs (with other funding sources). For our CRSP project, our videos have been shared with Drs. Robert Mazur and Cynthia Donovan so that they can use these materials in the countries they are working in (Rwanda and Mozambique). In FY11 we will perform studies to address the access of women in rural areas to cell phones in Burkina Faso (the Human Subjects approval request at UIUC has already been applied for in order for us to begin this work in January of 2011).

Collaborators:

Peace Corps
Scientific Animations Without Borders (UIUC organization)
Local Extension Services and farmer organizations in Nigeria, Niger, Burkina Faso, and Mali
Benin: Universite d'Abomey Calavi, 3 collaborators
Service Protection des Vegetaux, 2 collaborators
Togo: Universite du Benin, 1 collaborator (1 female)
Ghana: Plant Protection and Regulatory Services, 1 collaborator (1 female)
Crop Research Institute Kumasi, 3 collaborators
Savanna Research Institute Tamale, 1 collaborator
UIUC Extension, 4 collaborators (2 female)
University of Illinois, School of Business
Dr. Cynthia Donovan, Michigan State University (we have shared our extension materials for use on cell phones; the videos will contain the local languages in the regions where they work and will be deployed locally)
Dr. Robert Mazur, Iowa State University (we have shared our extension materials for use on cell phones; the videos will contain the local languages in the regions they work in and will be deployed locally)
Mr. Francisco Seufferheld, UIUC-Extension
Ms. Martina Mohrbacher, UIUC-Extension

Approaches/Methods/Results:

<u>Farmer Field School</u>

Farmer field schools have been used as an effective method of deploying information into rural communities, along with developing the skills sets for farmers to adopt new technologies for crop production. We have performed a minimum of two farmer field schools in each of the host countries in FY10, including a 50%: 50% mix of men and women. Each farmer field school will have a minimum of 20 individuals. We have held farmer field schools (FFSs) in Nigeria, Niger, Burkina Faso, and Mali in 2010. 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 development 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. MP3 players and animations on cell phones were also distributed into villages in order to explore the potential strategies that we will test in FY11 in controlled experiments. Based on suggestions and feedback, we will focus our future efforts on cell-phone based deployment strategies, as the hardware is readily available in the villages where we have worked in, unlike the MP3 players, which represent a less sustainable approach for deploying such information.

As part of the farmer field schools, the farmers directly set up test plots with different technologies for cowpea production (*e.g*., host plant resistant lines, neem sprays, and viral sprays), assessed insect attack in detail along with the impact of other production technologies, and made decisions on the outcomes of these experiments. Thus, as part of the FFSs, the farmers were also enabled in understanding how to develop assessments of new technologies and literacy training also occurred in many of our FFSs with Peace Corp volunteers. Technologies deployed in the farm field schools involved: (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) hermetic storage of cowpeas, (7) soil preparation and planting density testing, (8) how to minimize the use of traditional pesticide sprays in areas where farmers typically spray their cowpea crops, and (9) discussions on the use of viral sprays/biological control agents to control *M. vitrata* (to set the stage for their use in FY11 and FY12).

Feedback from these FFSs have also allowed us to (1) identify which pest problems are the greatest concern in various regions of each country and (2) give the farmers the ability to identify early on, 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 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 FFS (in 2008 and 2009) have allowed us (1) to determine an estimate of the levels of pest populations before the release of the biological control agents. These are places and will be places where we will release biological control agents. In FY11 and FY12 we will work with these same farmer groups to determine potential impacts on local pest populations. We will continue to do 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 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, multiply, 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 Corp volunteers can continue to integrate improved technologies into their village-level programs. We expect that in future years, FY11 and FY12, we will be able to get this information into the hands of hundreds of Peace Corps volunteers and extension agents.

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, and Tolulope Agunbiade at UIUC on a manuscript to summarize the critical knowns and unknowns of the gender differences. Dr. Bello has a manuscript currently in submission dealing with FFSs and women, discussing 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) a 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) known for his efforts of developing novel educational and assessment tools for low literate learners in developing nations. He was recently awarded the "2010 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).

<u>Technician Training</u>

Research assistant exchanges occurred between IITA-Benin, INERA, and INRAN to demonstrate and implement various methodologies for rearing of *M. vitrata* and its parasitoids *A. taragamae* under laboratory conditions, both with an artificial diet and natural diet using cowpea sprouts. This involved multiple-day training sessions for both scientists and technicians. INERA and INRAN now have functional systems rearing *M. vitrata* in order to produce enough insects for virus and parasitoid production.

Publications Specific to this Activity

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

Objective 5: Dissemination Project

Summary of Accomplishments for Objective 5A-5D

1) Low-cost/highly efficient system for mass rearing techniques for *M. vitrata* (and its parasitoid *A. taragamae*) using cowpea sprouts adapted for HC conditions and currently in use in Benin, Burkina Faso and Niger.
   i. Approximately 30X less expensive and much easier technology than the previous rearing technology.
   ii. Parasitoids and viruses can be produced on a much larger scale for a fraction of the costs.
   iii. The technology can easily be transferred to new programs and organizations.
   iv. Videos have been developed for eventual online training of technicians in these techniques for use within our project, for potential scaling up of the project, as well as beyond the current project.
2) In-field rearing and slow-release delivery systems developed for the *parasitoids A. taragamae*, *T. eldanae* and *G. fulviventris*, and ready to be field-tested in FY11. This will position our project to deploy these parasitoids in large-scale based on FY11 and FY12 results confirming that pest numbers and yield are impacted.
3) Viral sprays of MaviMNPV reduced *M. vitrata* larval population comparable to the synthetic insecticide and a yield increase over 26% under field conditions in Kano, 34% in Burkina Faso, and in Niger they are still tabulating the data. The results look very encouraging in Niger; they are also highly suggestive of significant yield increases similar to that of Burkina Faso.

Objective 5A: Build capacity at host country institutions for the rearing and mass release of bio-control agents that are currently ready for release.

Approaches and Methods: We will be developing rearing and delivery systems for biological control agents (including training of staff, extension agents, and farmers where necessary) against major cowpea pest infestation which can easily be implemented by Host Country (HC) collaborators. In particular, we will carry out the following activities:

1. Refining and validating the recently developed mass rearing technique for *M. vitrata* using germinating cowpea sprouts. The methodology needs to be refined using

different sources of cowpea, and different types of materials. In addition, this rearing procedure needs to be validated in a range of different temperatures and air humidity regimes in order to determine its suitability in varying conditions as met in HC laboratories (years 1-2). Dr. Tamò at IITA will be responsible for development and deployment of this technology to HC scientists. The above rearing methodology will be used to mass rear the parasitoid *A. taragamae* in HC laboratories for field inoculations. At the same time, we will be developing an in-field mass rearing techniques using nurseries of the host plant *Sesbania* sp. (year 2-3). All three HC scientists will perform these activities. We will also use the above rearing methodology, developed in years 1-2, for mass production of the entomopathogenic virus MaviMNPV in HC laboratories for field applications. This will lead to the development of in-field mass production techniques using nurseries of the host plant *Sesbania* sp (year 2-3) in all three host-countries.

2. Establishing nursery plots of the host plant *Tephrosia candida* at different locations in HC for in-field mass rearing of the thrips parasitoid, *Ceranisus menes*. The plots will be inoculated with a start-up culture of the parasitoids provided by IITA (year 1-3). All three HC scientists will perform these activities.

Results for year 1 (FY10)

1. The main breakthrough under this objective was to be able to obtain the same quality of *M. vitrata* larval output using cowpea sprouts as we have been previously using with the artificial diet. Three different varieties of cowpea (one improved and two local ones) were tested with different quantities of water, and by varying the period of pre-germinating the cowpea grains. The best results were obtained by using white seeded cowpea, which gave the highest larval survival rates and the least contamination with molds. Thereby, the Benin local variety Tewe was best in all aspects, with larval yields of over 200 larvae per 150gr cowpea grains. These yields are comparable to the ones obtained in the same rearing containers with similar volumes of artificial diet. *It should be noted that using cowpea grains for M. vitrata rearing is 25-30 times less expensive than with the artifical diet rearing system.* Also, some of the important ingredients in the artificial diet such as agar-agar and Wesson salts are not readily available for purchase at the local level and need to be imported thus adding an additional, significant cost component for handling and shipping from abroad. The reduced costs and ease of access to materials is a *"game changer"* in making rearing *of M. vitrata* and bio-control agents extremely easy and inexpensive for host-country scientists.

   Instead of letting the cowpea germinate for 72h or more as in the case of the mungbean and soybean sprouts, our results indicate that the highest survival and shortest developmental time were obtained with 8h soaking in water and 16-40h grain germination period.

   This novel rearing technique was also used for successfully rearing the parasitoid *A. taragamae*. Overall parasitism rates are higher using cowpea sprouts as feeding substrate (67% average of three different cowpea varieties) than artificial diet (43%), and given the much cheaper costs and ease of handling, and again the readily availability of the rearing ingredients. This methodology is well suited for mass rearing in national programs.

When one produces *A. taragamae* with the cowpea sprout method it is advisable to add to the pre-germination water 15mg/l of a water-soluble fungicide; in our case Mancozeb gave the best results. This is to prevent excessive development of molds which might be detrimental to parasitoid emergence from the cocoons.

Both methodologies were demonstrated and implemented in Dr. Dabire's lab at INERA Kamboinse and in Dr. Baoua's lab at INRAN Maradi, and they are currently being used for routine *M. vitrata* rearing.

Figure 1. The in-field mass rearing technique using *Sesbania cannabina* scheduled for year 2-3 could already be developed during the current FY10. Cages made of ¾ in. galvanized plumbing pipes (dimensions 1.6x2x2 m, see below pictures) were set out in natural vegetation habitats where the presence of some of the major host plants for *M. vitrata* (e.g. *Lonchocarpus cyanescens*, *L. sericeus*, *Tephrosia* spp.) had been previously ascertained by scouting surveys. The cages were installed at 7 different locations in southern and central Benin. *Sesbania cannabina* was sown at high density (40 plants/m2), and the cages were covered with white muslin cloth. Six weeks after sowing, the plants of *S. cannabina* inside the cages were infested with 1000-1200 eggs of *M. vitrata*. Four days later, the cages were inoculated with 30 pairs (male and female) of the parasitoid *A. taragamae*. After 5 more days, the muslin cloth covering the cages was removed, allowing the parasitoids emerging from the pupae formed on the plants inside the cages to disperse in the surrounding habitat. Previous to this, the plants inside the cages were inspected for the presence of formed *A. taragamae* pupae. Apart from the site of Bassila in central Benin, cocoons of *A. taragamae* were observed in high number at all other sites. The next step (FY11) will be to try to quantify and optimize the cocoon yield per cage.

2. Nursery plots of *T. candida* were established at INERA Farakoba and INRAN Maradi as planned. The plants will have their first flowering starting June 2011, so we will carry out the first experimental inoculative releases with *C. femoratus* supplied by IITA-Benin around that time.

<u>Objective 5B</u>: Collections of biological control agents for sequencing and development and of IPM-omics tools

Approaches and Methods: Priority natural enemies for sequencing (these are all introduced ones in West Africa):

1. The parasitoids *Apanteles taragamae* (attacking the pod borer *Maruca vitrata*): we will compare a presumably 'genetically bottlenecked' population from our current rearing colony at IITA in Benin with samples from wild population from different locations in Taiwan (years 1-2) and from continental Asia (years 2-3).

2. The parasitoid *Ceranisus femoratus* (attacking the flower thrips, *Megalurothrips sjostedti*): compare released populations from various locations in Benin, Ghana and Ibadan with rearing population from lab (year 1), original population from Cameroon (years 1-2) and samples from Kenya (year 2-3).

   Dr. Manu Tamò will be primarily responsible for the collection and shipping of insect samples to UIUC. Dr. Pittendrigh's laboratory will receive samples of the biological control agents from IITA, sequence populations of insects, and determine molecular markers useful in the monitoring of these pest populations. The current budget has enough funds, based on 2009 prices and technology to perform such experiments with two of the biological control agents. Thus, we will work with *Apanteles taragamae* and *Ceranisus femoratus* for the molecular component of this project (years 1-2). Where time and resources permit the Pittendrigh laboratory will also perform these genomics studies on the other biological control agents. In year 3, Dr. Pittendrigh will use these tools to test biological control agents that have been found in monitoring project, to determine if they are genetically similar to those insects that were initially released.

Results for year 1 (FY10)

1. *Apanteles taragamae* samples from our initial rearing at IITA-Benin have been processed for RNA extraction in our labs and sent to UIUC for sequencing.

2. Samples of *C. femoratus* have been collected from Benin and Ghana, and have been processed for RNA extraction in our labs and sent to UIUC for sequencing.

<u>Objective 5C</u>: Bring new bio-control agents into the pipeline for development and deployment;

Approaches and Methods: In partnership with HC collaborators, we will be developing rearing and delivery systems for the following priority natural enemies:
Against *M. vitrata*:

1. The trichogrammatid, *Trichogrammatoidea eldanae*. This parasitoid is locally available in the moist savanna of West Africa. We propose to use field cages to demonstrate its potential (year 1), while at the same time develop simple and efficient rearing and delivery systems for field inoculations (year 2-3 FY11-FY12).

2. The tachinid, *Nemorilla maculosa*. Upon delivery of import permits into our laboratories at IITA Benin (FY10), we will introduce this parasitoid from AVRDC Taiwan and develop rearing and delivery systems (year 2-3 FY11-FY12).

Against *C. tomentosicollis*:

1. The parasitoid, *Gryon fulviventre*. This parasitoid is locally available in West Africa. We will first need to develop a cheap and efficient rearing technique for its intended host, *C. tomentosicollis* using dry cowpea seeds or continuous green pods in a cowpea field planted throughout the year (year 1). Subsequently, we will develop a rearing methodology adapted to HC laboratories (year 1-2), and finally a delivery system, which can be applied directly by farmers in their own field (year 2-3 FY11-FY12).

Results for Year 1 (FY10)

1. Due to the devastating flood rains which hit Benin in October, the cages to field-test the egg parasitoid, *Trichogrammatoidea eldanae* were set up quite late in conjunction with a MaviMNPV virus experiment in the locality of Save which experiences constant high *M. vitrata* infestation levels throughout the years. The cowpea is just starting to flower and first releases of *T. eldanae* and treatments of the virus are being carried out while this report is being submitted. First results are expected by late November. Results from a similar, though preliminary field experiment to test the methodology, carried out under artificial infestation in August at the IITA station, indicated 78% egg mortality due to the activity of *T. eledanae*.

   At the same time, a simple, cheap but efficient rearing and slow-release system, scheduled to start in FY11, is already being developed with locally available materials (see Figure 1). We are currently testing different types of jute bags (with varying mesh size) available in the local markets. The bags are suspended inside 5 in. evacuation PVC pipes whose bottom has been removed. The pipes will provide rain shelter and also increase shading.

   Figure 2. Slow release system for bio-control agents using inexpensive local materials.

2. Import permits for the parasitoid *Nemorilla maculosa* have been obtained from the Benin Plant Protection and Quarantine Services. The first shipment of *N. maculosa* pupae will be hand-carried by an AVRDC staff visiting Nigeria in December.
3. Different rearing systems are currently being evaluated for optimum production of the egg parasitoid *Gryon fulviventre*. Green cowpea pods from different cowpea varieties are compared with dry cowpea grains in terms of *Clavigralla tomentosicollis* egg yield, and parasitization success. The use of cowpea grains for this rearing has the advantage that this methodology does not need to have a constant field supply of fresh green pods to feed the pod-sucking bugs. Substantial differences have been noted between different varieties: white-seeded, rough coat cowpea varieties have by far given the best *C. tomentosicollis* egg output.
4. Additional result: an experiment was set up at the IITA-Kano station (where among the highest *M. vitrata* populations in the region can be expected every year), to assess the potential of the entomopathogenic virus MaviMNPV in the field. Three treatments (no-spray control, conventional insecticide and virus) were repeated 4 times in a completely randomized block design. Treatments started at the onset of flowering; the conventional insecticide (Cypermethrine + Dimethoate) was sprayed every 14 days, while the virus was sprayed every five days throughout the flowering period at the concentration of 1,6 10^{11} OB (viral occlusion bodies) per ha. The results (which just came in and have not been statistically analyzed yet) are highly suggestive that bio-pesticides are as effective at controlling *M. vitrata* as conventional insecticides. The viruses also resulted in an estimated 26-34% yield gain (of cowpea grains) as compared with the control non-sprayed plots.

   Similar experiments have been conducted in Burkina Faso and Niger and the final (statistically analyzed) results from all locations should be available soon. In Benin, this experiment was planted quite late because of the flood rains, and the results will only be available the end of November.

Objective 5D: Cross training activities in rearing and release of biological control agents

Approaches and Methods: The collaborating host country scientists will perform cross-training of each other and each other's staff in developments that lead to better rearing, release and monitoring of biological control agents. This will occur throughout the three years of the project and will occur continuously during the project as needed.

Results for year 1 (FY10)

This cross-training activity has occurred by exchanges of technicians between institutions and by intra- and inter-institutional one-day and multiple-day training sessions.

Training

Non-degree training

Research assistant exchanges occurred between IITA-Benin, INERA, and INRAN to demonstrate and implement various methodologies for rearing of *M. vitrata* and its parasitoids *A. taragamae* under laboratory conditions, both with artificial diet and natural diet using cowpea sprouts. This involved multiple-day training sessions for both scientists and technicians. INERA and INRAN now have functional systems rearing *M. vitrata* in order to produce enough insects for virus and parasitoid production.

IITA has four interns (two female; all citizens of Benin) working on our project, including.

Degree Training
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 partially through cost-sharing provided by UIUC. Two more graduate students (both female), who are fully funded by UIUC, are also extremely active on our CRSP project mainly developing our extension system (SusDeViKI), our extension animations, and working on the molecular biology aspects of the project.

Additionally, Dr. Pittendrigh has recently had a Doctoral student complete his Ph.D. program (Fall of 2009) (Dr. Venu Margam) on the genomics and population dynamics of *M. vitrata*. Dr. Margam's work dealing with *M. vitrata* is now being continued by Agunbiade Tolulope (a female graduate student from Nigeria current studying towards her Ph.D. UIUC; she is funded 100% by UIUC and is not currently supported by the CRSP beyond the S&E's for her project).

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. One graduate student is working with INRAN in Niger on pests of cowpea.

Degree Training:
First and Other Given Names: Tolulope Adebimpe
Last Name: Agunbiade
Citizenship: Nigerian
Gender: Female
Degree Program for training: PhD at UIUC
Program Areas or Discipline: Entomology
Host Country Institution to Benefit from Training: Tolulope is actively working on extension materials and basic research that will be used in Mali, Niger, Burkina Faso, and Nigeria
Training Location: USA
Supervising CRSP PI: Pittendrigh
Start Date of Degree Program: 2009
Program Completion Date: July 2013
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): none

First and Other Given Names: Laura
Last Name: Steele
Citizenship: USA
Gender: Female
Degree Program for training: MS at UIUC
Program Areas or Discipline: Entomology – She is currently contributing to the project both on the molecular studies and in the development of extension materials. She is fully funded by UIUC as a teaching assistant.
Host Country Institution to Benefit from Training: Laura is actively working on extension materials that will be used in Mali, Niger, Burkina Faso, and Nigeria
Training Location: USA
Supervising CRSP PI: Pittendrigh
Start Date of Degree Program: 2009
Program Completion Date: July 2011
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): none

First and Other Given Names: Alice
Last Name: Vossbrinck
Citizenship: USA
Gender: Female
Degree Program for training: MS at UIUC
Program Areas or Discipline: Entomology – She is currently contributing to the project both on the molecular studies and in the development of extension materials. She is fully funded by UIUC as a teaching assistant.
Host Country Institution to Benefit from Training: Alice is actively working on extension materials that will be used in Mali, Niger, Burkina Faso, and Nigeria
Training Location: USA
Supervising CRSP PI: Pittendrigh
Start Date of Degree Program: 2010
Program Completion Date: July 2012
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): none

First and Other Given Names: Traore
Last Name: Fousseni
Citizenship: Burkina Faso
Gender: Male
Degree Program for training: MS at University of Ouagadougou
Program Areas or Discipline: Entomology
Discipline: Entomology
Host Country Institution to Benefit from Training: INERA
Training Location: Burkina Faso
Supervising CRSP PI: Dabire
Start Date of Degree Program: 2008
Program Completion Date: July 2012
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Hermann
Last Name: Somakpon
Citizenship: Benin
Gender: Male
Discipline: Entomology/Biology
Host Country Institution to Benefit from Training: Benin, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamo
Start Date of Degree Program: July 2009
Program Completion Date: July 2011
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Joelle
Last Name: Toffa
Citizenship: Beninese
Gender: F
Degree: PhD
Discipline: Entomology
Host Country Institution to Benefit from Training: Benin, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamo
Start Date of Degree Program: July 2010
Program Completion Date: July 2012
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Elie
Last Name: Dannon
Citizenship: Beninese
Gender: M
Degree: PhD
Discipline: Entomology
Host Country Institution to Benefit from Training: Benin, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamo
Start Date of Degree Program: Sept 2009
Program Completion Date: March 2011
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Laouali
Last Name: Karimou
Citizenship: Niger
Gender: Male
Degree Program for training: MS at University of Niamey
Program Areas or Discipline: Pests of cowpea
Starting date: Beginning in FY11
Discipline: Entomology/Biology
Host Country Institution to Benefit from Training: INRAN, Niger

Training Location: Niamey and Maradi
Supervising CRSP PI: Baoua
Start Date of Degree Program: Sept 2010
Program Completion Date: August 2011
Training Status during Fiscal Year 2010: on-going
Type of CRSP Support (full, partial or indirect): partial

Host Country Institution to Benefit from Training: For one student Burkina Faso and for the second student is from Nigeria. The student was a former employee of IITA and hopes to return to West Africa to work in the area of cowpea pests upon completion of her degree program (the country likely to benefit would be Nigeria).

Universities to provide training: University of Ouagadougou, University of Illinois at Urbana-Champaign, University of Niamey, and Universite d'Abomey Calavi (Benin).

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? The UIUC student has been directly funded by UIUC and thus entered the United States on an F1 VISA.

Supervising CRSP PI: Dr. Dabire in Burkina Faso, Dr. Pittendrigh at UIUC, Dr. Baoua at University of Niamey, and Dr. Manuele Tamò at IITA (for the students in Benin)

Start Date: For the student in Burkina Faso the start date will be October 2008. For the student at UIUC, the start Date was fall semester of 2009.

Projected Completion Date: The completion date of the UIUC student will be in FY12. Internal UIUC funding will be used to support her studies.

Type of CRSP Support (full, partial or indirect): CRSP funds have provided the full support for the student in Burkina Faso. For the student at UIUC the funding has been 100% leveraged resources.

If providing Indirect Support, identify source(s)s of leveraged funds: Endowment and start up funds to Dr. Pittendrigh

Short Term Training:

Type of Training: internship
Description of Training Activity: biocontrol of cowpea pests
Status of this Activity as of September 30, 2010: on-going
When did the Short Term Training Activity occur? July – Oct 2010
Location of Short Term Training: IITA Benin
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Students
Number of Beneficiaries by Gender: Male- 0
Female- 2
Total- 2

Type of Training: technician
Description of Training Activity: biocontrol of cowpea pests
Status of this Activity as of September 30, 2010: on-going
When did the Short Term Training Activity occur? FY10
Location of Short Term Training: Burkina Faso and Niger
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Students

Number of Beneficiaries by Gender:	Male-	2
	Female-	2
	Total-	4

Type of Training: technician
Description of Training Activity: Farmer field fora
Status of this Activity as of September 30, 2010: August-October
When did the Short Term Training Activity occur? FY10
Location of Short Term Training: Burkina Faso, Mali, Nigeria, and Niger
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Farmers

Number of Beneficiaries by Gender:	Male-	>340
	Female-	>340
	Total-	>680

Networking and Linkages with Stakeholders

Dr. Pittendrigh has visited both the USAID missions in Mali and Nigeria during the current CRSP grant. Dr. Tamò is continuing to work 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 (an IITA activity). The concept note has been submitted to the USAID mission, by the Ghanaian government (with information provided by Dr. Tamò). If funded, our IITA collaborator will receive direct funding to work in Ghana on activities that have been made possible, in part, by our CRSP project. If funded part of our CRSP program (at IITA) would certainly benefit, as would the country of Ghana.

In Benin, efforts are underway to work with the biggest federation of agro-ecological farmers (Federation Agro-ecologique du Benin), which is already grouping over 800 farmers, to promote biocontrol agents and bio-pesticides in the context of their organic production approach, mainly in cowpea and horticultural crops. This will enable IITA to make faster progress in participatory evaluation of the proposed biological control agents, bio-pesticides, and validate their delivery systems currently under development.

In Niger, our program is partnered with Peace Corps for the development of joint farmer field schools. Additionally, numerous farmer organizations have been engaged to help distribute pest control technologies, including seeds of cowpeas that are from insect tolerant lines of cowpeas (germplasm generously provided to us by the UC-Riverside DGP-CRSP group; we are collaborating with this group by helping to deploy materials generated by their group).

IITA, in close collaboration with DGP-CRSP and other partners, has successfully organized the 5th World Cowpea Research Conference in Saly, Senegal, Sept 26-Oct 2, 2010. This has provided an excellent discussion platform for scientists from a very broad range of disciplines, extension agents, farmer and donor representatives, journalists and policy makers, for sharing the progress made along the value chain of cowpea. DGP-CRSP sponsored the participation of four CRSP scientist, and a total of 6 papers were authored/co-authored by DGP-CRSP PIs. *This meeting provided us an opportunity to meet with a CORAF representative, Professor Abdourahamane Sangare (he is part of Biotech/Bio-security at CORAF), to explain our project in detail, and outline the beginnings of our future interactions with CORAF.* This is in keeping with suggestions by the TMAC and we plan to follow-up this meeting in FY11 with conference calls with CORAF and a detailed plan of collaboration.

<u>Other Universities involved:</u>
Benin: Universite d'Abomey Calavi, 3 collaborators (1 female)
Service Protection des Vegetaux (Benin), 2 collaborators
Togo: Universite du Benin (Togo), 1 collaborator (1 female)
Ghana: Plant Protection and Regulatory Services, 1 collaborator (1 female)
Crop Research Institute Kumasi, 3 collaborators
Savanna Research Institute Tamale, 1 collaborator

Leveraging of CRSP Resources

1) Dr. Pittendrigh will leverage funds from (i) his endowed chair position, (ii) general university funds provided to him, (iii) or both, at UIUC, to support a graduate student. Two MS students at UIUC have been funded through teaching assistantships. Dr. Pittendrigh is also using leveraged funds to pay the student for the *M. vitrata* resistance model.
2) Part of Dr. Pittendrigh's time at UIUC has been cost-shared.
3) Dr. Joe Huesing's (formerly of Monsanto Company) time will be donated to the project. Dr. Onstad's time will also be donated. They are both involved in the IRM modeling work for *M. vitrata*.
4) Drs. Dabire, Ba, Baoua, and Ishiyaku held farmer field schools in conjunction with other NGOs in order to increase the impact of the current resources.
5) Dr. Pittendrigh has received an approximately $400,000 grant from USDA to work on resistance mechanisms in pests of cowpeas.
6) Dr. Bello has received CIBER funding for her efforts dealing with the extension component of our project.
7) Dr. Tamo received $15,000 from GTZ/BMZ for work on the biocontrol of *M. vitrata*
8) Dr. Bello's participation in the meeting in Ecuador was cost-shared by UIUC funds.

List of Scholarly Activities and Accomplishments

Adati, T., Tamò, M., Downham, M.C.A., 2010. Migration and mating status of the legume pod borer, *Maruca vitrata* in Northern Nigeria with reference to the efficacy of synthetic sex pheromone traps. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

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).109-113

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

Bello Bravo, J., Seufferheld, F., Ba, M., Binso-Dabire, C.L., Baoua, I., Tamò, M., Pittendrigh, B., 2010. Plant protection deployment strategies for extension services and cowpea farmers. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

Dabiré, C., Tamò, M. Ouédraogo, T.J., Tignegré, J. B., Ba, M., Hammond, W. Coulibaly, O., 2010. Efforts de gestion des contraintes biotiques au Burkina Faso et en Afrique de l'Ouest. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

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

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

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).

Huesing, J., Romeis, J., Tamò, M., 2010. Assessment of potential impact of Bt-cowpea on non-target organisms. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

Margam V. M., Coates, B., Ba, N.M., Dabire-Binso, I. Baoua, Tamò, M. M. F. Ishiyaku, and Pittendrigh B. R. 2010. *Maruca vitrata* Fabricius (lepidoptera: pyraloidea: crambidae) mitochondrial genome. Submitted to PLoS One.

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.

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

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

Pittendrigh, B. and J. Bello. Expanding the Impact of Practical Scientific Concepts in Developing Nations through Cutting Edge Technologies. World Universities Forum, Davos, Switzerland, January 9-11, 2010.

Pittendrigh, B., Gassmann, A., Margam, V., Coates, B., Ba, M., Dabire C., Baoua, I., Tamò, M., 2010. IPM-omics: how omics is reshaping the way we do integrated pest management and implications for cowpea in West Africa. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

Sanon, A.,Ba, N.M., Dabire-Binso C. L. and Pittendrigh, B. R. 2010. Effectiveness of Spinosad (Naturalytes) in controlling the cowpea storage pest, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). J. Econ. Entom. 103(1): 203-210.

Tamò, M., Srinivasan, R., Dannon, E., Agboton, C., Datinon, B., Dabiré, C., Baoua, I., Ba, M., Haruna, B., Pittendrigh, B., 2010. Biological Control: a Major Component for the Long-Term Cowpea Pest Management Strategy. Paper presented at the 5th World Cowpea Research Conference, Saly, Senegal, Sept 27-Oct 2, 2010. (full paper to be included in the book of proceedings).

Contribution to Gender Equity Goal

We have made every effort to maintain gender equity in graduate student training, farmer training, technician training, and we have made significant efforts to maintain and bring female professionals onto the project. Additionally, Dr. Bello has worked with our host country collaborators to address gender issues associated with helping to increase female participation in farmer field fora (also known as farmer field schools). One project will be presented (as a virtual presentation) at the Science and Society meeting in Madrid in November 2010, along with a supporting manuscript submitted to the associated journal (Journal of Science and Society). Our current efforts with educational materials that can be deployed on cell phones will require that we have a much better understanding of the access that women have to cell phones such that we can try to maintain gender equity in terms of deployment. To this end we wrote an <u>Institutional Capacity Building</u> proposal to assess the capacity of women to access cell phones and hence access to the information we will be deploying through this medium; the proposal was funded by the DGP-CRSP for FY11. An application for human subjects study approval has already been submitted at UIUC and we expect to have the approval in place by January 2011.

For biological control agents that are released into the environment (and require no more human intervention), we expect the impact to be gender neutral (having the same positive impact on men and women). In FY11, we will address the access that women have to materials that are important for neem and viral sprays to determine the levels of gender equity that may occur with this control strategy. For host plant resistance seed lines, we have continually and will continue to make sure seeds are given to women's organizations, to ensure gender equity.

Progress Report on Activities Funded Through Supplemental Funds

1) *Institutional Capacity Building* - Funds for IITA to create training videos -- Results for year 1 (FY10)
A series of eight training and demonstration videos were produced locally in Benin. The first set of four videos is illustrating the four major field pests of cowpea: aphids, thrips, pod borers and pod sucking bugs. After a general introduction to cowpea, the videos describe the different life stages of the pest, as well as their feeding habit, damage symptoms on the plant, and natural enemies in the field. The second set of videos is more of a technical nature and describes in details the steps of rearing *M. vitrata* and its parasitoid *A. taragamae* both on artificial diet and cowpea sprouts. The first version of the videos are in French language, an English version is already being prepared while translation in the most important local languages (Hausa, Yoruba, Bambara, Mooré, Zarma, Dendi, etc.) is planned early next year.

2) *Institutional Capacity Building* - Funds to IER for Farmer Field School Activities
IER has observed that the best (appropriate and affordable technology) local control method for dealing with pest problems of cowpeas is through a neem spray program. The major pests of cowpea in this region were *Anocplemis curvipes, Aphis cracivora, and Megalurothrips sjostedti*. Additionally, neem trees are fairly common in the Ségou area of Mali and their seeds can be ground into a fine powder and then the fine powder can be mixed with water and sprayed on fields of cowpeas. This control strategy has resulted in an estimated >30% increase in yield of the cowpea crop in the farmer field schools (held in Diakoro, Katiéna and Bougoukoura). Based on this, IER would like to expand their efforts to promote their neem extract strategy for control of the pests of cowpea. In response to this, UIUC (in collaboration with IER, INRAN, and INERA) has developed a 3-D animation to explain to extension agents, NGOs and farmers how to properly select the seeds, prepare the seeds, the spray solution, and the final spraying of the product (UIUC funding paid for this animation). The animation has been completed and is currently being translated into local languages for IER to use in training sessions in the field. This will allow IER to deploy this technology in FY11 and FY12 through other extension organizations and NGOs and potentially give the animations directly to farmers to use on their cell phones.

3) The “*Technology Dissemination*” project is described under Objective 5. Please see objective 5 for details.

Summary of Impact of these Supplemental Funds on the Overall Project:

Ultimately, the large-scale release of an IPM program to suppress pest populations across a region in West Africa is going to rely on three major components: (1) knowing which pest species cause the major production constraints in given areas; (2) having cost-effective pest control strategies that can be deployed for long-term pest population suppression; and, (3) cost-effective methods of sharing information with extension agents, NGOs, and farmers that will benefit from these control strategies. The additional funds provided by the CRSP have been critical for our project to progress towards these aforementioned goals that will be reached at the end of FY12; having all these components in place will allow for the potential for a large-scale IPM program that can be performed in Niger, Northern Nigeria, Burkina Faso, and Mali for suppression of populations of the pests of cowpeas in these regions.

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: April 1, 2009 -- October 1, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

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	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	Y	N*	10/1/10	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 for 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													
Collaborator teleconferences/face-to-face meetings	X	X		X	X		X	X		X	X		X	X		X	X	
IPM *Maruca* model in development	X	X		X	X								X	X				
Manuscripts submitted/published	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				
Plant of experimental plots to test pest control strategies				X	X		X	X		X	X							
Manuscript in Process	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	X				
Scouting Manuscript(s) Published	X	X		X	X		X	X		X	X							
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 NCs				X	X		X	X		X	X		X	X				
Nigerian Graduate 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				
Initial video messages developed and voiceovers done in multiple languages	X	X		X	X		X	X		X	X		X	X		X	X	
Objective 5 - Dessemination Project																		
Maruca rearing on cowpea sprouts/efficient system for biocontrol production				X	X		X	X					X	X				
Establish nursery plots of *Tephrosia candida*				X	X		X	X					X	X				
Begin collection of insects for genomics work				X	X		X	X					X	X				
Initial steps for sequencing of biological control agents (protocols established)	X	X																
Trichogrammatid field cage experiments													X	X				
Rearing of *Gryon Fulviventre*													X	X				
Import permits for *Nemorilla maculosa*													X	X				
Rearing of *C. tomentosicollis*													X	X				
Cross training of techniques in developed for the dessmination project	X	X		X	X		X	X					X	X				
Creation of videos useful for insect identification, rearing, and rearing of biological control agents													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

Signature

Sept. 30, 2010

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, 2009 – September 30, 2010)

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

Project Title: Biological Foundations for Management of Field Insect Pests of Cowpea in Africa – Technology Dissemination Project UIUC West Africa
Lead U.S. PI and University: Barry Robert Pittendrigh (UIUC)
Host Country(s): Burkina Faso, Niger, Mali, Nigeria, and Benin

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	1	4
Number of men	1	4
Short-term Training: Number of individuals who received short-term training		
Number of women	>100	>340
Number of men	>100	>340
Technologies and Policies		
Number of technologies and management practices under research	4	4
Number of technologies and management practices under field testing	4	4
Number of technologies and management practices made available for transfer	4	4
Number of policy studies undertaken		
Beneficiaries:		
Number of rural households benefiting directly	>150	>700
Number of agricultural firms/enterprises benefiting	N/A	6
Number of producer and/or community-based organizations receiving technical assistance	10	>20
Number of women organizations receiving technical assistance	5	6
Number of HC partner organizations/institutions benefiting	5	5
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	N/A	>1000

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. ‘ICTAZAM’, a small black bean cultivar, with BGYMV and BCMV resistance and web blight tolerance, was released in Guatemala by ICTA. ‘ICTA Sayaxche’, a disease resistant, high yielding black bean cultivar developed by EAP and ICTA researchers with support of the DGP-CRSP project, is a candidate for release in Guatemala. The BGYMV and BCMV resistant, high yielding small red cultivar ‘INTA Matagalpa’ (released in Honduras as DEHORO) will be released in Nicaragua by INTA. DEHORO and ‘Amadeus 77’, are the principal bean cultivars being disseminated by governmental seed programs in Honduras and El Salvador which annually reach more than 120,000 farmers. The BGYMV and BCMV resistant small white seeded, cultivar ´Surú´, was released in Costa Rica. A significant quantity of the black bean cultivars ‘Aifi Wuriti’ and ‘Arroyo Loro Negro’ were multiplied the National Seed Service in Haiti. This seed was used to establish demonstration plots in the fields of 300 cooperating farmers, in the Vallée de Jacmel area in southeastern Haiti. The Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) formally released ‘DPC-40’. This BGYMV, BCMNV and BCMV resistant black bean variety was developed in collaboration with University of Nebraska and the University of Puerto Rico with support from the Bean/Cowpea CRSP. The bean grower association in the San Juan de la Maguana Valley sold FAO 100 tons of seed of ‘DPC-40’ and ‘Arroyo Loro Negro’ to distribute to bean producers in Haiti. The multiple disease resistant light red kidney bean cultivar ‘Badillo’ and the heat tolerant gemplasm lines TARS-HT1 and TARS-HT2 were developed and jointly released by the University of Puerto Rico and the USDA-ARS Tropical Agriculture Research Station. More than 50 small red and black bean elite breeding line nurseries (VIDAC) and (ECAR), 40 promising breeding line evaluation trials (COVAMIN, PASEBAF) and > 400 on-farm cultivar validation trials (Aifi Wuriti, ICTAZAM, INTA Matagalpa, MER2226-41) were conducted in collaboration with National Bean Programs, NGO and technical personnel and farmer groups in Central America and the Caribbean (CA/C). Several promising materials were identified for continued testing by the NBP in CA/C. During 2011, we expect that at least one cultivar will be released in Guatemala, Nicaragua and El Salvador. Inbred backcross populations for developing small red and black bean cultivars that combine BGYMV, BCMV and BCNMV resistance for Central America were generated and advanced to early generations. Marker-assisted selection was used to insure that small red and black bean varieties have BGYMV and BCMV resistance genes. Populations were developed from crosses between commercial seed types used in Angola and sources of resistance to BCMV, CBB, and ALS resistance. Marker assisted selection

has been used for selection of CBB and BCMV resistance and phenotypic selection for ALS resistance. Yellow bean cultivars from Mexico were crossed with red mottled bean breeding lines that have resistance to BGYMV and BCMV and common bacterial blight. Bean breeding lines from Oregon State University had high levels of resistance to the bean weevil. Bean lines with greater nodulation scores, root, shoot and total dry matter accumulation under low N conditions were identified in greenhouse trials conducted at Zamorano. Experiments were conducted in Honduras using the soil cylinder technique containing a substrate low in N to study the response to inoculation with *Rhizobium* strains CIAT 899 (*R. tropici*) and CIAT 632 (*R. etli*) and to identify potential parents for a recurrent selection program for high nodule number, early nodulation and N2 fixation. Additional BNF studies in Honduras include testing the response of 50 inbred-backcross (IB) lines to inoculation with strains CIAT 899 and CIAT 632 under low fertility conditions. In field trials planted at Isabela, Puerto Rico over a two-year period, the black bean line PR0443-151 and the small red lines VAX 3 and IBC 309-23 produced superior seed yields and were found to be efficient in the acquisition and use of N. Field experiments were conducted at two locations in Puerto Rico to test the effectiveness of the commercial inoculant "Nodulator" (Becker Underwood). *Bacillus subtilis strain MBI 600 Integral*™ was included as a seed treatment to control root rots. In Isabela, nodulation scores were significantly different among treatments. Plant biomass was greater with fertilization (NPK). Response to inoculation was observed with Nodulator when combined with Integral, indicating a synergistic effect However, the highest seed yields were obtained with Integral alone. In Juana Diaz, inoculation with Nodulator plus application of a starter of NPK significantly increased seed yield. Inoculation with Nodulator alone was not effective unless combined with Integral or with starter fertilizer. *Bacillus subtilis* seed treatment was effective in increasing plant biomass, nodulation and seed yield probably due to reduction of root rot. Because the putative RAPD markers for ashy stem blight were proven to be ineffective, recombinant inbred lines (RILs) from crosses between BAT 477 and susceptible bean lines were evaluated for the development of novel markers. A detached leaf technique for *Macrophomina phaseolina* evaluation has been implemented for screening the BAT 477 x DOR 364 RIL population. Significant differences were found between RILs in the population and some lines were identified in which seed yield and detached leaf score corresponded. Morphological and agronomic traits of Lima bean landrace varieties from Puerto Rico were evaluated. We identified significant differences among varieties for seed type, leaf and pod type, days to flowering, seed yield and concentration of HCN in the leaves and seed.. PL-08-14 was the only landrace variety that had early flowering in Puerto Rico (51 DAP) and Honduras (71 DAP) and a seed HCN concentration < 100 ppm in the seed. The diversity of Angolan cowpea germplasm, in relation to a diverse worldwide collection, was evaluated through phenotypic characterization in a field trial planted at Isabela, Puerto Rico. The initial seed elemental composition results indicate some unique nutritional characteristics of Angolan germplasm, including high protein and iron content. Two students from Angola continued studies at the University of Puerto Rico for M.S. degrees in plant breeding. Short term training was provided in research techniques for BNF and breeding for Ascochyta blight resistance. A workshop to discuss and identify bean research and training priorities for Central America and the Caribbean was held in 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.

The development of improved bean varieties has proven to be an effective strategy to address biotic and abiotic factors that limit bean production in Central America and the Caribbean. During the past 10 years, however, only a limited number of black bean cultivars have been released in Latin America and the Caribbean. This is the result of a lower level of investment in black bean breeding and less emphasis in Central America on the testing and on-farm evaluation of advanced black bean breeding lines by national programs. As a consequence, black bean cultivars tend to have lower seed yield potential and less disease resistance than the most recently released small red bean cultivars. The most promising small red bean cultivars developed at Zamorano can be readily used to improve black beans. In fact, the lowland bean breeding project of the Bean/Cowpea CRSP initiated the development of black bean breeding lines and a sizeable number of breeding lines have already been distributed to bean research network members in Guatemala and Haiti. The bean research network supported by the Bean/Cowpea CRSP was a key element in the success of the cultivar development program in Central America. The Dry Grain Pulse CRSP project will emphasize field-testing of black bean breeding lines in Central American and Caribbean countries. The project will also complete the evaluation, release and dissemination of Andean (red mottled and light red kidney) bean lines that have resistance to BGYM, BCMNV and rust.

The research project is in the position to make significant impacts in Central America, the Caribbean, and Angola. Many small red and black bean breeding lines with enhanced disease resistance and tolerance to abiotic stress are already in an advanced stage of development. There is an established network of bean researchers in Central America with a proven capability of testing, releasing and disseminating improved bean cultivars. The Dry Grain Pulse CRSP project will complement ongoing collaborative bean research in Central America. In addition, it will bring in partners from Haiti that will extend the potential impact of the collaborative research. The project will also train researchers in Angola based on the critical experiences and successes in Central America and the Caribbean.

Improved bean breeding lines developed by the Dry Grain Pulse CRSP bean breeding program in Central America and the Caribbean may be useful in some bean production regions of Africa, given the similarity in agroecological zones and production constraints. Some small red bean cultivars and breeding lines developed in Central America have resistance to diseases (BCMNV, rust, angular leaf spot, and anthracnose) and tolerance to abiotic stresses (low soil fertility, drought and high temperature) that are important constraints to bean production in Africa. Because there is increased interest in Africa in bean production at lower altitudes, Central American bean breeding lines with resistance to common bacterial blight and web blight may be of particular value to northeastern

Angola where small red beans are produced in hot and humid conditions. Although black beans are estimated to account for < 5% of bean production in Africa, this seed type is often a component of mixtures grown in low fertility soils. The lowland bean breeding team has also developed Andean (red mottled and light red kidney) bean breeding lines with resistance to BCNMV and rust that may be useful in Eastern Africa. Angola, a major importer of pinto beans, may benefit from testing the BelDakMi bean breeding lines that have resistance to BCNMV and rust. We will collaborate with Dry Grain Pulse CRSP projects and bean research networks in Africa (e.g., SABRN, ZARI, CIAT) in the evaluation of improved bean breeding cultivars and breeding lines from the U.S., Central America and the Caribbean. Project personnel will meet frequently to evaluate bean lines in nurseries and to exchange information at scientific meetings.

Planned Project Activities for April 1, 2009 - September 30, 2010

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

Approaches and Methods: Plant breeders 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 were crossed with sources of resistance to pests or tolerance to abiotic stress. Bean lines were 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 were 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 were multiplied and small lots of seed were 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 also produced basic seed stocks of the most promising bean breeding lines and made seed available to the national bean research programs and NGO's involved in the multiplication and dissemination of improved seed.

The project initiated 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, were 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 small red, black and Andean bean breeding populations were developed and evaluated during the past year. The overall goal is to combine resistance to diseases with drought and low fertility tolerance in improved cultivars and breeding lines. This should lead to the release of improved small red, black and Andean bean cultivars with enhanced adaptation and greater consumer acceptance. 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 2011 second 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_3 and F_4 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.

Inbred backcross populations for developing small red and black bean cultivars that combine BGYMV, BCMV and BCMNV resistance for CA/C were generated and advanced to early generations using the XRAV40-4 black bean cultivar and the small red breeding line PR9825-49-4 as BCMNV resistance sources. F_4-F_5 families selected for superior agronomic performance, desirable seed traits and disease resistant SCAR markers, will be sent during the upcoming year to the University of Puerto Rico to be screened for resistance to BCMNV. The availability of BCMNV resistant bean cultivars for Central American is vital to deal with the potential spread of this virus which has caused severe reductions to bean production in the Caribbean. In addition, the black bean lines under development should be useful for bean production in Haiti and other Caribbean countries, where resistance to BCMNV, in combination with other disease resistance genes and adaptation to production constraints such as limited rainfall and low soil fertility are necessary.

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

Figure 1. Bean seed types found in the public market in Huambo, Angola.

The yellow bean is a preferred seed type in Haiti and Angola. Azufrado bean breeding lines from Mexico were obtained from Dr. Jorge Acosta, INIFAP bean breeder and former Bean/Cowpea CRSP HC-PI. These yellow bean lines were crossed with red mottled bean breeding lines that have resistance to BGYMV, BCMV and common bacterial blight. Approximately 100 F_5 lines were selected based on seed type, adaptation and agronomic characteristics. The lines will be screened in the greenhouse and with molecular markers to identify lines with BGYMV and BCMV resistance.

Evaluation of breeding populations

The University of Puerto Rico received black and light red kidney breeding lines from Dr. James Myers at Oregon State University that were expected to segregate for resistance to bean weevil (Mobogo et al., 2009). The resistance of the breeding lines was derived from the tepary bean G40199. A bioassay was developed to screen bean lines for resistance to the bean weevil (*Acanthoscelides obtectus*). Plastic cups (150 ml) containing 25 seed were infested with 20 adults of the bean weevil. The lids were perforated to permit aeration. Date of first emergence was noted and damage to the seed was measured at 60 days after infestation. The local white bean varieties 'Verano' and 'Morales' were very susceptible to the bean weevil whereas four black and two red kidney lines from OSU had useful levels of resistance (Table 1). The date of first emergence of adults of the resistant lines was approximately three weeks later than the susceptible checks. Most of the seed of the resistant lines was undamaged at 90 after infestation. The resistant lines had ≤ 10 holes in the damaged seed whereas 'Morales' and 'Verano' had > 200 holes in damaged seed. These bruchid resistant lines will be crossed with white, black, light red kidney and red mottled cultivars that have commercial seed type and resistance to other diseases such as BGYMV, BCMNV and CBB.

Table 1. Results from a preliminary screening of lines from Oregon State University for reaction to the bean weevil.

Line	Pedigree	Seed type	Date of first emergence	Number of damaged seed	Number of undamaged seed	Total number of holes in the seed
1012-15-2	ICA Pijao*2/G40199	Black	24-May	6	19	9
1012-18-1		Black	24-May	4	21	10
1012-23-1		Black	24-May	7	18	8
1012-24-3		Black	24-May	7	18	10
1012-27-2	Rojo*3/SMARC2/// ICAPijao*2/G40199	Red kidney	24-May	0	25	0
1012-29-3		Red kidney	24-May	2	23	4
Verano		White	1-May	25	0	223
Morales		White	1-May	25	0	219

Regional performance trials

More than 50 small red and black bean breeding line VIDAC nurseries (Tables 2 & 3) and ECAR trials (Tables 4 & 5) were distributed to collaborators from the National Bean Programs (NBP) from Central America and the Caribbean. Results indicating the performance of the most promising lines in comparison with improved and local check cultivars are presented below. In addition, more than 40 elite line evaluation trials (COVAMIN, PASEBAF) and > 400 on-farm cultivar validation trials (Aifi Wuriti, ICTAZAM, INTA Matagalpa, MER2226-41) were conducted in collaboration with researchers from NBP, NGO and farmer groups from Central America and the Caribbean, resulting in the identification of several promising materials for in-country testing by the NBP of the CA/C bean network, and the potential release in 2011 of at least one cultivar in Guatemala, Nicaragua and El Salvador. Due to the cancellation of the 2010 meeting of the PCCMCA, the 2009 results from the VIDAC nurseries and ECAR trials were not presented at this annual meeting. In keeping with the tradition of 15 years of coordination by the EAP of the SISTEVER, the regional system of advanced lines nurseries and trials, results from 2009 and 2010 nurseries will be presented at the 2011 meeting of the PCCMCA which will be held in El Salvador.

Table 2. Performance of elite small red breeding lines from the VIDAC 2009 Nursery conducted in five locations in Costa Rica, Honduras and El Salvador.

Line	Seed yield (kg/ha)	AA	CV	BGYMV	Maturity
MHR 311-52	2432	4	3	3	I (intermedia)
SRS 2-38-14	2415	4	3	2	I
SRS 2-37-50	2308	4	2	3	I
SRS 2-33-58	2960	4	4	2	L (late)
MHR 311-32	2043	5	3	3	I
SRS 2-31-85	2007	5	3	5	I
Improved check	1732	4	4	2	I
Landrace check	1167	6	3	7	E (early)
Mean (n=71)	1487	5	3	4	

AA= Agronomic adaptation (scale 1-9; 1=excellent, 9= poor)), CV= Commercial value (scale 1-9; 1= excellent, 9= poor) , BGYMV (1-9; 1-3= resistant, 7-9= susceptible)..

Table 3. Performance of elite small black breeding lines from the VIDAC 2009 Nursery conducted in three sites in Honduras, Costa Rica and Puerto Rico.

Line	Seed yield (kg/ha)	AA	Rust	ALS	Maturity
SEQ 344-11	1548	6	1	7	I
SEQ 344-21	1394	5	1	5	I
SEQ 344-102	1335	5	1	7	I
SEQ 344-69	1208	4	4	6	I
SEQ 344-13	1172	6	5	6	I
RBF 20-86	1137	5	4	3	L
Local check	1232	4	1	2	I
Mean (n=39)	905	5	3	5	

ALS= angular leaf spot (scale 1-9; 1-3= resistant; 7-9= susceptible)

Table 4. Performance of promising small red breeding lines from the ECAR 2009 trials conducted in three sites in Honduras and El Salvador.

Line	Seed yield (kg/ha)	AA	CV	BGYMV	Maturity
IBC 306-55	2742	5	4	3	I
IBC 309-23	2402	4	4	2	I
MER 2226-35	2558	5	3	2	I
MER 2226-29	2400	7	4	2	I
IBC 306-95	2412	5	5	3	I
MHR 314-3	2344	5	4	2	I
Local check	2029	7	4	2	I
Improved (Dorado)	2232	4	8	5	I
Mean (n=16)	1972	5	4	3	

Table 5. Performance of promising small black breeding lines from the ECAR 2009 trials conducted in three sites of Honduras, Nicaragua and El Salvador.

Line	Seed yield (kg/ha)	AA	ALS	BGYMV	Rust	Maturity
MHN 322-20	1480	4	5	3	4	I
MHN 322-49	1405	5	5	2	5	I
SEQ 344-116	1282	3	2	4	3	L
RBF 15-70	1249	6	3	7	5	I
SEQ 342-89	1203	4	5	4	4	I
Local check	960	3	3	7	3	I
DOR 390 (check)	932	6	5	6	6	L
Mean (n=16)	1024	4	4	5	4	

Ten ERMUS trials (Table 6) including web blight resistant lines from the first and second cycle of recurrent selection were distributed to NBP in CA/C and farmer research committees (CIAL) in Honduras. Most of web blight resistant lines in the ERMUS trial were superior to the moderately resistant (Talamanca and VAX 6) and susceptible (Tio Canela 75) checks and were also resistant to BGYMV and BCMV, and have good agronomic adaptation and desirable commercial red and black seed types The ERMUS 2010 includes 19 advanced lines selected from the previous year that combine WB, BGYMV and BCMV resistance, agronomic adaptation and commercial seed types and 5 checks (Talamanca, VAX 6, Tío Canela 75, Carrizalito and the recently released cultivar ICTAZAM).

Table 6. Mean performance of WB resistant lines from ERMUS trials (40 lines) conducted at five sites in Honduras, El Salvador and Puerto Rico in 2009-10.

Line	Seed yield (kg/ha)	Web blight incidence (%)	Agronomic adaptation (1-9)	BGYMV (1-9)	Seed type (1-9)
MHN 322-49	1803	20	2	3	Black
MHC2-9-37	1776	27	3	3	Red (2)
MH62-12	1744	17	4	6	Black
MHR 314-45	1735	20	3	3	Red (2)
MHR 314-49	1628	20	3	2	Black
Talamanca	1684	23	3	5	Black
VAX 6	1535	30	3	5	Red (6)
Tio Canela 75	1641	43	3	2	Red (5)
Range (n= 40)	1357-1802	17- 50	2-5	2-6	Red (2-7)

Seed for regional performance trials were prepared at the University of Puerto Rico and sent to Haiti, Angola and Rwanda. Entries in the trials included the differentials for rust, angular leaf spot and anthracnose and improved bean breeding lines from Michigan State University, the University of Puerto Rico, USDA-ARS Tropical Agriculture Research Station, Zamorano and INIAP. Information from these trials will be valuable to identify the most important biotic and abiotic constraints and to select bean lines that can serve as parents in a breeding program for Angola. Field trials were planted in Angola in October, 2008, August and October 2009 and 2010. Results from these trials identified bean breeding lines with different seed types that were well-adapted, had good yield potential and were resistant to disease (Table 7). The red mottled line PR9745-232 was the top yielding red mottled line in trials planted in Puerto Rico (2,406 kg/ha) and Haiti (1,039 kg/ha) and Angola (2,237 kg/ha).

Table 7. Performance of bean lines planted in Huambo, Angola.

Name	Seed type	Traits	Seed yield (kg/ha)		
			October 2008	August 2009	October 2009
PR9745-232	Red mottled	*bgm,I*	2237		
PR0633-4	Red mottled	*bc3*	2237		
PR0634-13	White	*bgm,I,bc3*	1163	1611	2061
Matterhorn	White	*I,Ur3*	2341	2638	
BCN20094	Black		2790		
MH-43-2	Black	*bgm,I*	2325		
Amadeus 77	Small red	*bgm,I*	1908	2405	
IBC-301-204	Small red		3619		
BelDakMi RMR 22	Pinto	*I,bc3,Ur11*	2448		

Three small white lines with resistance to BCMV, BCMNV and BGYMV yielded well in trials planted in Puerto Rico and Haiti in 2008 and 2009 (Table 8). These lines were sent to Dr. M.A. Pastor Corrales to screen for rust resistance.

Table 8. Seed yield (kg/ha) of elite white lines in Puerto Rico and Haiti.

Line	*Pedigree*	*Puerto Rico*		*Haiti*
		2008	*2009*	*2009*
PR0806-70	*PR0301-295 /BelMiDak RMR 11*	3,790	2,619	1,656
PR0806-72	"	3,724	2,656	1,786
PR0806-82	*PR0301-304 /BelMiDak RMR 11*	3,018	2,521	1,430
Verano		3,764	2,591	1,460

On-farm validation of promising breeding lines

On-farm validation trials were conducted in Nicaragua and Honduras in collaboration with the National Bean Research programs, Local Agricultural Research Committees (CIAL), NGOs and other extension organizations. The PASEBAF validation trial included drought, low fertility tolerant lines developed with support from the Bean/Cowpea CRSP and the Red SICTA. The Agrosalud (COVAMIN) trial included small red lines with greater mineral content (iron and zinc) developed in collaboration with CIAT and INTA/Nicaragua. It is expected during 2011 that at least one bio-fortified line will be released as a cultivar in Honduras and/or Nicaragua. The PASEBAF trial was supported by IICA/COSUDE. The EAP bean research program will continue to evaluate and utilize as parents the bio-fortified bean breeding lines developed by the Agrosalud project.

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 the lowlands and cultivars with higher yield potential and greater disease resistance are needed in Guatemala.

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

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

The BGYMV and BCMV resistant, high yielding small red cultivar 'INTA Matagalpa' will be released in Nicaragua by INTA researchers with support from the DGP CRSP. This cultivar was previously released in Honduras under the name of 'DEORHO' in 2007 and in El Salvador as 'CENTA Nahuat' in 2008. DEHORO and 'Amadeus 77', are the principal bean cultivars being disseminated by seed governmental programs in Honduras and El Salvador which annually reach > 120,000 farmers.

The small white-seeded, BGYMV and BCMV resistant cultivar ´Surú´, derived from the cross PAN 68/Bribri, was released in Costa Rica in December 2009 in collaboration with the National Bean Program. This cultivar was developed in response to farmer requests for an improved small white cultivar which obtains good prices in local markets, although consumption is not as high as the small blacks and red seed types.

In February 2010, the Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) formally released 'DPC-40'. This black bean variety was developed in collaboration with University of Nebraska and the University of Puerto Rico with support from the Bean/Cowpea CRSP. This black bean cultivar, which combines resistance to BGYMV, BCMNV and BCMV, is produced in the Dominican Republic for local consumption and export. The bean grower association in the San Juan de la Maguana Valley sold FAO 100 tons of seed of 'DPC-40' and 'Arroyo Loro Negro' for distribution to bean producers in Haiti.

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 description of the release was published in the *J. of Plant Registrations* (4:1-4)

Figure 2. Seed increase of black bean variety 'Arroyo Loro Negro' on the Double Harvest farm in Haiti – Feb. 2009.

The USDA-ARS, University of Puerto Rico, Cornell University, and the University of Tennessee released TARS HT-1 and TARS HT-2, heat tolerant dark red and light red, respectively, kidney beans with tolerance to high temperature stress in both temperate and humid tropical environments. This germplasm can be used to improve tolerance to high temperatures of kidney beans produced in tropical lowlands of Jamaica, Belize and Panama. The germplasm release was published in *HortScience* (45:1278–1280).

The pink bean line PR0401-259 and the black line PR0650-31 are under consideration for release as improved germplasm. Both lines have the *I* locus conferring resistance to BCMV and high levels of resistance to common bacterial blight (CBB) and moderate levels of resistance to web blight. PR0401-259 also has the *bgm* gene for resistance to BGYMV. In field trials conducted in Puerto Rico from 2006 to 2009, PR0401-259 and PR0650-31 produced mean seed yields of 1,816 and 1,967 kg ha^{-1}, respectively, whereas the check variety 'Talamanca' had a mean seed yield of 1,617 kg ha^{-1}. PR0401-259 and PR0650-31 should serve as useful sources of resistance where CBB and web blight are important diseases.

The University of Puerto Rico has developed red mottled bean lines that combine resistance to BGYMV, BCMNV, BCMV 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 2011.

The white bean breeding line PR0634-13 is under consideration for release in collaboration with the University of Nebraska and IDIAF as 'Beniquez'., This cultivar has resistance to BCMV, BCMNV and BGYMV. 'Beniquez' produced yields similar to the white bean cultivars 'Morales' and 'Verano' in 8 field trials conducted from 2006-2009 (Table 9). The release of 'Beniquez' will provide protection against the possible emergence of BCMNV in Puerto Rico. This virus already causes significant losses in the Dominican Republic and Haiti.

Table 9. Performance of white lines with *bgm, I* and *bc-3* planted at the Isabela Substation from 2006-2009.

Line		Seed yield (kg/ha)		
		Mean from 8 trials	b	R^2
PR0634-1	PR0003-124 / Raven	1998	1.00	0.91
9	PR0003-124 / Raven	2069	0.82	0.86
13	"	2138	1.11	0.92
Morales		2082	1.11	0.84
Verano		1885		

Note: Lines originally derived from XRAV lines from the Dominican Republic (Expt. 0349).

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 (BNF) 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 BNF 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 plan to utilize recurrent selection to develop Mesoamerican and Andean breeding lines with greater adaptation to low soil N. 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 the CIAT bean breeding line 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 BNF. Black bean lines developed at the University of Puerto Rico will serve as a source of root rot resistance. Breeding lines will be evaluated in the F_3 and F_4 generations in replicated field trials. The field trials received low levels (20 kg/ha) of N fertilizer. The bean lines were inoculated with recommended bean *Rhizobium* strains to create conditions favorable for biological nitrogen fixation. Dr. Tim Porch evaluated the F_3 generation for root rot resistance in a field maintained specifically for root rot screening and selection. The most promising F_4 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 that 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 that normally produce 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.

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 + N treatments, and both were superior to the no inoculation and - N treatments. 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 had almost twice nodule DW and 50% greater plant DW, than those with lower nodulation.

Experiments were conducted in Honduras using the soil cylinder technique containing a soil: sand (1:2) substrate low in N to study the response of selected genotypes to inoculation with *Rhizobium* strains CIAT 899 (*R. tropici*) and CIAT 632 (*R. etli*) and to identify potential parents for a recurrent selection program for high nodulation and N_2 fixation. Since common bean is also nodulated by strains of *R. leguminosarum*, additional experiments are being conducted including the strain UPR-Rl1 de *R. leguminosarum*. After conducting these experiments, we expect to select parents for the breeding program that have a greater response to a wide array of strains capable of nodulating more effectively common bean plants in the field. The same set of bean genotypes are being characterized for early nodulation using the pouches technique and inoculation with the three *Rhizobium* species that were previously mentioned.

Additional BNF studies in Honduras included testing the response of 50 inbred-backcross (IB) lines to inoculation with strains CIAT 899 and CIAT 632 under low fertility conditions. Complementary controlled studies will include an evaluation of differences in nodulation speed and nodule occupancy using mutant strains. These IB lines have Amadeus 77 genetic background and were developed with support from the EAP/Penn State University DGP CRSP project (PI-PSU-1) to study the adaptation of bean lines and multi-lines to low soil fertility. The similarity of the genetic background of the IB lines will facilitate the study of the expression of nodulation and N_2 fixation traits, and their contribution to plant growth and seed yield, as well as the response to inoculation under highly variable environmental conditions encountered on farmer fields.

Thirty-three bean lines were selected from an initial screening of 228 breeding lines from Zamorano and the University of Puerto Rico conducted by Haitian graduate student Ronald Dorcinvil. The varieties ‘Morales’ and ‘Verano’ from Puerto Rico and ‘Salagnac 90’ from Haiti were used in the trials as checks. Values of N utilization efficiency (NUE) were calculated as the ratio of seed yield (kg/ha) and extractable NO_3 in the soil. In trials planted at Isabela, Puerto Rico over a two-year period, the mean seed yields of the black bean line PR0443-151 and the small red lines VAX 3 and IBC 309-23 ranked no lower than 9^{th} in the – N plots (Table 10). The NUE values of these lines were > 30 over both years. Muurinen et al. (2006) reported that spring cereal lines with NUE scores ≥ 35 were considered efficient in nutrient acquisition. Results from this research were published in Field Crops Research (118:264-272).

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

Table 10. Seed yield (rank) in kg/ha and N utilization efficiency (NUE) of the most promising bean breeding lines evaluated at Isabela, Puerto Rico.

Line	June 2007 planting			Jan 2008 planting		
	Fertilized NPK	Fertilized PK	NUE (kg/kg)	Fertilized NPK	Fertilized PK	NUE (kg/kg)
PR0443-151	2544 (3)	1707 (2)	31.0	1918 (2)	1461 (3)	72.3
VAX 3	1929 (16)	1880 (1)	62.5	1467 (3)	1479 (2)	66.1
IBC-309-23	2184 (9)	1258 (5)	47.2	1460 (4)	950 (9)	32.6

Source: Dorcinvil et al. 2010. Field Crops Res. 118:264-272.

Less progress has been made in developing larger-seeded Andean bean lines that are adapted to low N soils. We evaluated 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. The landraces were evaluated during the summer of 2010 in a low fertility/root rot nursery at the USDA/ARS research farm near Isabela, Puerto Rico. Rainfall was excessive during the growing season and all of the Caribbean landraces proved to be poorly adapted in this stressful environment. Bean breeding lines selected by Dr. Porch for root rot resistance and adaptation to low soil fertility produced more biomass and had better pod set than the Caribbean landraces.

Figure 3. Planting a bean trial inoculated with *Rhizobium* in Angola, November 2009 and Ana Vargas and Monica Mmbui Martins participating in informal training concerning in BNF research techniques.

Field experiments were conducted at two locations in Puerto Rico to test the effectiveness of the commercial inoculant “Nodulator” (Becker Underwood). The inoculant contained 1 x 10^7 *Rhizobium leguminosarum* cells per gram of peat at the time of inoculation. Treatments were applied at planting in Isabela (Oxisol) and Juana Diaz (Vertisol), Puerto Rico in February and March 2010, respectively (Tables 11 & 12). *Bacillus subtilis strain MBI 600 Integral*™ was included as a seed treatment to control root rots. The white bean cultivar ‘Verano’ was inoculated before planting. The experiments were planted in a randomized complete block design with four replications. Nodulation score (1-9 scale) and shoot and root biomass were evaluated at the flowering stage. Seed yield was measured at harvest. In December 2009, three trials were planted in Malague, Cela and Huambo, Angola. However, only one trial in Angola was harvested.

In Isabela, nodulation scores were significantly different among the inoculated treatments and the uninoculated treatments with or without fertilizer. Plant biomass was greater with fertilization (NPK). Response to inoculation was observed with Nodulator when combined with Integral, indicating a synergistic effect (Table 11). However, the highest seed yields were obtained with Integral alone. In Isabela, nodulation by populations of soil rhizobia was less than 10 nodules per plant in the uninoculated control. The response to inoculation may have been reduced by the presence of native soil rhizobia because the most probable number counts indicated that 1.23 x 10^2 rhizobia per g of dry soil was present in the soil. Further tests to determine nodule occupancy by specific strains are warranted. Root biomass was not significantly different among treatments. In conclusion, there was response to inoculation with Nodulator when combined with Integral. However, the highest seed yields were recorded with Integral alone probably due to control of root rots. The NPK and N treatments increased yields when compared to PK and PK + Nodulator (Table 12).

In Juana Diaz, a starter fertilizer treatment with inoculation was included because of low nitrogen in the soil. Inoculation with Nodulator plus application of a starter of NPK significantly increased seed yield (Table 7). Inoculation with Nodulator alone was not effective unless combined with Integral or with starter fertilizer. *Bacillus subtilis* seed treatment was effective in increasing plant biomass, nodulation and seed yield probably due to reduction of root rot associated with *Fusarium solani* identified in Juana Diaz soils. Plant biomass was significantly lower for the untreated control and the PK treatment. In general, seed yield was low due to unfavorable growing conditions in the field including excessive rain during the season and the presence of root rots.

In Huambo, Angola, there were no significant differences among the inoculation with Nodulator, uninoculated control and NPK treatments. The highest seed yield was obtained with the NPK treatment (data not shown).

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

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

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

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

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 Central America 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, 2009 and 2010, these lines were planted at Isabela, Puerto Rico in a replicated field trial that was inoculated with the pathogen. The disease reactions of the RILs will be used to initiate the search for molecular markers for resistance to ashy stem blight using bulk segregant analysis (BSA).

A detached leaf technique for *Macrophomina phaseolina* evaluation has been implemented for screening the BAT 477 x DOR 364 RIL population. Significant differences were found between RILs in the population and some lines were identified in which seed yield and detached leaf score corresponded (Table 13). The experiment is being replicated in order to attempt QTL analysis for detached leaf response in common bean.

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

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

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

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: Morphological and agronomic traits of Lima bean landrace varieties from Puerto Rico were evaluated and compared with the 'Sieva' and 'Christmas' Lima bean varieties from Seed Savers' Exchange (Table 14). Although most of the varieties were collected within a few kilometers from the Isabela Substation, a wide range in seed types were observed among the landrace varieties. Seed size and altitude of cultivation of landraces from Puerto Rico are consistent with the values reported for Lima beans of the Middle American gene pool. All of the varieties had an indeterminate growth habit whereas there were differences among varieties for leaf and pod shape. Days to flowering of the landrace varieties ranged in Puerto Rico from 46 to 100 days after planting (DAP). When planted in Honduras in June, four landraces (PL08-01, PL08-02, PL08-03 and PL-08-18) flowered < 60 days after planting, suggesting that these varieties could be planted in the tropics throughout the year. When planted in Delaware in June, the earliest landrace varieties (PL08-01, PL08-02 and PL08-03) flowered at 81 days after planting versus 35 for 'Sieva' and 47 days for 'Christmas'. The mean number of seed per pod in Puerto Rico ranged from 2.7 to 3.4. Mean seed yield per plant during the first 180 days of the growing season in Puerto Rico ranged from 149 g to 1475 g. PL-08-1 and PL-08-2 were the highest-yielding lines in Puerto Rico and Honduras. The project collaborated 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. Only four of the landraces had seed HCN concentrations < 100 ppm which is the maximum concentration recommended for Lima bean varieties released in the U.S. Leaf concentrations of HCN ranged from 200 to 800 ppm. PL-08-14 was the only landrace variety that had early flowering in Puerto Rico (51 DAP) and Honduras (71 DAP) and a seed HCN concentration < 100 ppm. Seed of the landraces from Puerto Rico will be sent to the USDA germplasm collection and the most promising line may be considered for release in Puerto Rico as a variety.

The University of Puerto Rico received seed of 10 Lima bean landraces from Haiti and 24 Lima bean landraces from the Dominican Republic. The morphological, phenological and agronomic characteristics of these landraces will be evaluated at the Isabela Substation during the upcoming year. Seed of the Lima bean landraces will be sent to the CIAT and the USDA germplasm collections. One or two of the most promising lines may be considered for release as cultivars.

Figure 4. Lima bean landraces saved by Juanita Abreu, Isabela, PR and seed increase of Lima bean landraces in Damien, Haiti.

Table 14. Performance of a few of the Lima bean landraces from Puerto Rico

Identity	Mean seed yield per plant (g)	Days from planting to flowering			Seed HCN conc.[1] (ppm)	Leaf HCN conc. (ppm)
		PR (Oct.)	Hond. (Jun)	DE (Jun)		
PL-08-01	1288	51	57	81	500	400
PL-08-02	1475	56	57	81	400	300
PL-08-05	613	76	-	101	75	500
PL-08-06	422	100	-	-	60	200
Christmas	558	56	50	47	10	700
Sieva	701	56	94	35	50	300

[1] Seed and leaf HCN levels determined by Emmalea Ernest – Univ. of Delaware.

As part of the M.S. thesis research of Antonio David, the diversity of Angolan cowpea germplasm, in relation to a diverse worldwide collection, was evaluated through phenotypic characterization in a field trial planted at Isabela, Puerto Rico in March 2010. Lines were evaluated for general adaptation, phenology, growth habit, yield components, seed characteristics, and elemental composition of the seed (Table 10). The experiment consisted of 16 cowpea lines of Angolan origin, 28 lines representing the worldwide cowpea collection, and two local checks. The initial seed elemental composition results indicate some unique nutritional characteristics of Angolan germplasm, including high protein and iron content. The results were presented at the World Cowpea Conference in Senegal from Sept 27- Oct 1, 2010.

Complementing the phenotypic analysis, genotypic characterization using a subset of SNPs from the Illumina Cowpea platform is currently underway. The genotypic analysis is conducted in collaboration with the University of California, Riverside.

Objective 5: Increase the capacity, effectiveness and sustainability of agriculture research institutions that serve the bean and cowpea sectors in Central America, Haiti and Angola.

Degree Training:

Trainee # 1

Name: Monica Mbui 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 & James Beaver
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 # 2

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 & Tim Porch
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 #3

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 # 4

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: Bean research planning meeting for Central American and Caribbean.
Description of training activity: Central American and Caribbean bean researchers and CIAT and Dry Grain Pulse CRSP scientists met to discuss the status of bean research in the region. Future priorities for bean research and training activities were identified. Coordination of the network for the testing and validation of bean breeding lines were discussed. Conclusions from the workshop will be presented at the 2011 PCCMCA meeting in El Salvador and published in *Agronomía Mesoamericana*.
Location: Zamorano
Duration: 5 days
Scheduling of training activity: August 2010
Participants/Beneficiaries of Training Activity: 18
Anticipated numbers of Beneficiaries (male and female): 17M, 1F
Amount Budgeted in Workplan:
Direct cost: $10,000
Indirect cost: $0
If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: None
Comments: Supplemental funds were provided by the Dry Pulse CRSP Management Office to support the workshop.

Training activity # 2

Type of training: Informal training of biological nitrogen fixation research techniques.
Description of training activity: Trainees learned laboratory and field research techniques related to biological nitrogen fixation of beans.
Location: University of Puerto Rico
Duration: 2 weeks
Scheduling of training activity: Sept. 2010
Participants/Beneficiaries of Training Activity: Monica Mbui Martins, Ana Vargas, a research technician for the Zamorano bean research program and Jim Heilig, a graduate student from MSU under the supervision of Dr. James Kelly.
Anticipated numbers of Beneficiaries (male and female): 2 female and 1 male
Amount Budgeted in Workplan:
Direct cost: $ 0
Indirect cost: $0
If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: None
Comments: Dr. Rosas and Dr. Kelly provided funds to support the travel expenses of Ana Vargas and Jim Heilig.

Training activity # 3

Type of training: Informal training of Ascochyta blight research and participatory plant breeding techniques
Description of training activity: Trainees learned laboratory and field research techniques related to breeding beans for resistance to Ascochyta blight. They also had an opportunity to review participatory plant breeding activities in northern Ecuador. The training was coordinated by Dr. Consuelo Estevez and Ing. Eduardo Peralta.
Location: INIAP
Duration: 4 days
Scheduling of training activity: 12-15 April 2010
Participants/Beneficiaries of Training Activity: Antonio Chicapa and Antonio Castame of the Instituto de Investigação Agronómica in Angola.
Anticipated numbers of Beneficiaries: 2 males
Amount Budgeted in Workplan:
Direct cost: $ 0
Indirect cost: $ 0
If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: Mr. Chicapa and Mr. Castame took advantage of the Researcher Meeting of the Dry Grain Pulse CRSP to stay a few extra days in Ecuador to participate in the training.
Comments: The trainees returned to Angola with INIAP bean breeding lines and varieties, including JEMA which has been reported to have moderate levels of resistance to Ascochyta blight and INIAP Rocha (canario), Rojo del Valle TP-6 (red mottled), Afro-Andino (black), INIAP Paragachi (cranberry), Blanco Fanesquero (large white).

Training activity # 4

Type of training: Training farmers in participatory plant breeding (PPB) techniques
Description of training activity: A training course on participatory bean breeding was offered to farmer leaders from Honduras, Nicaragua, El Salvador, Guatemala and Nicaragua, and technical personal of the Mesoamerican PPB Program supported by the Norwegian Development Fund. The HC-PI and technical personnel from the DGP-CRSP project at Zamorano, were responsible for the classroom and field activities during this training course held at EAP facilities.
Location: Zamorano
Duration: 2 days
Scheduling of training activity: March 2010
Participants/Beneficiaries of Training Activity: farmer leaders from Honduras, Nicaragua, El Salvador, Guatemala and Nicaragua, and technical personal of the Mesoamerican PPB Program supported by the Norwegian Development Fund.
Anticipated numbers of Beneficiaries: 15 males and 4 females
Amount Budgeted in Workplan:
Direct cost: $ 0
Indirect cost: $ 0

If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount:

Norwegian Development Fund: $ 4,000.00

Comments: The training enhanced the capability to conduct participatory research in Central America.

Training activity # 5

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

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

Location: Chianga, Angola

Duration: 3 days

Scheduling of training activity: November 2009

Participants/Beneficiaries of Training Activity: IIA technical personnel

Anticipated numbers of Beneficiaries: 5 males and 3 females

Amount Budgeted in Workplan:

Direct cost: $ 0

Indirect cost: $0

If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: None

Comments: Prevention and management of plant diseases depends of a correct diagnosis. During the visits to Angola, emphasis has been given to informal training in diagnostics of plant diseases on common beans.

Networking Activities with Stakeholders

Using molecular (SCAR) markers for common beans, cultivars developed in collaboration with CIAT and National Bean Programs (NBP) were purified for the presence of the SR2 (*bgm* gene), SW12 (major QTL) and SW13 (*I* gene) markers for resistance to BGYMV and BCMV. In addition, individual plants identified to have the previously described SCAR markers, were characterized with >10 other markers associated with resistance to CBB, anthracnose, rust and ALS. This marker-assisted selection included the small red cultivars 'INTA Zamorano', 'INTA Ferroso' and 'INTA Sequía' recently released in Nicaragua under CIAT/INTA/Zamorano collaboration. Similar MAS procedures have been applied during the past years to purify bean cultivars and breeding lines developed by the project; cultivars currently being used by farmers, and the breeding lines that are being validated by NBP collaborators in several countries.

The participants in the CA/C bean research workshop expressed support for the recruitment and training of young researchers to strengthen the scientific and technical capacities of national as well as regional bean research programs. Formal training of new bean researchers in the CA/C region should be of priority activity during the next few years. Informal training and participation in regional meetings of bean researchers that expect to be active during the next 10-15 years, should be supported.

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

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. The project received seed of five black bean lines from Ing. Julio Cesar Nin, IDIAF bean breeder in the Dominican Republic. The UPR and TARS will assist IDIAF by screening these bean breeding lines for resistance to BCMV and BGYMV using molecular markers and greenhouse inoculations. Dr. Godoy-Lutz, Dr. James Steadman and James Beaver collaborated in the preparation of a report for the Bean Improvement Cooperative web site that describes the research techniques for web blight of beans.

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 will be 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.

Explanation for Changes
Ascochyta blight was identified as an important bean disease in Angola. Informal training of Angolan scientists dealing with Ascochyta blight research techniques was conducted in Ecuador.

Dr. Consuelo Esteves and Dr. Mildred Zapata joined the project as collaborators. Their expertise in plant pathology and biological nitrogen fixation strengthen the capacity of the project to achieve objectives.

Leveraged Funds
Name of PI receiving leveraged funds: Management office of the Dry Grain Pulse CRSP and the PII-UPR-1 project.
Description of leveraged project: Associate award from USAID-EGAT to promote the production and dissemination of seed of improved cultivars and to promote biological nitrogen fixation in Central America and Haiti.
Dollar Amount: $ 3,300,000
Funding Source: Associate award from USAID-EGAT
Name of PI receiving leveraged funds: J.C. Rosas
Description of leveraged project: Improvement of farmer bean and maize cultivars thru participatory plant breeding
Dollar Amount: $ 50,000 (annually)
Funding Source: Norwegian Development Fund

Name of PI describing leveraged funds: J.C. Rosas
Description of leveraged project: Adaptation of corn and beans to climatic change in Central America and the Dominican Republic: A tool for poverty reduction.
Dollar amount: $ 57,000 (3 years)
Funding source: IDB/Republic of Korea

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
A Central America and Caribbean bean research conference was held in Zamorano, Honduras, on August 2010. Participants from the NBP of Honduras, El Salvador, Nicaragua, Guatemala, Costa Rica, Haiti and the Dominican Republic attended this conference. Steve Beebe from CIAT, Irvin Widders and Jim Beaver from the DGP-CRSP and Juan Carlos Rosas from the EAP participated in the presentations and discussions. Two invited speakers from the Agribusiness Department of Zamorano made

presentations. The meeting focused on the direction of bean research for the next 5 years. The group recommended continuing the development of disease resistant cultivars. The diseases of greatest economic importance are the viral diseases BCMV, BCNMV and BGYMV, the bacterial disease common bacterial blight, and the fungal diseases web blight, rust and angular leaf spot. Disease resistance should be combined with tolerance to drought, heat and low soil fertility to reduce seed yield reductions caused by these abiotic factors. The participants also recommended continuing the effort to increase the nutritional value of beans (higher iron and zinc grain content) based on the progress made in recent years. The continuation of the bean research network for the testing of breeding nurseries (VIDAC) and trials (ECAR), using the same format of the last 10 years, was strongly supported by the participants. The EAP/Zamorano research program should serve as the coordinating institution of the bean network activities. Bean research in the CA/C should involve collaboration with CIAT, the Dry Grain Pulse CRSP, Red SICTA and other regional programs such as the Participatory Plant Breeding Mesoamerican network.

Equipment to improve the plant pathology laboratory in Huambo, Angola has been purchased. Materials have also been purchased to repair greenhouses in Huambo. Tim Porch will visit Angola in November 2010 and will review progress in the establishment of the plant pathology facilities. Quotations have been obtained to purchase threshers for Haiti and Angola.

The purchase of equipment and laboratory facilities for Haiti has been delayed due to the earthquake in Haiti in January 2010. A portion the supplemental funds for the improvement of laboratory facilities in Haiti may be needed to replace equipment and materials damaged by the earthquake. Juan Carlos Rosas, Luis Flores and Jim Beaver traveled to Haiti in October 2010 and discussed what was needed to rehabilitate bean research facilities in Haiti.

Contribution of the Project to Target Performance Indicators

All of the host countries participating in this Dry Grain Pulse CRSP proposal are USAID-eligible countries. Increased or more stable bean yields contribute to economic growth and improve the lives of the families who produce the crop. A more reliable supply of staple crops such as beans fosters stability in the Latin American and Caribbean region. Bean research in Central America and the Caribbean can help identify emerging bean diseases and permit researchers to respond more rapidly and effectively when new diseases threaten bean production in the U.S. All of the abovementioned activities support U.S. foreign policy in Latin America and the Caribbean. The development of bean cultivars for Angola with enhanced levels of resistance to biotic and abiotic constraints contributes directly to the Presidential Initiative to End Hunger in Africa (IEHA) The proposed research provides the innovations needed to reduce vulnerabilities and risks of bean producers in Angola. This Dry Grain Pulse CRSP project establishes collaborative research and training activities among U.S., LA/C and Angolan bean research institutions which is in accord with the IEHA science and technology strategy.

The research addresses two of the four global themes of the Dry Grain Pulse CRSP. The development and release of bean cultivars with enhanced disease resistance and greater tolerance to abiotic stress should reduce production costs and reduce risk for bean producers in Central America, the Caribbean and Angola. Lines with resistance to bean diseases, such as rust, should also be useful germplasm for U.S. bean breeding programs. Disease and pest resistance are key components in effective crop management systems. Bean breeding lines developed by the project will be screened for tolerance to drought and low soil fertility. Bruchid resistance should improve the quality of bean seed. Participatory plant breeding methods and multiplication of basic stocks on underutilized research stations may result in more sustainable seed production and distribution systems. The proposed research project will use informal training and web sites to strengthen the capacity of the bean research programs in Central America, the Caribbean and Angola.

Publications and Scientific Presentation

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Literature Cited

Mbogo KP, Davis J, Myers JR. 2009. Transfer of the Arcelin-Phytohaemagglutinin-α Amylase Inhibitor Seed Protein Locus from Tepary bean (*Phaseolus acutifolius* A. Gray) to common bean (*P. vulgaris* L.). Biotechnology 8:285-295.

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Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by September 30, 2010

Project Title: **Development, Testing and Dissemination of Genetically Improved Bean**

	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	9/30/10	Y	N *	9/30/10	Y	N *	9/30/10	Y	N *	9/30/10	Y	N *	9/30/10	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[1]	X	X					X		X						
Harvest F2 seed for the first cycle of recurrent selection[1]	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[2]				X		X									
SCAR markers designed and initially tested[2]				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															
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 PR in bean research techniques	X	X													
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

Signature: *James A. Beaver*

Date: *29 September 2010*

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

[1] First cycle of crosses have been delayed in order to test additional lines with representative strains from the main Rhizobia species that nodulate common beans

[2] 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).

Dry Grain Pulses CRSP		
Research, Training and Outreach Workplans		
(October 1, 2009– September 30, 2010)		
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		
Lead U.S. PI and University: James S. Beaver, University of Puerto Rico		
Host Country(s): Central America and Angola		
	2010 Target	**2010 Actual**
Output Indicators	**(Oct 1 2008-Sept 30, 2009)**	
Degree Training: Number of individuals who have received degree training		
Number of women (Monica Martin)	2	1
Number of men (Antonio David & Luis Ruiz)	1	2
Short-term Training: Number of individuals who have received short-term training		
Number of women	21	2
Number of men	10	20
Technologies and Policies		
Number of technologies and management practices under research (cultivar development & release, germplasm collection an characterization, development of molecular markers, biological nitrogen fixation and N use efficiency)	3	4
Number of technologies and management practices made available for transfer (release and dissemination of improved varieties)	1	1
Number of policy studies undertaken	0	0
Beneficiaries:		
Number of rural households benefiting directly (Improved bean varieties developed with support from the Dry Grain Pulse CRSP are distributed by government programs and NGOs to > 100,000 farm families in Central America and Haiti).	140	> 100,000
Number of producer and/or community-based organizations receiving technical assistance	8	> 8
Number of women organizations receiving technical assistance	1	> 1
Number of HC partner organizations/institutions benefiting	6	> 6
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices (Improved varieties developed with support from the Dry Grain Pulse CRSP are currently planted on at least 50,000 ha in Central America and Haiti. The project has conducted	2,000	50,000

Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda, and Tanzania

Principle Investigator
Mark E. Westgate, Iowa State University, USA

Collaboratoring Scientists
John Steven Tenywa, Makerere University, Uganda
Lynne Carpenter-Boggs, Washington State University, USA
Karen Cichy, USDA-ARS, USA
Phillip Miklas, USDA-ARS, USA
James D. Kelly, Michigan State University, USA
Henry Kizito Musoke, VEDCO, Uganda
Susan Mchimbi-Msolla, Sokoine University, Tanzania
Hamisi Tindwa, Sokoine University, Tanzania
Augustine Musoni, ISAR, Rwanda
Daniel Krohn, Becker Underwood Inc., USA
Michael Ugen, NCRI, Uganda
Peg Armstrong-Gustafson, Amson Technologies l.c., USA

Abstract of Research Achievements and Impacts

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

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

Although the project activities have been underway for only 2-3 months, all the 6-month benchmarks outlined for Objectives 1 and 2 in the revised FY10 workplan have been accomplished. These include: Identifying the genotypes and research demonstration sites to be examined at HC institutions, Quantifying soil physical and chemical characteristics at all test sites, Obtaining experimental and adapted common bean germplasm for genetic marker analyses, and Increasing seed of existing mapping populations for QTL analysis. A number of 12-month benchmarks are being addressed and are ahead of schedule for

completion in FY11. While no funding was allocated to conduct activities outlined under Objective 3, a number of initial steps were taken to ensure progress on this objective during FY11.

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

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

Project Problem Statement and Justification

Loss of soil fertility is the most important constraint to food security in sub-Saharan Africa (CIAT 2002, Bationo 2004). Low levels of nitrogen and phosphorous are the primary fertility constraints (Ndakidemi et al 2006). Because soils are increasingly becoming degraded, an affordable means of improving soil fertility and productivity of nitrogen-accumulating crops is critical. Numerous studies have shown the potential of improving legume productivity by enhancing nodulation through proper use of biological inoculants (e.g. Ndakidemi et al 2006, Silver and Nkwiine 2007). Yet field trials have provided mixed results (Nkwiine 1999, Musdandu and Joshua 2001). Potential reasons for failure include poor quality of inoculants, failure to compete with local rhizobia, inhibition by indigenous microbial flora, or failure of the inoculants to survive in low pH and droughty soils (Graham, 1981). Modern inoculant formulations designed to deliver a synergistic suite of biological and chemical enhancements for biological nitrogen fixation under stressful soil conditions have been made available to our collaborative research project by Becker Underwood, Inc. (see letter of collaboration). Becker Underwood's BioStacked® inoculant technologies for legume crops consist of well stabilized *Rhizobium* bacteria, a biological fungicide, plant growth promoting rhizobacteria, and other biologically derived proprietary biostimulant technologies which promote plant growth and overall plant health. These stacked inoculants decrease chemical fertilizer use in crop rotations, increase legume yields, suppress root diseases, and improve rhizosphere conditions for root growth. And they are suitable for use on a variety of legume crops such as soybean, common bean, cowpea, and pigeon pea. We anticipate they will be particularly effective under degraded soil conditions encountered on small-landholder farms in Uganda, Rwanda, and Tanzania.

To optimize BNF, it is essential to identify germplasm with greatest capacity for this trait (Bliss et al 1989, Diouf et al 2008). Although common bean has the potential for BNF, it is reported to have the lowest percent N_2 derived from N fixation among legumes (Martinez-Romero 2003). Genetic variation for BNF has been reported and lines with superior BNF have been identified (Bliss, 1993; Graham et al., 2003). Superior BNF lines such as Puebla 152 and BAT 477 (Vadez et al., 1999; Miklas et al., 2006) have been used as parents in crosses to generate populations for genetic studies and breeding for improved BNF. Few breeding lines with improved BNF, however, have been developed. Low heritability estimates for BNF and related traits indicate that BNF traits are quantitatively inherited and influenced by environment. The optimal selection environment for BNF is under low soil N since application of nitrogen fertilizer reduces N fixation capacity (Schulze 2004). Marker-assisted selection under such conditions is highly sought after as a means to facilitate breeding for improved BNF because of its low heritability.

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

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

Planned Project Activities for April 1, 2009 - September 30, 2010

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

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

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

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

Germplasm: In Uganda, there are three common bean varieties with market preference considered i.e. K 132, Kanyebwa (local cultivar) and K131 (V_1, V_2, V_3, respectively). Kachwekano was selected for climbing bean and three varieties namely NABE10C, NABE12C and local cultivar (V_1, V_2 and V_3 respectively) were selected and planted under the same treatments. Figure 1 shows the general outline of the field study.

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

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

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

In Uganda these are located in three agro-ecological zones identified in cooperation with Dr. Tenywa and two masters students (Ms. Martha Abwate and Mr. Peter Ssenyonga at Makerere University) in central Uganda at Namulonge (NaCRRI) and southwestern Uganda at Mbarara ZARDI and Kachwekano ZRDI research stations. Treatments include three rhizobia types sourced from USA (Becker Underwood), and from Universities of Nairobi and Makerere. The latter two were considered as indigenous for comparison purposes.

In Rwanda, two sites were selected at ISAR Nyagatare research station and at the farmers' field in Nyakigando sector of Nyagatare district. Nyagatare lies within 30°20E and 1°20S. The mean altitude is 1450 masl and 700 - 900 mm and 22.4C for the rainfall and temperature respectively. The soils are generally sand (41 - 68%), clay (20-38% and loam 8 - 27%). Silt content is very low while percolation is moderate and evapotranspiration is high. Nyakigando site was selected for research but also for demonstration and training purposes of the members of the farmers' cooperatives and other farmers in the area.

In Tanzania, the field sites are located at the research stations at Morogoro, Mbeya and Arusha. Details of the field location and plot design to be provided in the next semi-annual report.

Additional field management details: At the NaCCRI stations, phosphorus being the most constraining nutrient in the soils of east Africa and yet very crucial to effective BNF, was considered as a treatment (0 and 40 kg P ha^{-1}) to evaluate to what extent the imported rhizobia can withstand the limited P supply in the soil. The factorial combinations culminated into a total of 72 treatment plots. The spacing was 10cm x 50cm for common bean varieties in Namulonge and Mbarara and 20cm x 50cm for climbing bean varieties in Kabale (Kachwekano ZARDI). The project has also planted 130 lines of bush beans at NaCRRI for multiplication to be shared with other countries in the coming season.

At ISAR, four varieties (V1, V2, V3 and V4) x rhizobia (Ru, Rn with or without: Ro) x P fertilizer at 2 levels (with and without) were applied in all combinations to give a total of 24 treatments (Table 2). Rhizobia inoculants were applied at 20 g per kg of seed, while P was sprinkled in planting rows at 20 kg per ha. Inoculation was done separately in plastic basins using hand grooves to avoid cross contamination. Eight 4m long rows were planted per plot of 4m x 4m with 4 replications at the on-farm site of Nyakigando. The plot size was 6m x 6m at the on station site of Nyagatare. Randomization was of treatments was done for each replication at planting. Planting was done after rains in moist soils.

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

- (6 mo) Quantified soils physical and chemical characteristics at all test sites

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

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

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

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

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

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

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

Michigan State University: Parental materials were for inheritance studies were identified based on previous knowledge of BNF capacity. One line, Puebla 152, was identified as BNF efficient and a RIL population exists with Eagle (snap bean) as the other parent. Additional genotypes were planted that are parents of other available RIL populations. Ninety two genotypes were planted in low nitrogen (25 lbs/acre) in Frankenmuth, MI. These materials included Eagle, Puebla 152, 72 Eagle x Puebla RILs, a no nod mutant, and 17 additional genotypes. The materials were planted under two treatments: 1) plus Becker Underwood 'Nodulator' inoculant, 2) no inoculant.

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

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

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

The Prosser trial site is a Warden Silt Loam and is used for selecting bean lines under multiple stresses (low fertility, soil compaction, drought, and root rot diseases). Historically the residual N for this trial has been about 25 lbs/A; however, this year 75 lbs/A residual N was detected in the trial ground right after planting. The high residual soil N appears to have compromised examination of the BNF response for the 23 genotypes tested at Prosser. Therefore, results from the Prosser trial will not be interpreted in detail at this time (supplementary Table).

The Paterson trial site is a Quincy Sand. Low residual N (25lbs/A) was confirmed for this trial prior to planting. The same set of genotypes plus five more (28 genotypes total) was tested in Paterson. Soil and plant samples obtained from specific treatments and genotypes at harvest maturity were recently transferred to the lab in Pullman (LCB) for examination of N levels but have not been analyzed yet. Soil total, available, and mineralizable N will be analyzed. Plant %N and 15/14N ratio will be analyzed. This information combined with yield data will be used to quantify the proportions and total amounts of BNF by these genotypes and treatments.

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

Note that nodules for typing Rhizobium strains were not collected from the WA trials this season, but will be collected and characterized across treatments from select genotypes for both WA test locations next season. Procedures to analyze nodule and soil rhizobia will primarily use full community pyrosequencing of nifH, nifD, and (for nodules) 16SrDNA genes. Pyrosequencing is available through the WSU Core Molecular Biology laboratory. This method bypasses isolation of individual strains and cloning, and determines not only the nitrogen-fixing organisms present, but their relative proportions in soils and nodules of the various soil and bean genotype treatments. Where individual treatments are of particular interest for very high BNF, individual strains will be isolated from nodules for pure culture.

Preliminary greenhouse trials were undertaken in July – October to optimize growth conditions for P. vulgaris in the WSU-Pullman greenhouse facilities. A perlite-vermiculite mixture was found to reduce seedling growth but increase nodulation and final biomass as compared to perlite alone. Inoculated plants supplied Hoagland solution (N-free recipe after wk 2) twice weekly produced more biomass and nodules than plants fertilized once weekly. A severe infestation by thrips caused some defoliation in September; diligent observation and control of thrips will be undertaken for successful genotype and strain trials. Fifty lines including the 28 genotypes tested in the field and 23 additional lines were sent to Pullman for analysis of BNF response in the greenhouse (supplemental Table). The greenhouse studies will commence in early November 2010.

QTL analyses: Development of genetic populations for mapping and QTL analysis has not commenced yet because suitable parental genotypes with clear differential BNF efficiency responses have not been identified. An existing RIL population (Eagle/Pueblo-152) was increased in the greenhouse for 2011 field planting but lack of adaptation of the parents for this population in 2010 WA field trials indicated that this population may only be useful for greenhouse examination of BNF response.

Michigan State University: Plant samples of the BNF trial were taken at mid pod fill for each genotype/treatment/rep. The sample consisted of all above ground biomass of 2 plants for each entry. Samples were oven dried and ground to a fine powder. These samples are being analyzed for N15 via natural abundance analysis at the UC Davis Stable Isotope Facility. Results are expected by December 15, 2010. Nitrogen from fixation will be estimated relative to the nitrogen accumulated by a non-nodulating bean line included as a control in the experiment.

SSR screening was conducted on Eagle and Puebla 152 to identify polymorphic markers. The BNF trial, including Eagle x Puebla RILs and additional 18 lines, was harvested on Oct 1, 2010. The Eagle x Puebla population did not do well in the field in MI. Many of the lines were very late maturing and did not have desirable growth habit. Marker analysis for the entire RIL population has yet to be conducted pending yield evaluation from the field plots.

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

3a. Improve farmer awareness of inoculation technologies
3b. Conduct on-farm demonstrations comparing inoculant strategies
3c. Strengthen farmers' collective capabilities to purchase inoculants and incorporate them into a profitable and sustainable system for small landholders.

- No funding allocated or benchmarks for this period.

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

PI Westgate met with the Chair of PELUM Uganda and Communications Coordinator for VEDCO, Agnes Kirabo, to initiate outreach activities with participating farmer organizations in PELUM Uganda, PELUM Kenya, PELUM Tanzania, and PELUM Rwanda. Strategy meeting among PELUM country coordinators to initiate dissemination activities is scheduled for November.

<u>Objective 4</u>: Institutional Capacity Building: Three laptops (Dell) and one printer HP LaserJet P1006 were purchased by Makerere University for a total cost of US$ 5369 through the procurement system of the University. This equipment is being shared by two graduate students and the PI (Tenywa) at Makerere University.

<u>Degree Training</u>:
Iowa State University
First and Other Given Names: Mercy
Last Name: Kabahuma
Citizenship: Ugandan
Gender: Female
Degree: MSc
Discipline: Crop Production and Physiology
Host Country Institution to Benefit from Training:
Training Location: Iowa State University
Supervising CRSP PI: Mark Westgate
Start Date of Degree Program: August 2010
Program Completion Date: August 2012
Training Status during Fiscal Year 2010: Just starting
Type of CRSP Support (full, partial or indirect): Full

Makerere University
First and Other Given Names: Martha
Last Name: Abwate
Citizenship: Ugandan
Gender: Female
Degree: MSc
Discipline: Soil Science
Host Country Institution to Benefit from Training: Makerere University
Training Location: Makerere University
Supervising CRSP PI: Steven Tenywa and Michael Ugen
Start Date of Degree Program: September 2010
Program Completion Date: August, 2012
Training Status during Fiscal Year 2010: Just starting
Type of CRSP Support (full, partial or indirect): Full

Makerere University
First and Other Given Names: Peter
Last Name: Ssenyonga
Citizenship: Ugandan
Gender: Male
Degree:. MSc
Discipline: Soil Microbiology
Host Country Institution to Benefit from Training: Makerere University
Training Location: Makerere University
Supervising CRSP PI: Steven Tenywa and Michael Ugen
Start Date of Degree Program: September 2010
Program Completion Date: August, 2012
Training Status during Fiscal Year 2010: Just starting
Type of CRSP Support (full, partial or indirect): Full

Sokoine University
First and Other Given Names: Charles
Last Name: Komba
Citizenship: Tanzanian
Gender: Male
Degree:. MSc
Discipline: Agronomy
Host Country Institution to Benefit from Training: Sokoine University of Agriculture (SUA)
Training Location: SUA
Supervising CRSP PI: Susan Nchimbi-Msolla
Start Date of Degree Program: September 2010
Program Completion Date: September, 2012
Training Status during Fiscal Year 2010: Just starting
Type of CRSP Support (full, partial or indirect): Full

Sokoine University
First and Other Given Names: Beata
Last Name: Khafa
Citizenship: Tanzanian
Gender: Female
Degree:. MSc
Discipline: Plant Breeding
Host Country Institution to Benefit from Training: Sokoine University of Agriculture (SUA)
Training Location: SUA
Supervising CRSP PI: Susan Nchimbi-Msolla
Start Date of Degree Program: September 2010
Program Completion Date: September, 2012
Training Status during Fiscal Year 2010: Just starting
Type of CRSP Support (full, partial or indirect): Full

Washington State University
First and Other Given Names: Acceptance to program pending for January 2011.
Last Name: Pending acceptance
Citizenship:
Gender: Female
Degree: MSc
Discipline: Plant Genetics and Plant Breeding
Host Country Institution to Benefit from Training: Washington State University
Training Location: Washington State University
Supervising CRSP PI: Lynne Carpenter-Boggs
Start Date of Degree Program: January 2011
Program Completion Date: December 2012
Training Status during Fiscal Year 2010: Not on site
Type of CRSP Support (full, partial or indirect): no support
Short Term Training:

Two undergraduate students were recruited for attachment to the project to undertake field data collection at ISAR in Rwanda. 1. Emma Uwera 2. Justin Tuyisenge from Umutara Polytechnic University in Rwanda. The recruitment of a third undergraduate is being concluded. Their training on laboratory and field BNF techniques is underway.

Explanation for Changes

The project was approved and funding acquired by HC collaborators after July 2010. This was towards the end of the first growing season that started in March and ended in the same June/July 2010. Any activities not implemented as per performance indicators were due to this off-season arrangements. The main growing season for the implementation of the project started this September/October, 2010.

Due to an abrupt change from Professor Bekunda Matete to Dr. J.S. Tenywa at Makerere University, which followed shortly after the funds were transmitted, project activities started in August with selection of students. Field activities started mid September. As such data collection is underway and therefore we cannot present realist datasets at the moment.

The short-term training visit planned for Mr. Hamisi Tindwa of SUA to Washington State University to learn soil microbiology techniques from Dr. Lynne Carpenter-Boggs did not take place in this funding period due to late disbursement of funds from the MO. This training will take place in FY11.

Networking and Linkages with Stakeholders

Obtained germplasm from the NARs in Tanzania and from CIAT.

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

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

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

Leveraged Funds

ISAR is a partner in the N2Africa program led by the University of Wageningen and CIAT investigating effects of inoculants on yields of improved bean germplasm. Funding from this program supports training for one PhD and MSc student in Rwanda. ISAR is also part of the AGRA Soil Health Program project investigating interactions between inoculants, varieties, and soil conditions. Complementation among these projects leverages results on germplasm sources and inoculants developed locally, regionally, and from the US.

Scholarly Activities and Accomplishments

No publications, technical reports, or theses submitted during this funding period.

Tables/Figures

Figure 1. General field map for one replicate of the inoculant evaluation trials. R_0 = No Rhizobium strain Inoculated, R_M = Rhizobium strain from Makerere University Bio-fix, R_N = Rhizobium strain from Nairobi Bio-N-fix, R_U = Rhizobium strain from Underwood BioStacked®, P_0 = No phosphorus fertilizer applied, P_+ = Phosphorus fertilizer (TSP) applied at 40 kg P ha^{-1}. Varieties V1-3 varied by location.

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

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

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

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Contribution to Gender Equity Goal

Of the eight graduate and undergraduate students formally involved in training activities at US and Host Countries thus far, five (62.5%) are female. It is our plan to involve where possible at least 50% women to participate in field demonstrations and on-farm trials.

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2009 -- September 30, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2010

Project Title: *Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda, and Tanzania*

	Abbreviated name of institutions																							
	ISU			MSU			WSU			VEDCO			NaCRRI			SUA			Makerere			SAR		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*	9/30/10	Y	N*
(Tick mark the Yes or No column for identified benchmarks by institution)																								
Objective 1																								
Identify variety set for field testing				X	X		X	X					X	X		X	X					X	X	
Identify research demonstration sites				X	X		X	X					X	X		X	X					X	X	
Soil identified the soil for field trials	X	X		X	X		X	X					X	X		X	X					X	X	
Established field plot design at research stations	X	X		X	X		X	X					X	X		X	X					X	X	
Field Trial 1 established				X	X		X	X					X	X		X	X					X	X	
Quantified yield of inoculation Field Trial 1				X		X	X		X				X		X	X		X				X		X
Quantified soil physical characteristics													X	X		X	X		X	X		X	X	
Quantified soil chemical characteristics													X	X		X	X		X	X		X	X	
Analyzed initial soil and weather data	X	X											X	X		X	X		X	X		X	X	
Established sampling procedures to quantify BNF	X	X		X	X		X	X					X	X		X	X					X	X	
Established lab procedures to quantify BNF	X	X		X	X		X	X					X	X		X	X					X	X	
Sampled soil for DNA extraction							X		X				X		X	X		X				X		X
Established procedures to analyze soil microbes							X	X								X	X							
Objective 2																								
Obtain experimental and selected germplasm	X	X		X	X		X	X					X	X		X	X					X	X	
Initial screen for increased BNF in low soil N +/- inoculants				X	X		X	X					X	X		X						X	X	
Initiate Greenhouse BNF screening on selected lines							X	X																
Increase seed of mapping populations for QTL analysis							X	X																
Initiate phenotyping for divergent responses of BNF				X	X		X	X					X	X		X	X					X	X	
Begin field testing of parental lines and selected populations				X	X		X	X					X	X		X	X					X	X	
Established procedures to analyze for nodule...	X	X					X	X					X	X		X	X					X	X	
Objective 3																								
Train field staff on use of inoculation technology													X	X		X	X					X	X	
Establish farmer and farmer groups for inoculant technology																								
Identify local bean varieties to include in field trials													X	X		X	X					X	X	
Train farmers on proper methods for conducting on-farm trials																								
Complete farmer KPA evaluation; on inoculation and BNF																								
Design and format field demonstrations of inoculum technology	X		X										X		X	X		X				X		X
Incorporate BNF/inoculant information in PELUM activities																								
Objective 4																								
Graduate students identified	X	X					X	X								X	X		X	X				
Graduate research programs initiated	X	X					X	X								X	X		X	X				
Undergraduate student interns identified																						X	X	
Undergraduate student projects initiated																						X	X	
Visiting scientist activities completed							X		X							X		X						
Name of the PI reporting on benchmarks by institution	Westgate			Cichy/Kelly			Miklas/Carpenter-Boggs			Mugisha			[illegible]			Ndakidemi			Tenywa			Musoni		

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

Mark E. Westgate (signature) — Signature

10/1/10 — Date

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

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2009 – September 30, 2010)

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

Project Title: Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda, and Tanzania
Lead U.S. PI and University: Mark E. Westgate, Iowa State University
Host Country(s): Rwanda, Tanzania, Uganda

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	4	4
Number of men	4	4
Short-term Training: Number of individuals who received short-term training		
Number of women	50	0
Number of men	50	0
Technologies and Policies		
Number of technologies and management practices under research	3	3
Number of technologies and management practices under field testing	3	3
Number of technologies and management practices made available for transfer	0	0
Number of policy studies undertaken	0	0
Beneficiaries:		
Number of rural households benefiting directly	100	0
Number of agricultural firms/enterprises benefiting	3	3
Number of producer and/or community-based organizations receiving technical assistance	10	3
Number of women organizations receiving technical assistance	0	0
Number of HC partner organizations/institutions benefiting	5	5
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	

Pulse Value Chain Initiative – Zambia (PVCI-Z)

Principle Investigator
Vincent Amanor-Boadu, Kansas State University, USA

Collaboratoring Scientists
Gelson Tembo, University of Zambia, Zambia
Mukwiti Mwiinga, University of Zambia, Zambia
Prisilla Hamukwala, University of Zambia, Zambia
Rebecca Lubinda, University of Zambia, Zambia
Tim Dalton, Kansas State University, USA
Allen Featherstone, Kansas State University, USA
Mahmud Yesuf, Kansas State University, USA

Abstract of Research Achievements and Impacts
This project is just about to start. Therefore, we have no research achievements to report. However, we have completed the U.S. institution project planning and the lead PI is going to Zambia September 22-October 5 to begin the HC institution project planning. We have also recruited 6 (out of 6) undergraduate students, 1 (out of 3) MS students and 0 (out of 3) MAB students.

Project Problem Statement and Justification
Information provided in the work plan has not changed and need no revisions.

Planned Project Activities for April 1, 2009 - September 30, 2010

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

Approaches and Methods: The approach to achieving this objective (and others) includes starting with a developing a common appreciation of the project and engaging both PIs and students. Therefore, organizing PI strategic planning session and recruiting students were seen as priority activities.

Results, Achievements and Outputs of Research: Our project was just approved (at the end of August). We have only been successful completing the strategic planning of the U.S. PIs and planned a planning session in Zambia from September 22 to October 5, 2010. The Zambian session aims to also initiate the development of the project's survey instruments.

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

<u>Objective 2</u>: Identify and estimate the effects of stakeholder characteristics on producers' supply chain participation decisions.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

<u>Objective 3</u>: Describe and estimate the pecuniary and non-pecuniary value for different supply chain participants.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

<u>Objective 4</u>: Identify the institutional and policy issues influencing value creation and determine if any effect differences exist by crop, location, gender and stage of the chain.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

<u>Objective 5</u>: Based on the results from the foregoing, develop and deliver education and outreach programs targeting specific stakeholders and provide policy recommendations to facilitate solutions.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

<u>Objective 6</u>: Work with specific industry stakeholders to pilot different governance systems to identify the factors and participant characteristics influencing performance.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

<u>Objective 7</u>: Use the results of the experiment to develop outreach programs, program advocates and program advisory support systems to help producers and their partners develop appropriate governance systems to improve their economic well-being.

Approaches and Methods: No change in proposed methods and approaches in technical report and addenda.

Results, Achievements and Outputs of Research: Not started yet.

Objective __ (Capacity Building):

Name	Citizenship	Gender	Degree Program	Training Location	Type of Support	Training Status
Esther Tatenda Zulu	Zambian	Female	5th -Year UG	UNZA	Tuition & Stipend	Started
Agness Myece	Zambian	Female	5th -Year UG	UNZA	Tuition & Stipend	Started
Natasha Chilundika	Zambian	Female	5th -Year UG	UNZA	Tuition & Stipend	Started
Chimuka Samboko	Zambian	Male	5th -Year UG	UNZA	Tuition & Stipend	Started
Edna Ngoma	Zambian	Female	5th -Year UG	UNZA	Tuition & Stipend	Started
Sunga Chalwe	Zambian	Female	5th -Year UG	UNZA	Tuition & Stipend	Started
	Zambian		MS	UNZA	Tuition & Stipend	Started

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

Principle Investigator
Maurice R. Bennink, Michigan State University, USA

Collaboratoring Scientists

Theobald Mosha, Sokoine University of Agriculture, Tanzania
Henry Laswai, Sokoine University of Agriculture, Tanzania
Elizabeth Ryan, Colorado State University, USA
Reuben Kadigi, Sokoine University of Agriculture, Tanzania.

Abstract of Research Achievements and Impacts

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

Project Problem Statement and Justification

The overall goal of the research is to determine if eating beans or cowpeas will improve the immune status of HIV positive children that are not being treated with antiretroviral drugs. The global theme addressed by this research is B – "To increase the utilization of bean and cowpea grain, food products and ingredients so as to expand market opportunities and improve community health and nutrition" and the topical area that will be addressed is #2 – "Achieving Nutritional Security for Improved Health of Target Populations". HIV has caused an estimated 25 million deaths worldwide in just 27 years and there are approximately 33 million people in the world infected with HIV [1]. Around 2 million children less than 15 yr of age have HIV and 90% of the children living with – and dying from – HIV live in sub-Saharan Africa. Furthermore, about 140,000 of these children live in Tanzania [2]. Most children living with HIV are innocent victims as they are infected during pregnancy, at birth or via breastfeeding. It is well known that insufficient intake of macronutrients and some micronutrients leads to a decrease in immune function and an increase in infectious diseases. Infections in turn cause nutrient loss that quickly leads to greater malnutrition and a vicious cycle is set in motion [3]. Since the human immunodeficiency virus destroys CD4 cells (immune cells), opportunistic infections are common place among those living with HIV [4,5]. In addition, most young children (not infected with HIV) in resource poor countries are under nourished or have marginal nutrition status. Since the insults of malnutrition and HIV on the immune system are synergistic, it is not surprising that young children with HIV are 2.5 – 4 times more likely to die than their counterparts that are not infected [1,6].

We previously showed that providing HIV+ children with a bean-maize supplement containing minerals and vitamins could reverse malnutrition if present and improve the immune system (increased CD4 counts) even though the children were not receiving highly active antiretroviral (HAARV) drugs. This is an extremely important finding since 50% of HIV+ people do not have access to HAARV drugs and consuming the bean based supplement could be an important stop gap until more people are able to obtain HAARV drugs. Children receiving HAARV treatment also benefited from the bean-based supplement in a second study we have done and so, the bean-based supplement would also be useful to children that have access to HAARV medicine. Cowpea is a widely consumed pulse in Africa, but there is no published data regarding the effect of feeding cowpeas to HIV+ children. If cowpea is also effective in improving nutritional and immunological status, consuming a bean-based or cowpea-based supplement could improve the lives of millions of HIV infected people which would at the same time benefit the entire bean/cowpea value-added chain from farmers to consumers.

Planned Project Activities for April 1, 2009 - September 30, 2010

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

Approaches and Methods:

1. Assemble research team members in Tanzania (field supervisors, nurses, technicians).
2. Install blood cell counter (cytometer) and train technicians to use and maintain the instrument.
3. Enroll 270 subjects into the HIV study.
4. Train one Ph.D. and three M.S. students to assist in research.
5. Provide field practical training in community nutrition and health for 10 undergraduates.
6. Analyze 540 blood samples for CD4 and related lymphocytes.

Results and Outputs: The study sites are remote from SUA – Turani is approximately 100 km from SUA and not easily accessible due to a 45 km stretch of very poorly maintained dirt road and Rombo is a rural area 550 km from SUA. Therefore, on-site, local research teams were assembled for each study site. The team members were trained to be responsible for the day to day administration and monitoring of the study. Community meetings were held to inform families about the upcoming study and to gauge willingness to participate in the study. The meetings suggest that each site can provide the required 270 subjects.

Approximately 30,000 individual packages of food supplement (daily servings for about 2 months) have been prepared. This requires purchasing and transporting raw materials to SUA where the supplement is processed and weighed into packages that form individual daily servings.

A laboratory capable of receiving, processing and storing biohazardous materials was assembled at SUA. Except for the flow cell counter, all other pieces of equipment necessary for the study have been installed. Likewise, the laboratory has been stocked with the necessary supplies and pieces of small equipment.

Three MS students completed their coursework and received training to assist in the study and to gather data for their research dissertation. This project allowed 11 undergraduate students to receive practical field training in community nutrition and health. The project provides a “focal point” for the 11 undergraduates which is a great benefit not only for the students, but also for the Food Science and Nutrition Department at SUA. There is no cost to the project associated with the undergraduate training.

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

Protocols for eluting and analyzing viral RNA, ribosomal 16s RNA, and various proteins from dried blood spots were standardized. Viral RNA will be monitored to determine if dietary treatment affects innate ability to suppress the human immuno virus. Ribosomal 16s RNA is an indicator of bacterial products in blood and will reflect bacterial translocation from the gut.The proteins being analyzed (C-reactive protein, soluble tumor necrosis factor receptor p55 and interferon-γ) are inflammatory markers. These assessments will be performed to monitor HIV status and to provide hypotheses regarding treatment effectiveness. No actual blood spots from subjects were analyzed due to the delay in flow cytometer installation.

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

Approaches and Methods:

1. Determine costs associated with cooking beans in a pot and preparing Ugali (corn based local food).
2. Determine costs associated with preparation of the bean-maize supplement and thin porridge from the supplement.
3. Determine costs associated with preparation of the fish-maize supplement and thin porridge from the supplement.
4. Determine costs associated with HAARV drug treatment.

Results and Outputs:

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

Objective 3: Capacity building at SUA.

Results and Outputs:

One Ph.D. and 3 MS students received support and training for their respective research projects which are part of this research activity. The ability and capacity to conduct research related to HIV monitoring at SUA is a significant advancement for SUA. It is expected that other researchers at SUA will now be willing to engage in similar research activities which will increase the overall research capacity at SUA.

Institutional Capacity Building:

Degree Training:

Trainee # 1
First and Other Given Names: Pudensiana
Last Name: Kiwale
Citizenship: Tanzania
Gender: Female
Degree: Doctorate
Discipline: Agricultural Marketing
Host Country Institution to Benefit from Training: Tanzania
Training Location: SUA
Supervising CRSP PI: Reuben Kadigi
Start Date of Degree Program: August, 2009
Program Completion Date: August, 2012
Training Status during Fiscal Year 2010: Active
Type of CRSP Support (full, partial or indirect): Indirect

Trainee # 2
First and Other Given Names: Amos
Last Name: Nyangi
Citizenship: Tanzania
Gender: Male
Degree: MS
Discipline: Food Science
Host Country Institution to Benefit from Training: Tanzania
Training Location: SUA
Supervising CRSP PI: Henry Laswai
Start Date of Degree Program: August, 2009
Program Completion Date: August, 2011
Training Status during Fiscal Year 2010: Active
Type of CRSP Support (full, partial or indirect): Full

Trainee # 3
First and Other Given Names: Sarah
Last Name: Johnson
Citizenship: Tanzania
Gender: Female
Degree: MS
Discipline: Food Science
Host Country Institution to Benefit from Training: Tanzania
Training Location: SUA
Supervising CRSP PI: Henry Laswai
Start Date of Degree Program: August, 2009
Program Completion Date: August, 2011
Training Status during Fiscal Year 2010: Active
Type of CRSP Support (full, partial or indirect): Full

Trainee # 4
First and Other Given Names: Rosemary
Last Name: Marealle
Citizenship: Tanzania
Gender: Female
Degree: MS
Discipline: Nutrition
Host Country Institution to Benefit from Training: Tanzania
Training Location: SUA
Supervising CRSP PI: Theobald Mosha
Start Date of Degree Program: August, 2009
Program Completion Date: August, 2011
Training Status during Fiscal Year 2010: Active
Type of CRSP Support (full, partial or indirect): Full

Short Term Training:
Type of Training:
Description of Training Activity:
Status of this Activity as of September 30, 2010: Did not occur
When did the Short Term Training Activity occur?
Location of Short Term Training:
If Training was not completed as planned, provide a rationale: The HACCP/Food Safety Course was not offered by MSU in August or September as in previous years.
Who benefitted from this Short Term Training Activity?
Number of Beneficiaries by Gender: Male-
Female-
Total-

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

Explanation for Changes

There were two reasons why the baseline data was not collected and the supplementary feeding was not initiated. The first reason is that SUA had a two month delay in releasing their annual financial allocation from their government. SUA in turn delayed classes for two months and thus the academic obligations were not completed by the host country PIs until the end of Aug. Normally there would have been two months available to get the clinical trial underway. Equally important is the second reason – the "loaner" flow cytometer did not become available until late August. It took a month for SUA to approve the financial arrangements to purchase the reagents for the flow cytometer from a non-Tanzanian source. Apparently, once Tanzania has some money, they want it spent within the country and they do not want to allow funds to go to another country (Belgium in this case). (Note: Since this report is being prepared on 11-1-2010, I can add that the flow cytometer has been installed and training by the manufacturer has occurred. Now that their presidential election has occurred, the baseline data will be obtained immediately). The reason for not completing the short-term training for Drs. Mosha and Laswai is the HAACP course was not offered by MSU due to lack of sufficient enrollment. The course may be taught at some future date if the demand is sufficient.

Networking and Linkages with Stakeholders

In June 2010, Drs. Mosha and Bennink visited the Tanzanian USAID Mission and the World Bank to inform them of the research activities being conducted and planned by this activity. The host country PIs provided advice and assistance to two agricultural firms/enterprises: a) Tanzania Foods Limited – composite food producers for special groups; and b) Tanzania Power Foods – producer of foods for children, hospitals, and rehabilitation centers and for retail outlets. The host country PIs provided advice and assistance to three women's; groups: a) WAVUMO – women's group fighting against HIV/AIDS; b) TUNAJALI "We care" is an NGO women's group that provides Home

Based Care and counseling for HIV+ families; and c) FARAJA TRUST FUND – A women's group dealing with women's and children's needs due to HIV infection.

Leveraged Funds

No direct leveraged funds were received. The Heinz Company Foundation supports two research projects with the PIs of this activity. The Heinz supported projects are synergistic to this activity, but their support does not directly increase the capacity of this activity. The loan of the flow cytometer avoids the need to spend to purchase one and is a huge savings for the project. Lastly, support for the PIs' time and efforts comes from their respective institutions, not from USAID and should be considered "in kind" leveraged resources.

Scholarly Activities and Accomplishments:

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

Literature Cited

1. UNAIDS. *2008 Report on the global aids epidemic*. 2008. (http://www.unaids.org/en/KnowledgeCentre/HIVData/GlobalReport/2008/2008_Global_report.asp. accessed 8/15/08).
2. UNAIDS. Data Mapping. 2009. (http://www.unaids.org/en/KnowledgeCentre/HIVData/mapping_progress.asp. accessed 8/15/08).
3. Katona, P. and J. Katona-Apte, *The interaction between nutrition and infection.* Clinical Infectious Diseases, 2008. **46**(10): p. 1582-1588.
4. Cunningham-Rundles, S., D.F. McNeeley, and A. Moon, *Mechanisms of nutrient modulation of the immune response.* Journal Of Allergy And Clinical Immunology, 2005. **115**(6): p. 1119-1128.
5. Colecraft, E., *HIV/AIDS: nutritional implications and impact on human development.* Proceedings Of The Nutrition Society, 2008. **67**: p. 109-113.
6. Fergusson, P. and A. Tomkins, *HIV prevalence and mortality among children undergoing treatment for severe acute malnutrition in sub-Saharan Africa: a systematic review and meta-analysis.* Transactions Of The Royal Society Of Tropical Medicine And Hygiene, 2009. **103**(6): p. 541-548.

Contribution to Gender Equity Goal

Three women graduate students are receiving support for advanced degrees and Tanzania is in great need of women with advanced degrees.Tanzania Power Foods is a woman owned enterprise and host country PI interaction with her will assist her in maintaining her successful business. WAVUMO, TUNAJALI , and the FARAJA TRUST FUND are all women's groups that benefitted from this USAID supported research activity.

Progress Report on Activities Funded Through Supplemental Funds No supplemental funds were used for this activity.

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: Jan 1, 20010 – March 31, 2010)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2010

Project Title: *Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Support*

	Abbreviated name of institutions								
	SUA			MSU			0		
	Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	4/1/10	Y	N*	4/1/10	Y	N*	4/1/10	Y	N*
(Tick mark the Yes or No column for identified benchmarks by institution)									
Objective 1									
Apply for IRB approvals	1	√		0			0		
Obtain IRB approvals	0			0			0		
Install cytometer & training	0			0			0		
Assemble research team	0			0			0		
Enroll 150 subjects	0			0			0		
Provide student training	0			0			0		
Analyze blood samples	0			0			0		
Objective 2									
Investigate costs of	0			0			0		
supplement production	0			0			0		
Investigate costs of	0			0			0		
HAARV treatment	0			0			0		
0	0			0			0		
0	0			0			0		
0	0			0			0		
Objective 3									
Apply for permit to transport	0			0			0		
infectious materials	0			0			0		
Obtain approval for transport	0			0			0		
of infectious materials	0			0			0		
Protocol development	0			1	√		0		
Conduct animal studies	0			0			0		
Name of the PI reporting on benchmarks by institution	T. Mosha			M. Bennink					

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

Maurice R. Bennink

Signature

May 27, 2-10
Date

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

Explanation for not achieving benchmark indicators

For PIII-MSU-3: Improving Nutritional Status and CD4 Counts
in HIV-Infected Children Through Nutritional Support

Two benchmarks and one training output indicator were not achieved for this project for FY10 for the following reasons:

1. *Benchmarks* The flow cytometer that is "loaned" to our project did not become available from the manufacturer until late August. In addition, purchasing the reagents for the cytometer by SUA was a major problem and it took several weeks to finalize how this could be accomplished. Since the cytometer did not arrive at SUA until mid September and the reagents necessary operate the machine won't be available until about 10-12-2010, installation and training will take place the week of 10/18/2010. Oviously, no blood samples can be collected and analyzed until training has occurred.
2. *Training output indicator* The short term training for Drs Laswai and Mosha (HACCP/Food Safety Course) was not offered by MSU in September as is the usual custom. We hope that the course will be offered sometime during FY11 and that the short term training can then occur.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2009 – September 30, 2010)

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

Project Title: Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Support
Lead U.S. PI and University: Maurice R. Bennink, Michigan State University
Host Country(s): Tanzania

Output Indicators	2010 Target	2010 Actual
	(October 1 2009-Sept 30, 2010)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	4	
Number of men	0	
Short-term Training: Number of individuals who received short-term training		
Number of women	0	
Number of men	2	
Technologies and Policies		
Number of technologies and management practices under research	0	
Number of technologies and management practices under field testing	0	
Number of technologies and management practices made available for transfer	0	
Number of policy studies undertaken	0	
Beneficiaries:		
Number of rural households benefiting directly	150	
Number of agricultural firms/enterprises benefiting	2	
Number of producer and/or community-based organizations receiving technical assistance	2	
Number of women organizations receiving technical assistance	1	
Number of HC partner organizations/institutions benefiting	1	
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	

Increasing utilization of cowpeas to promote health and food security in Africa

Principle Investigator
Joseph Awika, Texas A&M University, USA

Collaboratoring Scientists
Susanne Talcott, Texas A&M University, USA
Lloyd Rooney, Texas A&M University, USA
Bir Bahadur Singh, Texas A&M University, USA
Chitundu Kasase, University of Zambia, Zambia
John Shindano, University of Zambia, Zambia
Kalaluka Lwanga Munyinda, University of Zambia, Zambia
Kennedy Muimui, Zambia Agriculture Research Institute (ZARI), Zambia
Abdul Faraj, Prisca Tuitoek, Egerton University, Kenya
Amanda Minnaar, University of Pretoria, South Africa
Gyebi Duodu, University of Pretoria, South Africa

Abstract of Research Achievements and Impacts

Cowpea is a drought tolerant crop that has a major potential as a nutrition and food security crop in Africa. In addition evidence indicates that legumes may contain compounds that have health benefits against chronic diseases like cancer and cardiovascular disease. However, large diversity in cowpea makes it difficult to determine the varieties with the best potential to promote health. We screened 81 cowpea lines of diverse phenotypes from around the world for phenol content and composition, and antioxidant properties to allow for selection of lines that can be used to study health-promoting potential of cowpea. Phenol content varied by a factor of more than 50 among the samples analyzed (minimum 0.3, maximum 17.0 mg/g, gallic acid equivalent, GAE). Based on seed coat color, the white varieties had the lowest phenol content (mean = 3.1 mg/g, GAE). The black, red, and light brown varieties had the highest phenol content (means = 11.9 – 14.8 mg/g, GAE). Tannin contents also varied widely, with the lowest values reported for the white cowpea varieties (mean = 0.59 mg/g, catechin equivalents, CE), and the highest values in the light brown varieties (mean = 10.4 mg/g, CE). Antioxidant activity followed the same trends as phenol content; the white cowpea varieties had the lowest antioxidant activity (28 – 45 Umol Trolox equivalents, TE/g, ORAC method), whereas the black, red and light brown varieties had the highest antioxidant activity (171 – 282 Umol TE/g, ORAC method). Phenol contents correlated significantly with antioxidant activity ($R^2 = 0.7 – 0.9$). The antioxidants and phenols were mostly (>97%) concentrated in the seed coat. Additionally, the trends for phenol and antioxidant activity were consistent regardless of where the samples were grown, suggesting that seed coat color is a major indicator of potential health benefits of cowpea. From the screening data we have narrowed down our sample selection to the black, red and light brown seed coat color as the ones most likely to have the best health promoting potential. These phenotypes will be used in more advanced chemical and biochemical studies. The selected lines will also be crossed with appropriate white cultivars to study the genetic inheritance of seed coat color and antioxidant properties. The HC PIs and technical personnel have been trained and are currently actively involved in generation of

data contributing to the goal of this project. Appropriate equipment were also purchased to enable HC institutions to adequately contribute to project objectives.

Project Problem Statement and Justification

Poor families in Sub Saharan Africa suffer high rates of malnutrition, especially among children, while diet-related chronic diseases have become a common phenomenon among urban African populations. For example, a recent survey reported that stunting and overweight due to malnutrition coexisted and were rampant among school age children in poor communities of Western Kenya, affecting up to 70% of the children (Abdulkadir et al 2009). Moreover, evidence indicates that childhood malnutrition may lead to increased risk of chronic diseases, e.g., cancer in adulthood. In fact nutrition-related chronic diseases are becoming increasingly common in Africa, especially in urban areas, thus putting a large strain on the limited health infrastructure and imposing economic burden among the poor.

Research shows that regular consumption of dry beans and other legumes may reduce serum cholesterol, improve diabetic therapy, and provide metabolic benefits that aid in weight control (Winham and Hutchins 2007; Anderson et al 1999), as well as reduce the risk for coronary heart disease (Bazzano et al 2001; Winham et al 2007), and cancer (Lanza et al 2006). Thus in addition to alleviating protein malnutrition, grain pulses have the potential to contribute to chronic disease prevention.

In Africa, malnutrition is closely linked to food insecurity, and thus the most vulnerable groups are those in marginal rainfall rural areas, and the urban poor. Cowpea is one of the most drought tolerant crops and has a big potential as a food security crop for many poor African subsistence farmers. Additionally, cowpea has high quality proteins that compare favorably with soybean proteins when substituted in diets at equivalent protein contents (Obatuli et al. 2003; Aguirre et al 2003). A limited number of studies have also demonstrated that cowpeas have high antioxidant capacity (Siddhuraju and Becker. 2007; Nzaramba et al. 2005), and that the antioxidant properties may be improved by heat processing or fermentation (Doblado et al. 2005). Recent evidence also suggests that whole cowpea is effective at binding cholesterol and lowering blood cholesterol in hamsters (Frota et al. (2008). However, information on how cowpea and its constituents may directly impact human health is lacking. Additionally, how variations in cowpea genetics affect their composition of potentially beneficial compounds is unknown. This makes it difficult to promote cowpea as a healthy grain which dampens its demand and utilization.

Constraints to consumption of cowpeas

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

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

Planned Project Activities for April 1, 2009 - September 30, 2010

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

Approaches and Methods: Seeds of improved varieties and land races of cowpea sourced from West Africa, East and Southern Africa, as well as the diverse types already found promising in US collection were obtained and screened for bioactive compounds. A total of 81 cowpea lines of diverse phenotypes have been screened for bioactive composition. An additional 20 lines are being screened in Zambia and Kenya.

Gross phenolic composition. The following analyses were used for the screening: gross phenol content, anthocyanin pigments, and tannins content. Samples were ground and extracted in 1% HCl in methanol. Anthocyanin pigment content was measured by pH differential method, which is based on measuring absorbance in pH 1.0 and pH 4.5 buffers at λ_{max} using a scanning UV-Vis spectrophotometer, The Folin-Ciocalteu method was used to estimate gross phenols content, by measuring reactant absorbance at 600 nm using gallic acid as the standard. The vanillin-HCl method was used for condensed tannin assay; reactant absorbance (with blank subtraction to correct for non tannin pigments) was measured at 500 nm, catechin was used as standard.

To confirm location of the phenolic compounds; three representative samples were selected and separated into seed coat and cotyledon, milled into flour and analyzed using above methods.

From above analyses, samples were grouped into six phenotypes based on seed coat color: black, red, light brown, brown, streaked, and white. Two representative samples within each phenotype were selected for use in detailed chemical characterization and biochemical assays.

Flavonoids profiling. Sample extracts obtained as described above were washed through a C-18 column to remove sugars and other non-flavonoid constituents. Flavonoinds were eluted using 70% acidified methanol, rotoevaporated and reconstituted in 10% methanol containing 10 mL/L formic acid and filtered through 0.45 μm membrane before analysis. A reversed phase C-18 column was used for separation; and an Agilent 1200 HPLC system was used for characterization.

Phenolic acid and phenolate esters. Free phenolic acids were measured in methanol extract whereas alkaline hydrolysis of residue was used to measure esterified phenolic acids. Reversed phase HPLC separation, with appropriate standards, was used to identify the compounds.

Results, Achievements and Outputs of Research: The gross phenolics content of the 77 cowpea lines screened are summarized in Table 1. There was a very broad variability in phenol content of the cowpea lines, with values ranging from 0.30 – 17 mg/g seed (dry basis), based on the Folin-Ciocalteu method with gallic acid as the standard. This represents more than 50 fold variability in phenol content of cowpea, which underscores the need for a clear understanding of how the cowpea genetics and phenotypes influence accumulation of the phenolics.

When the samples were grouped based on seed coat color, significant patterns were observed; the white varieties generally had the lowest phenol content (0.30 – 5.5 mg/g; mean 3.1 mg/g), with the higher value being observed in lines with a pigmented eye. The black (mean = 14.8 mg/g), red (mean = 11.9 mg/g), and light brown (mean = 12.0 mg/g) varieties had the highest level of phenols. The dark brown and streaked varieties had intermediate phenol content. The results were party expected based on evidence from other food plants; the darker seeded varieties of most plant materials usually have higher phenol content than the non pigmented varieties. However, one unexpected observation was that the high level of phenols in the light brown cowpea seeds, which were comparable to the black and red varieties, and significantly higher than the dark brown varieties. This data suggests that the types of phenols that are dominant in the light brown phenotype do not absorb visible light. Siddhuraju and Becker (2007) also recently observed that a light brown cowpea variety yielded extracts that contained more phenols than a dark brown variety.

Tannins content of the cowpea lines generally followed the gross phenol content data (Table 1). This suggests that synthesis of tannins in cowpea correlate with synthesis of other phenolics, or that tannins contribute significantly to the phenol content of cowpeas. The white varieties generally had very low levels of detectable tannins with an average of 0.59 mg/g (approximately 0.06%). On the other hand, the light brown cultivars had the highest tannin content (8.8 – 12.3 mg/g).

As expected, anthocyanins were highest in the black cowpea varieties (optical density, OD at λ_{max} = 1.1), compared to the red varieties (OD at λ_{max} = 0.14) and dark brown (OD at λ_{max} = 0.09). The rest of the phenotypes had trace levels of anthocyanins. The anthocyanins likely contributed significantly to the phenol content of the black cowpea varieties.

In investigating phenolic composition of cowpea with the goal to identify the lines with the best potential to promote health, it is important to confirm the location of the phenols within the seed. This would be essential when recommending processing strategies that would limit loss of these compounds. A set of three samples were decorticated to separate the seed coat from the cotyledon and these fractions analyzed separately. As expected, the phenols were mostly concentrated in the seed coat (Table 2). The cotyledons contained less that 2% of the total phenols in the cowpea. Among the major functions of phenolic compounds in the seed is protection against pathogens and pests; thus it makes sense that the plant would concentrate synthesis of these compounds in the seed coat. Cereal grains are known to contain most of their phenolics in the bran layer (Awika et al 2005) More important is the implication of this information in terms of how cowpea is processed for food in parts of Africa. In popular products like *akara* in West Africa, the seed coat is typically removed, which would mean that any health benefits contributed by the phenolics in the seed coat would be lost. As more data becomes available from this project, we will be able to advice on appropriate ways to preserve potential health benefits during cowpea processing.

A detailed analysis of the seed coat of selected varieties revealed that they contained significant quantities of phenolic acids, mostly in soluble esterified and bound forms (Table 3). The hydroxycinnamates were generally more abundant than the hydroxybenxoates. The bound phenolic acids in the seed coats were mainly hydroxycinnamates. The flavonoid group of phenols were more abundant than the phenolic acids. Catechin was the most abundant flavonoid, while quercetin, naringenin, kaempferol and rutin were also present in significant quantities. Many of these compounds have been associated with various health benefits and it will be interesting to discover how their levels in cowpea influence biomarkers for health.

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

Approaches and Methods: *Hydroxyl/free radical scavenging properties*; protection against oxidative stress is an important component of chronic disease prevention. Rapid screening methods were used to determine antioxidant properties of the cowpea lines. Antioxidant capacity of cowpeas and their fractions were measured by two widely accepted methods that involve hydrogen atom transfer (HAT) and single electron transfer (SET) that have been shown to correlate with biological oxidative status measures. Oxygen radical absorbance capacity (ORAC), was the HAT method. Ability of cowpea extract to protect fluorescein from free radical attack by AAPH was monitored for 90 min at 37°C using a fluorescence spectrophotometer (excitation 485 nm, emission 528 nm). The Trolox Equivalent Antioxidant Capacity (TEAC) was used for SET assay. Samples were reacted with preformed ABTS° free radical, and ability of the sample to quench the free radical measured after 30 min by monitoring absorbance at 734 nm. Trolox was used as standard in both assays.

Results, Achievements and Outputs of Research: As with the gross phenolics content there was wide variability in the antioxidant activity of the cowpea lines (Fig 1 & 2).

Antioxidant activity in the seeds ranged from 4.6 and 24.6 μmol TE/g (TEAC and ORAC methods, respectively) to 111 and 282 μmol TE/g (TEAC and ORAC methods, respectively). This represents 11 – 24 fold variation in antioxidant activity among the cowpea cultivars. Given that antioxidant activity is broadly accepted as a major indicator of health promoting potential of natural products and foods, this data clearly demonstrates the importance of caution when selecting raw material for any studies aimed at elucidating impact of legumes on health outcomes in animals and humans. Contradictory evidence on health benefits of pulses reported in literature may be partly attributed to the variability in phenolic composition and antioxidant activity of the raw material used in these studies.

When the samples were grouped based on seed coat color, the white varieties once more had the lowest antioxidant activity (5.2 – 9.6 and 28 – 45 μmol TE/g, by TEAC and ORAC methods, respectively. The light brown, red and black varieties had the highest antioxidant activity (ranging from 69 – 111, and 171 - 282, by TEAC and ORAC methods, respectively; the dark brown and streaked varieties had intermediate antioxidant activity. Also, as was observed for phenol content, the antioxidant activity was concentrated in the seed coat. The cotyledons had on average less than 3% of the antioxidant activity observed in the cowpea seed (Table 5). This further underscores the importance of processing method on potential health benefits of cowpeas.

Relationships between antioxidant activity and phenol content in the samples were strong (R^2 = 0.94 for TEAC versus phenol content and 0.67 for ORAC versus phenol content). This implies that the phenolics in the cowpeas are a major contributor of the antioxidant activity observed. Thus it is possible that determination of phenolic content of cowpea would be a useful predictor of antioxidant properties of the cowpeas.

Significance of findings

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

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

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

Approaches and Methods: Based on the results from Objectives 1&2, the following 10 varieties representing different seed colors were selected for inheritance studies:

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

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

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

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

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

Zambia: Through a participatory approach, a 1 day workshop was organized to which all the identified key stakeholders were invited. In attendance was the Dean of the School of Agriculture, University of Zambia, US PI and HC PI who gave presentations and moderated the meeting. The collaborators were drawn from School of Agriculture and ZARI; and key stakeholders were drawn from government ministries (Agriculture, Social and Community Development, Health); local community and key international NGOs (PAM, PELUM, Africare) as indicated in Table 6.

Kenya: The Kenyan stakeholders visited are detailed in **Part V** below.

Results, Achievements and Outputs of Research: Summary of stakeholders input from Zambia and Kenya.

Overall: Stakeholders agreed that this project was timely and headed in the right direction because health concerns are becoming a big demand driver in Africa. Thus the potential to change cowpea image and demand is significant. They also agreed that this project had a very good sustainability potential.

Specific key points

1. Need to involve stakeholders and learn from previous research experiences.
2. Must link output with strong business minded partners (business leaders) who can see value and commercialize the output. Lack of commercialization of promising technology has been a big problem.
3. Production goes hand in hand with utilization; i.e., do not overpromise farmers market potential until clear demand is established. One stakeholder in Kenya noted that we must learn from the 'soybean experience' when government encouraged production but there was no ready/established market.
4. Need scientific evidence supported by facts when promoting utilization; the evidence should be strong and compelling for easy government buy-in.
5. Involve medical doctors once data is available; people are more trusting of doctors.
6. Develop recipes especially those that will be liked by children; this will allow cowpea to be easily promoted through schools and youth organizations.
7. Ministry of Agriculture has a Programme that promotes 'orphan' crops. Cowpea is one of the crops
8. Change locals way of thinking/attitude especially of relying on only one crop (Maize) as a staple food
9. Develop/use of appropriate technologies e.g., using energy saving jikos, thus less fuel for cooking
10. Proper documentation of findings is important to help policy makers
11. Talk to implementers at province and district levels
12. Go to the ground level and see what people are doing in terms of using cowpeas
13. Improve on seed delivery systems
14. Mode of preparing the cowpea for consumption; resources should be invested in development of product variety that can appeal to not just the poor, but middle income families as well.
15. Need to develop partnership with the stakeholder/industries to follow through once project is completed. This could involve outcome implementation in a small pilot area to easily demonstrate benefit.

16. Incorporate cowpea as one of the items in (i) World Food Programme packages (ii) School feeding programme (iii) World Vision relief foods

Objective5: (Capacity Building) Strengthen cowpea nutrition research in Kenya and Zambia

Degree Training:

PhD Student 1:
First and Other Given Names: Twambo
Last Name: Hachibamba
Citizenship: Zambia
Gender: Female
Training Institution: University of Pretoria
Supervising CRSP PI: Amanda Minnaar, Gyebi Duodu, Joseph Awika
Degree Program for training: PhD
Program Areas or Discipline: Food Science
Host Country Institution to Benefit from Training: University of Zambia
Start Date: August 2010
Projected Completion Date: June 2013
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Full

PhD Student 2:
First and Other Given Names: Alice
Last Name: Nderitu
Citizenship: Kenya
Gender: Female
Training Institution: University of Pretoria
Supervising CRSP PI: Amanda Minnaar, Gyebi, Duodu, Joseph Awika
Degree Program for training: PhD
Program Areas or Discipline: Food Science
Host Country Institution to Benefit from Training: Egerton University
Start Date: August 2010
Projected Completion Date: June 2013

Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Full

<u>PhD Student 3:</u>
First and Other Given Names: Leonnard
Last Name: Ojwang
Citizenship: Kenya
Gender: Male
Training Institution: Texas A&M University
Supervising CRSP PI: Joseph Awika, Susanne Talcott
Degree Program for training: PhD
Program Areas or Discipline: Nutrition and Food Science
Host Country Institution to Benefit from Training: Egerton
Start Date: January 2010
Projected Completion Date: September 2012
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

<u>PhD Student 4:</u>
First and Other Given Names: Archana
Last Name: Gawde
Gender: Female
Training Institution: Texas A&M University
Supervising CRSP PI: Joseph Awika
Degree Program for training: PhD
Program Areas or Discipline: Molecular & Environmental Plant Science
Start Date: January 2009
Projected Completion Date: September 2012
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

<u>MS Student 1:</u>
First and Other Given Names: Billy
Last Name: Kiprop
Citizenship: Kenya
Gender: Male
Training Institution: Egerton University
Supervising CRSP PI: Abdul Faraj
Degree Program for training: MS
Program Areas or Discipline: Biochemistry
Host Country Institution to Benefit from Training: Egerton
Start Date: January 2010
Projected Completion Date: September 2011
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

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

Type of training: Hands on laboratory techniques
Description of training activity: Hands on training on use of modern equipment and laboratory techniques essential for the proposed project activities.
Location: University of Pretoria, Egerton University
Duration: 2 days
When did it occur: July 26 – 27, 2010; August 12, 2010
Participants/Beneficiaries of Training Activity: Chitundu Kasase (Zambia PI), Abdul Faraj (Kenya PI), Alice Nderitu, Billy Kiprop, others
Numbers of Beneficiaries (male and female): 10 male, 7 female
PI/Collaborator responsible for this training activity: Amanda Minnaar, Gyebi Duodu, Joseph Awika
List other funding sources that will be sought (if any): N/A
Training justification: PIs needed to familiarize themselves with the key techniques and equipment essential for accomplishing the project objectives so they can train their technical support staff to conduct the experiments.

<u>Equipment</u> (costing >$5,000)**:**

Based on identified research capacity need by Zambian and Kenya HC project leaders, the following equipment were acquired through Texas A&M and delivered to the HC institutions.

<u>Equipment 1</u>
Specific Type of Equipment to be purchased:
Fluorescence/luminescence plate readers, with fluid delivery system
Justification for equipment to achieve workplan objectives:
University of Zambia, Zambia, requested the fluorescence plate reader that will be essential for the free radical and related biochemical assays proposed. The data obtained from this instrument will complement data from Kenya and South Africa. This instrument is also very versatile and can be used to analyze DNA/RNA, cellular toxicology, cell proliferation and various health-related biological assays. We expect that as their human resource capability expands, University of Zambia researchers will be able to fully take advantage of the instrument.
Institution benefitting from equipment: University of Zambia
Amount spent on equipment by TAMU: ~ $16,000 (including shipping cost)

<u>Equipment 2</u>
Specific Type of Equipment to be purchased:
True dual beam scanning UV-Vis spectrophotometers
Justification for equipment to achieve workplan objectives:
Egerton University requested a modern UV-Vis spectrophotometers to be able to perform proposed phytochemical and biochemical characterization of cowpeas and related analyses. The instrument will allow Egerton University to produce data that is complementary to that from University of Zambia, and thus will enhance collaboration between the HC institutions.
Institution benefitting from equipment: Egerton University, Kenya
Amount spent on equipment by TAMU: $12,000 (including shipping cost)

Networking and Linkages with Stakeholders

During the Planning Meeting and Training Workshop held in Pretoria, South Africa from 26-29 July 2010. US PI and HC PI's met with Ms. Cecilia M Khupe, Senior Regional Agriculture Programme Manager from USAID Southern Africa to introduce the new CRSP project and HC PI's to the Mission.

USAID Zambia: the US PI and Zambia HC PI met with Mr Mlotha Damaseke, Agriculture and Natural Resources and Mission Environmental Officer, at the USAID mission in Lusaka. He was very enthusiastic about the project goals and promised to be supportive.

Other field/stakeholder visits:

Zambia: Meetings/visits were organized by HC PI, and attended by both HC and US PI

1. SADC Plant genetic Resources center – Thandie Lupupa (Senior Program Manager)
2. National Genetic Resource Center, ZARI – Mr Phiri
3. Golden valley Research Trust (GART) – Mr Simunji (Technical officer)
4. National Food and Nutrition Commission – Dr Cassim Masi (Executive Director)
5. Program Against malnutrition (PAM) – Dr Kayoya Masuhwa (Executive Director)
6. Africare - Frank P Chisamanga (Market Improvement and innovation facility Cordinator)
7. Participatory ecological land use management (PELUM) – Ms Faustina Chipalo – V/Board chairperson).
8. National Institute for Scientific and Industrial research (NISIR) – Mr Luke Mugode (Scientific Officer, Postharvest food processing and nutrition program)
9. National Plant protection Office, ZARI – Mr Ken Msiska (Technical Officer)
10. Ministry of Agriculture and Cooperatives(MACO) – Mr Aaron Simwanza
11. Ministry of Community Development and Social Services (MCDS) – Mr Siansimbi (Food Security Pack Coordinator)

Kenya: *Meetings/visits were organized by HC PI, and attended by both HC and US PI*

1. Head of Home Economics (Veronica Kirogo), Ministry of Agriculture HQ NBI
2. Chief Nutritionist (Rosemary Ngaruro), Ministry of Medical Servives HQ NBI
3. Head, Nutrition Division (Terry Wefwafwa), Ministry of Public Health and Sanitation HQ NBI
4. Legume Breeder (David Macharia) KARI Katumani
5. Simlaw Seeds Co. Ltd, a subsidiary of Kenya Seed Company (Robert Musyoki-Research officer-NBI)
6. World Vision (Haron Chesaina) Marigat District
7. Ministry of Agriculture Marigat District- Extension section (Benjamin Chemjor)
8. Agronomist (Timon Moi) KARI – Pekerra
9. Food Biochemist (John Ndungu) – KARI – Njoro.

Tables/Figures Cited in the Report

Table 1: Phenol and tannin content of cowpea varieties grouped by seed coat color.

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

N represents the number of varieties analyzed within a phenotype. Coefficient of variability for phenol content determination was 3.1% and for condensed tannins was 4.4%. Values with same letters in a column are not significantly different ($p < 0.05$).

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

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

[1]Results are means of four determinations, on dry weight basis
[2] Mean values for seed coats and cotyledons in each row and column with the same letter are not significantly different at ($p < 0.01$)
[3] Standard deviation values are given in parentheses

Table 3: Levels of phenolic acids and flavonoids (mg/kg sample on dry basis) in free, soluble-esterified and bound fractions from seed coats of Mae a tsilwane and Mogwe o kgotsheng cowpea varieties

Phenolic compound	**Mae a tsilwane**			**Mogwe o kgotsheng**		
	Free	**Soluble esterified**	**Bound**	**Free**	**Soluble esterified**	**Bound**
Hydroxybenzoates	30.6 ab[1] (1.5)[2]	30.5 ab (0.1)	41.8 d (0.1)	31.3 b (0.1)	28.2 a (0.1)	36.7 c (2.9)
Gallic acid	37.3 a (6.0)	97.7 c (0.2)	436.2 e (27.1)	53.4 ab (0.9)	149.4 d (19.5)	93.0 c (11.1)
Protocatechuic acid	ND[3]	1.9 a (0.1)	ND	ND	ND	2.3 a (1.5)
p-Hydroxybenzoic acid	45.0 c (10.8)	28.2 ab (0.2)	29.8 ab (1.6)	34.9 ab (1.1)	26.7 a (1.0)	26.9 a (0.1)
Vanillic acid	18.7 a (7.8)	ND	ND	ND	14.6 a (0.5)	14.9 a (2.3)
Syringic acid						
Hydroxycinnamates	63.5 ab (5.2)	70.1 b (0.6)	81.5 c (2.4)	106.9 d (13.5)	54.1 a (0.2)	70.7 bc (0.1)
Caffeic acid	26.8 a (0.8)	31.9 ab (0.1)	83.8 e (10.8)	26.9 a (1.5)	41.2 c (3.3)	51.9 d (0.8)
p-Coumaric acid	38.3 a (5.4)	35.5 a (0.9)	37.7 a (6.2)	29.0 a (0.1)	129.6 c (17.5)	23.1 a (15.7)
Sinapic acid	6.2 a (0.7)	14.8 b (0.1)	92.2 f (4.1)	7.0 a (0.1)	20.9 bc (1.5)	54.1 d (5.5)
Ferulic acid	17.6 b (0.6)	16.6 ab (0.1)	47.5 d (0.9)	16.6 ab (0.2)	16.3 ab (0.2)	16.0 a (0.1)
Cinnamic acid						
Flavonoids	919.7 b (21.5)	467.7 a (12.4)	2838.2 e (19.7)	1645.4d (48.9)	498.1 a (62.0)	1323.7 c (8.0)
Catechin	22.0 ab (4.4)	27.4 b (0.3)	ND	27.4 b (0.8)	17.8 a (2.2)	58.9 d (1.6)
Rutin	25.2 c (3.5)	14.1 a (0.4)	40.0 d (2.2)	20.6 bc (0.1)	15.4 a (0.8)	17.7 ab (2.6)
Naringin	ND	84.0 a (6.3)	ND	80.8 a (1.5)	ND	804.7 c (77.4)
Myricetin	56.1 e (6.3)	32.0 ab (0.1)	ND	33.1 ab (0.2)	31.3 a (0.1)	39.1 cd (0.2)
Quercetin	6.2 b (0.7)	ND	ND	0.9 a (0.2)	ND	ND
Naringenin	29.2 abc (3.4)	27.3 ab (0.1)	31.5 cd (1.0)	28.4 abc (0.6)	26.5 a (0.1)	30.5 bc (0.5)
Kaempferol	ND	ND	ND	ND	ND	ND
Hesperetin						

[1]Mean values with different letters across the row are significantly different ($p < 0.05$)
[2]Standard deviations in parentheses [3]ND – not detected

Table 4. Cowpea line Identification (for Fig 1&2)

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

Table 5: Antioxidant (free radical scavenging) activity (TEAC)[1] of extracts prepared from cowpea seed coats and cotyledons with acidified dimethyl formamide (DMF) and acidified methanol[2]

Variety	Solvent	
	Acidified DMF	**Acidified methanol**
	Seed coat	**Seed coat**
Glenda	2470 d[3] (39)[4]	1187 a (44)
Mae a tsilwane	3053 e (30)	1625 b (32)
Mogwe o kgotsheng	3385 f (60)	1796 c (11)
	Cotyledon	**Cotyledon**
Glenda	50 d (1)	36 b (1)
Mae a tsilwane	46 c (1)	24 a (1)
Mogwe o kgotsheng	44 c (1)	23 a (1)

[1](μM Trolox Equivalent (TE)/ g)
[2]Results are means of four determinations, on dry weight basis
[3]Mean values for seed coats and cotyledons in each row and column with the same letter are not significantly different at ($p < 0.01$)
[4] Standard deviation values are given in parentheses

Table 6. List of Participants. Stakeholders meeting workshop. Golfview hotel, Lusaka, Zambia, 4th August 2010.

NAME	INSTITUTION	ADDRESS
CASSIM MASI	NFNC	BOX 32669, Lusaka
JUDITH LUNGU	UNZA	32379,Lusaka
HENRY NKHOMA	MCDSS	P/B W252, Lusaka
JOSEPH AWIKA	TEXAS A&M	2474 TAMU
HIMOONGA.B.MOONGA	UNZA	BOX 32379
KENNEDY K. MUIMUI	ZARI-KASAMA	BOX 410055, Kasama
FRANK P. CHISAMANGA	AFRICARE/MIIF	BOX 3392 Lusaka
MUSONDA MOFU	NFNC	BOX 32669, Lusaka
FAUSTINA MWENDA	PELUM ZAMBIA	BOX 30443, Lusaka
AARON SIMWANZA	MACO	BOX 50291
KAYOYA MASUHWA	PAM	
KALALUKA MUNYINDA	UNZA	BOX 32379, Lusaka
MOSES BANDA	UNZA	BOX 32379, Lusaka
CHITUNDU KASASE	UNZA	BOX 32379, Lusaka

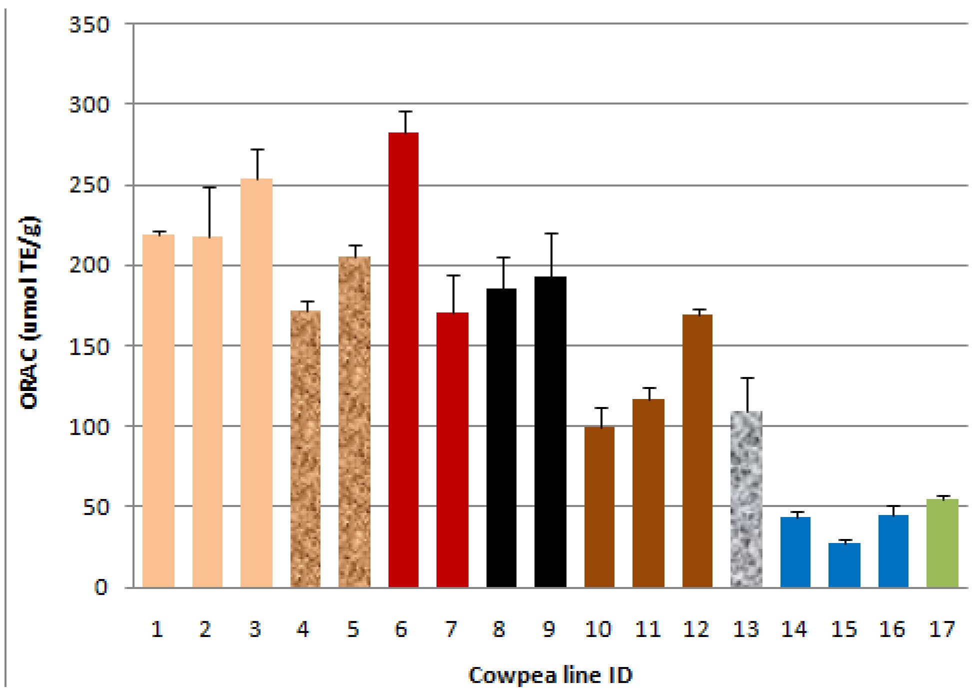

Fig 1. Antioxidant activity of 16 representative cowpea lines measured by the oxygen radical absorbance capacity (ORAC) method (values are on dry basis). Error bars are ±sd [see table 4 for sample identification]

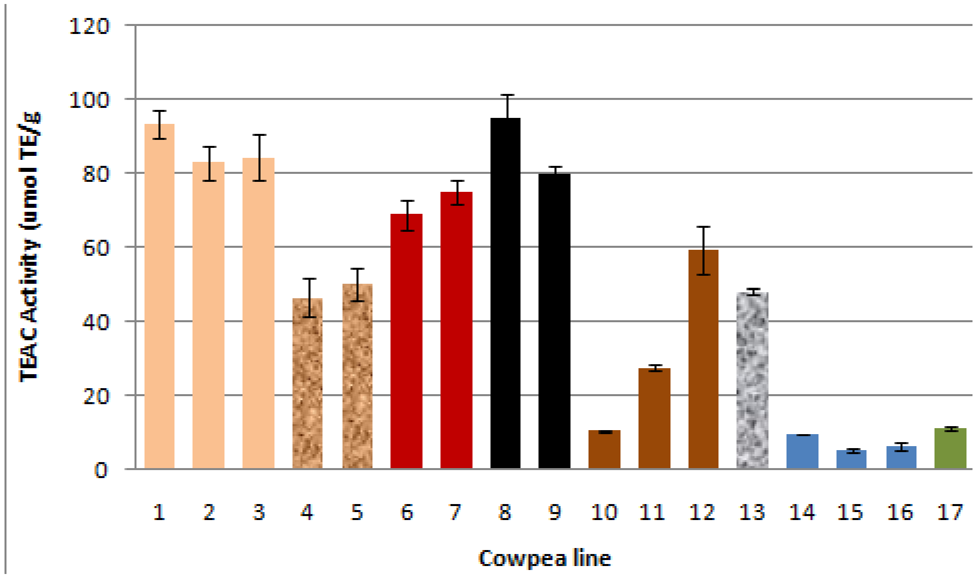

Fig 2. Antioxidant activity of 16 representative cowpea lines measured by the trolox equivalent antioxidant capacity (TEAC) method (values are on dry basis). Error bars are ±sd. (See table 4 for sample identification)

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FY 2011 SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

Project Title: *Increasing utilization of cowpeas to promote health and food security in Africa*

Identify Benchmark Indicators by Objectives	***Abbreviated name of institutions***											
	TAMU		UNZA		EGER		UP					
	4/1/11	**9/30/11**	**4/1/11**	**9/30/11**	**4/1/11**	**9/30/11**	**4/1/11**	**9/30/11**	**4/1/11**	**9/30/11**	**4/1/11**	**9/30/11**
Objective 1												
Phytates		X										
Protein content					X							
Protein quality and digestibility				X				X				
Screening backcrosses:												
Phenolic tests		X										
SET and HAT		X										
Objective 2												
Bile acid binding assay					X	X						
Inhibition of LDL oxidation							X	X				
Glycemic Index			X	X								
Phase II	X	X										
Anti-proliferation		x										
Biomarkers for inflammation	X	X										
Antioxidant biomarkers		x										
Objective 3												
Perform relevant crosses	x		x									
Obtain F3 seed		x		x								
Conduct field trials	x	x	x	x								
Objective 4												
HC stakeholder workshops		x		x		x						
Graduate training (PhD)	x	x					x	x				
Name of the PI responsible for reporting on benchmarks	J Awika		C Kasase		A Faraj		A Minnaar					
Signature/Initials:												

Date:

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Increasing utilization of cowpeas to promote health and food security in Africa
Lead U.S. PI and University: Joseph Awika, Texas A&M University
Host Country(s): Zambia, Kenya

Output Indicators	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	2	
Number of men	1	
Short-term Training: Number of individuals who received short-term training		
Number of women	15	
Number of men	15	
Technologies and Policies		
Number of technologies and management practices under research	4	
Number of technologies and management practices under field testing	1	
Number of technologies and management practices made available for transfer	0	
Number of policy studies undertaken	0	
Beneficiaries:		
Number of rural households benefiting directly	0	
Number of agricultural firms/enterprises benefiting	0	
Number of producer and/or community-based organizations receiving technical assistance		
Number of women organizations receiving technical assistance		
Number of HC partner organizations/institutions benefiting	3	
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	

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

Principle Investigator
Mywish K. Maredia, Michigan State University, USA

Collaboratoring Scientists
Richard Bernsten, Michigan State University, USA
Eric Crawford, Michigan State University, USA
Jim Beaver, University of Puerto Rico, Puerto Rico
Juan Carlos Rosas (EAP),
Eduardo Peralta (INIAP),
Emmanuel Prophete (Haiti),
Mathew Blair (CIAT),
Ndiaga Cisse (ISRA),
Issa Drabo (INERA),
Phil Roberts, University of California-Riverside, USA
Jeff Ehlers University of California-Riverside, USA

Abstract of Research Achievements and Impacts

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

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

Field activities to collect data and information to assess ex post economic impacts of CRSP investments in bean improvement research in Central America and Ecuador were initiated in FY 10. Researchers reported that CRSP's and CIAT's financial supports have been fundamental for the maintenance of the bean network in Central America. CRSP's support became more important after 2002, when PROFRIJOL support ended. The resources were used to keep the supply of germplasm flowing, conducting research (small grants were provided by Zamorano to other institutions), and maintaining the collaboration. Using seed production data, it was estimated that in 2009, Honduras, Nicaragua, and El Salvador distributed seed of IVs to cover 24-39 thousand hectares in each country (highest in Honduras, lowest in El Salvador). Ecuador produced the smallest quantity of seed (15,560 kg; or enough to plant 173 hectares with IVs).

Using seed production data, in 2009, it was estimated that Deorho was planted on approximately 26% of the bean area in Honduras, followed by Amadeus 77 (11% of the bean area). Amadeus 77 was also planted in three other countries: El Salvador, Nicaragua, and Costa Rica and covered 9-11% of the bean area in these countries. In El Salvador, CENTA Pipil (another CRSP variety) was the variety most widely distributed by the government program and was planted on approximately 14% of the bean area.

Project Problem Statement and Justification

Impact assessment is essential for evaluating publicly-funded research, capacity building and outreach programs and planning future research. Organizations that implement these programs should be accountable for showing results, demonstrating impacts, and assessing the cost-effectiveness of their implementation strategies. It is therefore essential to document outputs, outcomes and impacts of public investments in research for development (R4D) activities. Anecdotal data and qualitative information are important in communicating impact to policymakers and the public, but must be augmented with empirical data, and sound and rigorous analysis.

Methods have been developed to quantify economic impacts of agricultural research investments (e.g., Alston et al., 1998, Masters et al., 1996, Walker et al., 2008). The CRSP must make use of the best methods available in all fields, including impact assessment. The method of economic assessment is relatively well established because it can make use of secondary data collected in most countries (e.g., commodity prices, interest rates and crop production statistics). Assessment of other types of impact is less standardized and is currently the focus of methodological research by researchers and organizations active in agricultural R4D.

Impact assessments are widely recognized to perform two functions--accountability and learning. Greater accountability (and strategic validation) is seen as a prerequisite for continued support for development assistance. Better learning is crucial for improving the effectiveness of development projects and ensuring that the lessons from experience – both positive and negative – are heeded. Accountability and strategic validation has long been core concerns for **ex-post impact assessments** and learning has been primarily a concern of **impact evaluation**.[1] The primary focus of this project is on ex post impact assessment. However, attention is also devoted to finding opportunities to include impact evaluation as part of CRSP projects to be implemented in Phase II and III. In addition to measuring and evaluating impacts of past research investments, this project is also concerned with increasing impacts from current investments by examining 'impact pathways' of research projects and inculcating an impact culture within the Pulse CRSP research community.

Planned Project Activities for April 1, 2009 - September 30, 2010

Objective 1: To build an inventory of past documented outputs, outcomes and impacts of

[1] Although in the evaluation profession, the terms impact assessment and impact evaluation are used synonymously, in this project we make a nuanced distinction between ex post impact assessment and impact evaluation based on the timing of when they are conducted, the scale at which they occur and the motivation for doing an assessment (Maredia 2009).

investments by the Bean/Cowpea CRSP and develop a trajectory of outputs and potential impacts of investments made by the Dry Grain Pulses CRSP

1a. Building an inventory of past outputs and documented impacts: A systematic search of past CRSP reports and literature was conducted to compile a database of 41 studies (i.e., theses, dissertations, impact reports, journal articles, working papers, etc.) that report impacts related to the Bean/Cowpea or the Pulse CRSP program investments. The purpose of building this 'impact' database is to ensure that documented CRSP research outputs, outcomes and impacts are available to the CRSP MO or any potential user in one place and in one common framework. The database includes an inventory of major outputs (defined as technologies, practices, goods and services, intellectual properties and policy recommendations resulting from partial or full support of CRSP investments), characteristics of those outputs, and any evidence of documented outcomes and impacts of those outputs. The documented evidence range from anecdotal evidence to rigorous field based substantiation. The database is developed in Access but is also available in Excel and Word. A report summarizing the content of this database will be submitted to the Management Office.

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

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

To date, the project PI has received completed impact pathway worksheet from all Phase II and III project teams. A report summarizing the outputs of this analysis and plan for next steps will be presented to the CRSP Management Office. This information on the trajectory of outputs and steps towards achieving the vision of success should serve as a 'logframe' for the MO (and project teams) to monitor progress on how the CRSP projects are moving towards achieving not only the outputs (in the form of new knowledge, technologies and human capital) but how those outputs are translated into (or projected to be transferred into) developmental outcomes and impacts.

<u>Objective 2</u>: Conduct ex post impact assessment of Bean/Cowpea and Dry Grain Pulses CRSP Investments in Research, Institutional Capacity Building and Technology Dissemination in Africa, Latin America and the U.S.

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

During the Dry Grain Pulses CRSP Global Meeting held in Ecuador in April 2010, CRSP PIs, CIAT scientists and Byron Reyes met to discuss and plan the study. The feedback was incorporated in the execution of the study.

Five key informant instruments were developed, one for each key informant type. Table 1 shows the number of people interviewed between June through August 2010, by informant type.

Although Haiti was originally included as a Target Country for the study, several attempts to contact the key informant in Haiti to obtain information about potential key informants and to coordinate a visit to the country were unsuccessful, given the January earthquake. Therefore, information about Haiti was not collected during the summer trips.

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

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

Quantitative historical data about the bean area planted/harvested, production and prices (whenever possible) were collected from the statistical offices in each country. As part of the impact evaluation methodology, the use of molecular markers was proposed as a complementary method to estimate adoption of improved varieties (IVs) in Honduras.[2] For this, 53 bean market samples from the main three markets in Tegucigalpa were collected and sent to CIAT for analysis (*bgm-1* gene). Although the samples have been sent to CIAT, the results are not yet available. This information will be used to design the sampling methodology required to select a

[2] Because of time and financial limitations, this idea could not be implemented in each country. Therefore, it was decided to implement it in Honduras only.

representative sample of seed in Honduras (or at least the main two cities—Tegucigalpa and San Pedro Sula), if the analysis of the initial sample of seeds validates using molecular markers to evaluate farmer adoption of improved bean varieties.

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

The following are preliminary results about adoption of IVs in the bean programs in each country.

- Using *seed production data*, it was estimated that in 2009, Honduras, Nicaragua, and El Salvador distributed seed of IVs to cover 24-39 thousand hectares in each country (highest in Honduras, lowest in El Salvador). Ecuador produced the smallest quantity of seed (15,560 kg; or enough to plant 173 hectares with IVs).

- Using *seed production data*, in 2009, it was estimated that Deorho was planted on approximately 26% of the bean area in Honduras, followed by Amadeus 77 (11% of the bean area). Amadeus 77 was also planted in three other countries: El Salvador, Nicaragua, and Costa Rica and covered 9-11% of the bean area in these countries. In El Salvador, CENTA Pipil (another CRSP variety) was the variety most widely distributed by the government program and was planted on approximately 14% of the bean area (Figure 1).

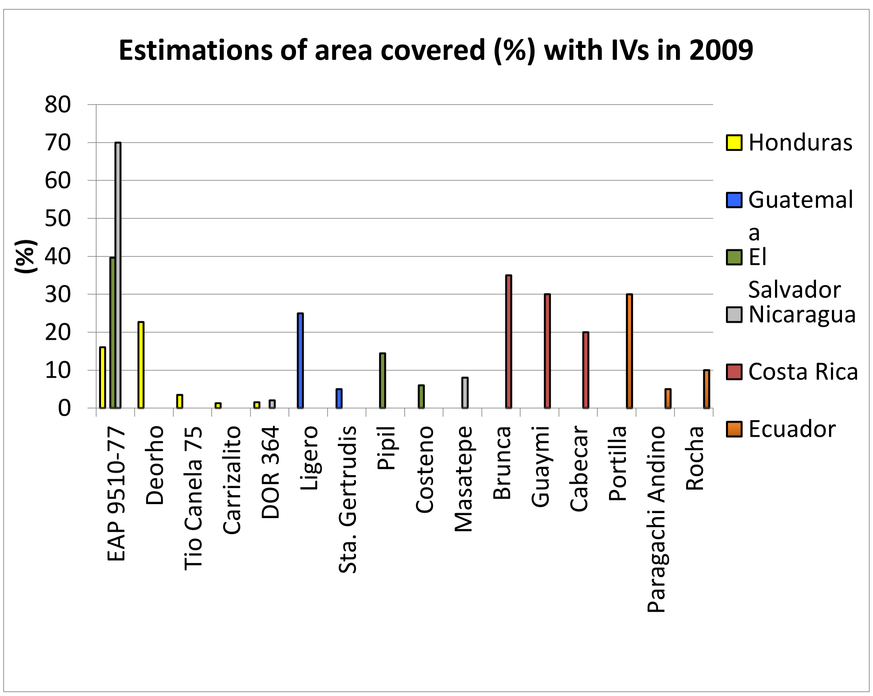

Figure 1. Most widely adopted (% bean area covered) improved bean varieties in 2009, per country (seed production data).

[1] Because of time and financial limitations, this idea could not be implemented in each country. Therefore, it was decided to implement it in Honduras only.

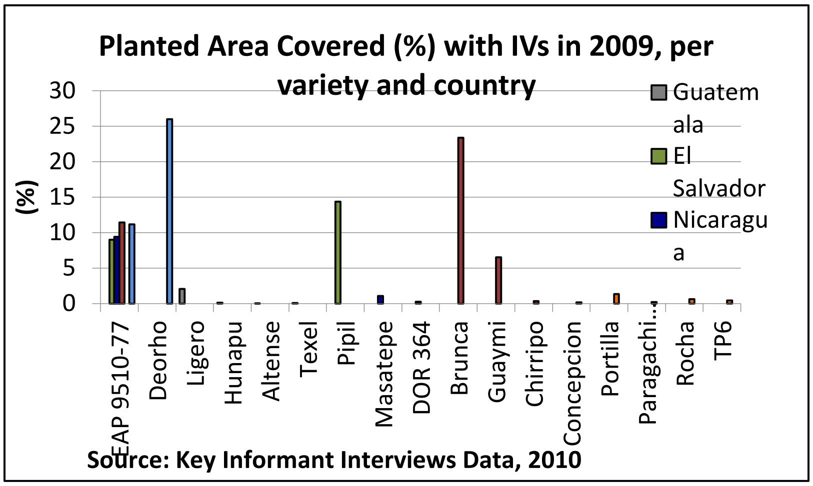

Figure 2. Most widely adopted (% bean area covered) improved bean varieties in 2009, per country (researchers' estimations).

- Researchers estimated that in 2009, Deorho was planted in approximately 23% of the bean area of Honduras, followed by Amadeus 77 (16% of the bean area). Two other bean researchers estimated Amadeus 77 was planted in 40-70% of the bean area in their country (El Salvador and Nicaragua). For Ecuador, the most widely planted variety was INIAP 430 Portilla (Figure 2). The percentage shown for Ecuador refers to each variety's share of the bush-type bean area, not the total bean area of the country).
- It was found that many of the bean researchers are close to retirement (average of 8 years to retire). While in Nicaragua the breeder will retire within one year, there is one person who will replace him. The (informal) bean network of the region is an important institution that could be used to train researchers' replacements, if no overlapping is possible in their institutions.
- Researchers reported that CRSP's and CIAT's financial supports have been fundamental for the maintenance of the bean network in Central America. CRSP's support became more important after 2002, when PROFRIJOL support ended. The resources were used to keep the supply of germplasm flowing, conducting research (small grants were provided by Zamorano to other institutions), and maintaining the collaboration.
- Detailed varietal information was collected. Table 2 shows the number of IVs released per country and the percentage that were released in the past 10 years. Except for Guatemala and Nicaragua, over one-half of the bean varieties have been released in the past ten years.

Table 2. Number of varieties released in target countries since 1990.

Country	# varieties released since 1990	since 2000	% since 2000
Honduras	21	15	71
Guatemala	13	0	0
El Salvador	9	5	56
Nicaragua	16	7	44
Costa Rica	17	9	53
Ecuador	26	16	62

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

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

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

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

- Reyes is in the process of entering and analyzing the data that was collected and will complete the analysis and report within the next six months.

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

To take a stock of all the genetic contributions of the research supported by the bean/cowpea and the Dry Grain Pulses CRSP, following activities were conducted in FY 10. Some of these are partly complementary to activity 1a and 2a.

1. A database template has been developed to inventory varietal releases of all commercially important bean varieties (*phaseolus vulgaris)* in countries/regions where CRSP has been historically active in bean improvement research. A data solicitation excel based form was developed to solicit variety-specific information from national bean research programs and the CRSP project PIs (past and present) in respective countries. The data is being collected by each country since varietal releases are made at the national level. Although, cowpea was not included in the original scope of this sub-objective, a similar database of commercially important cowpea varieties is also being developed parallel to the bean varietal database. The cowpea varietal database partly complements activities 1a and 2c.
2. Data on varietal releases collected from ‘key informants’ are sufficiently detailed so that CRSP content and the dynamics of new varietal production and dissemination can be assessed. Key descriptors include the following:
    a. Official name of the release (a common name, if any)
    b. Year of the release
    c. Institutional source of the material
    d. Genetic background (parentage, genetic ancestry, pedigree)
    e. Major distinguishing traits

f. Release classification (type of material, use of participatory plant breeding or molecular techniques, NARS input, IARC input, private sector input) (mainly for beans)
g. Dissemination efforts (information on seed multiplication efforts) (for beans only)
h. Any information on the size, scale, time and location of its peak adoption by farmers and assessment on whether a variety is on an increasing or declining adoption trend in recent years.
i. Perceived adoption of improved varieties in 2009-2010 (beans only).

Once this comprehensive database is developed, the next steps are to estimate an economic value of the contribution of CRSP program in terms of value addition to genetic materials grown by bean farmers around the world. Adoption information by varieties is key to estimating an 'economic value.' The prospects of obtaining such information at a global scale and the feasibility of estimating the 'economic value' of the contribution of CRSP investments in genetic improvement research of these two important food legume crops will be explored in FY 11.

2c. Benefits of genetic improvement of cowpea in Senegal and West Africa. Over the past 20 years, due to collaborative efforts of CRSP researchers, several varieties of cowpeas with resistance to biotic and abiotic stresses have been released in Senegal and other countries in West Africa. Although a few studies in the past have documented the impact stories in Senegal, the evidence is still spotty when it comes to West Africa as a region. Thus, a study was initiated in FY 10 to update and document the adoption of improved cowpea varieties in Senegal and to expand the analysis to include Burkina Faso where the Bean/Cowpea and the Pulse CRSP have been active for the past 7-10 years. The goal is to document the adoption and benefits attributed to CRSP-NARS investments in cowpea improvement research.

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

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

1. To identify the current extent of adoption by farmers in Senegal of improved cowpea varieties developed under the Bean/Cowpea (now Dry Grain Pulses) CRSP.
2. To gather information on the production and dissemination of improved cowpea seed, and the costs of these activities.
3. To gather information on the advantages (in the form of enhanced yield, quality, reduced yield variability, etc.) of improved cowpea varieties relative to traditional varieties, in order to estimate potential economic benefits of adoption of CRSP varieties.

The principal regions and departments in which CRSP-produced cowpea varieties have been disseminated will be identified through:

- Consultation with Ndiaga Cissé (CRSP/ISRA cowpea breeder) and representatives of NGOs and seed producer groups; and,
- Analysis of data from the 2010 DAPS national survey of farm households, which includes information on type of seed planted on each field.
- It is anticipated that Louga, Thies and Diourbel will be the main regions where improved cowpea varieties have been adopted, with Fatick, and perhaps Kaolack and Kaffrine also included.

A brief (~2 page) field survey will be carried out in the departments identified in objective 1. The sample for survey would be a sub-sample of 2010 DAPS survey farmers who indicated that they used "improved seed" for cowpea. Provisionally, we anticipate drawing a sub-sample of 500-700 households. Questions to be asked of farmers would include:

1. Name of improved cowpea variety planted.
2. What was the source of the seed?
3. Why was this variety used?
4. When was the first time the farmer used that variety?
5. Was cowpea planted in pure stand or intercropped?
6. If intercropped, what percentage of the field is in cowpea?
7. What do you believe are the advantages (drought resistance, disease or pest resistance, yield increase) of the improved variety relative to unimproved or traditional varieties?
8. How much cowpea did the farmer harvest from the plot (where improved variety was grown) last season in:
   a. Green pods
   b. As grain
   c. Any other form (i.e., fodder for animals)
9. What variety or varieties of cowpea do you intend to plant next season?
10. Reason(s) for choice of varieties to plant next season.

Interviews will be conducted with NGOs (e.g., World Vision) and seed producer groups concerning current and past seed production and dissemination activities. In addition, information will be also collected on the costs of those activities. This activity will also take place in Burkina Faso, where CRSP materials are at an early stage of dissemination and adoption.

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

The data collection and analysis efforts towards this study (2c) will continue in FY 11.

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

The workplans of all Phase II and III CRSP projects were reviewed in FY10 and a database of outputs and projected targets by activities in the workplan has been developed. This information, along with the impact pathway analysis is summarized in a report to be submitted to the MO in November. This report will identify and place different projects and show how the outputs of "research for development" (R4D) fall across a time and space dimension in terms of achieving developmental outcomes and impacts. This

Since resources to conduct research are scarce, many CRSP projects on the applied end of the R4D spectrum are pilot scale initiatives and programs designed to test the efficacy and effectiveness of a science-based intervention in a developing country setting with the aim of deriving lessons on what works and what doesn't. Such applied field based research initiatives are undertaken and supported by the CRSP with the goal of identifying the most effective strategy/models which can then be scaled up to achieve developmental impacts.

For a research project to be successful in achieving the developmental impacts requires some forethought on the design of field activities and a strategy for collecting appropriate data or making use of available data. Although, the Pulse CRSP projects will have only 2 years remaining in this five-year Phase, this review report identifies opportunities to integrate data collection and impact evaluation strategies as options (where feasible) for CRSP project teams to pursue. The purpose of such strategizing is to make sure that at the end of an intervention/activity, opportunity to collect data/information to assess the cause-effect relationship between a research project and indicators of outcomes/impact is not lost.

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

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

a. Field activities under objective 2 were conducted in collaboration with HC PIs and partners.
b. Activities under objectives 1 and 3 are conducted in close collaboration with the U.S. and HC PIs from existing CRSP projects.
c. The activities planned under this project involved two graduate students in the planning and conduct of field research. These students were recruited from within the Department of Agricultural, Food and Resource Economics at MSU as research assistants (and not as participant trainees). They include:
    1. Byron Reyes, a citizen of Ecuador
    2. Nelissa Jamora, a citizen of the Philippines

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

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

A. Degree Training

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

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

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

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

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

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

An estimated 6 graduate students at U.S. universities in 2010 were "indirectly" supported by the Dry Grain Pulses CRSP. These are students who are on research assistantships. CRSP funds therefore are only used to compensate them in the form of salary to conduct the research activities as outlined in the workplans. CRSP funds were not used to cover traditional academic expenses such as tuition, and the purchase of text books and computers. As a consequence, those universities supporting graduate students on assistantships are providing 25% match on these expenses as they are viewed as a cost to complete the CRSP research activities.

B. Non-Degree Training

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

In FY 2010, an estimated 1,135 individuals benefitted from short term training through the Dry Grain Pulses CRSP. Of these short term trainees, over 53% were female. Table 2 presents a listing of some of the short-term training activities completed in FY 2010. Experience has shown that short term training is an effective strategy to build the capacity of technical staff at a research institution. These individuals do not require an advanced degree to conduct their analytical work nor are they able to be released from their positions for any extended period of time. Moreover, short term training is highly cost effective and provides opportunities for the U.S. and Host Country PIs to join forces in the design and implementation of training activities.

Table 2: Examples of Short-term Training Activities Supported by the Pulse CRSP, FY 2010.

Pulse CRSP Project: PI-ISU-1
Type of Training: Technical - Mentored refinement and implementation of lab experiments
Description of Training Activity: Development of nutritious, quick-cooking composite flour.
Location of Short Term Training: Iowa State University
Beneficiaries: Makerere University, Uganda
Number of Participants: 1 Female

Pulse CRSP Project: PI-MSU-2
Type of Training: Basic survey analysis using STATA
Description of training activity: The training refreshed participants' skills in using the national household surveys for data analysis.
Location of Short Term Training: Maputo, Mozambique
Beneficiaries: Analysts of the National Agricultural Research Institute (IIAM) and the Directorate of Economics of the Ministry of Agriculture, Mozambique
Number of Participants: 6 Male; 4 Female

Pulse CRSP Project: PI-MSU-2
Type of Training: Basic GIS tools with survey data
Description of Training activity: The training introduced participants to basic mapping skills in using the national household surveys
Location of Short Term Training: Maputo, Mozambique
Beneficiaries: Analysts of the National Agricultural Research Institute (IIAM) and the Directorate of Economics of the Ministry of Agriculture, Mozambique
Number of Participants: 4 Male; 3 female

Pulse CRSP Project: PI-MSU-2
Type of Training: Statistical analysis
Description of Training Activity: The training will refresh participants' skills in analyzing recent household surveys.
Location of Short Term Training: Huambo, Angola
Beneficiaries: Students and faculty members of the Agricultural Sciences Faculty at the University of Agostinho Neto, Angola
Number of Participants: (5 Male; 3 Female

Pulse CRSP Project: PI-MSU-2
Type of Training: Short practical learning by doing training.
Description of Training Activity: Training on construction of solar facilities for seed drying using local materials.
Location: Rural Development Program, Zacapa, Santa Bárbara, Honduras
Beneficiaries: Farmers and technicians collaborating in the production of organic beans.
Number of Beneficiaries: 8 Males: 7 Females

Pulse CRSP Project: PI-MSU-2
Type of Training: Short course offered by ECOPOL (Ecology and Population, A.C., México).
Description of Training Activity: Workshop on Sustainable agriculture on small scale: Bio-intensive cropping.
Location: Zamorano, Honduras
Beneficiaries: Farmers and technicians collaborating in the production of organic beans
Number of Participants: 3 Males

Pulse CRSP Project: PI- UIUC-1
Type of Training: Technical Internship
Description of Training Activity: Biocontrol of cowpea pests
Location: IITA Benin
Beneficiaries: Students
Number of Participants: 2 Female

Pulse CRSP Project: PI-UIUC-1
Type of Training: Technician training
Description of Training Activity: Biocontrol of cowpea pests
Location: Burkina Faso and Niger
Beneficiaries: Students
Number of Participants: 2 Male; 2 Female

Pulse CRSP Project: PI-UIUC-1
Type of Training: Technician training
Description of Training Activity: Farmer field fora
Location: Burkina Faso, Mali, Nigeria, and Niger
Beneficiaries: Farmers
Number of Participants: >340 Male; >370 Female-

Pulse CRSP Project: PI-UPR-1
Type of Training: Bean research planning meeting for Central American and Caribbean
Description of Training Activity: Central American and Caribbean bean researchers and CIAT and Dry Grain Pulse CRSP scientists met to discuss the status of bean research in the region. Future priorities for bean research and training activities were identified. Coordination of the network for the testing and validation of bean breeding lines were discussed. Conclusions from the workshop will be presented at the 2011 PCCMCA meeting in El Salvador and published in *Agronomía Mesoamericana*.
Location: EAP Zamorano, Honduras
Beneficiaries: Network Members
Number of Participants: 17 Male, 1Female

Pulse CRSP Project: PI-UPR-1
Type of Training: Technical - Informal training of biological nitrogen fixation research techniques.
Description of Training Activity: Trainees learned laboratory and field research techniques related to biological nitrogen fixation of beans
Location: University of Puerto Rico
Beneficiaries: Monica Mbui Martins, Ana Vargas, a research technician for the Zamorano bean research program and Jim Heilig, a graduate student from MSU under the supervision of Dr. James Kelly.
Number of Participants: 2 Female; 1 Male

Pulse CRSP Project: PI-UPR-1
Type of Training: Informal training of *Ascochyta* blight research and participatory plant breeding techniques
Description of Training Activity: Trainees learned laboratory and field research techniques related to breeding beans for resistance to *Ascochyta* blight. They also had an opportunity to review participatory plant breeding activities in northern Ecuador. The training was coordinated by Dr. Consuelo Estevez and Ing. Eduardo Peralta.
Location: INIAP, Equador
Beneficiaries: Antonio Chicapa and Antonio Castame of the Instituto de Investigação Agronómica, Angola.
Number of Participants: 2 Males

Pulse CRSP Project: PI-UPR-1
Type of Training: Training farmers in participatory plant breeding (PPB) techniques
Description of Training Activity: A training course on participatory bean breeding was offered to farmer leaders from Honduras, Nicaragua, El Salvador, Guatemala and Nicaragua, and technical personal of the Mesoamerican PPB Program supported by the Norwegian Development Fund. The HC-PI and technical personnel from the DGP-CRSP project at Zamorano, were responsible for the classroom and field activities during this training course held at EAP facilities.
Location: EAP Zamorano
Beneficiaries: Farmer leaders from Honduras, Nicaragua, El Salvador, Guatemala and Nicaragua, and technical personal of the Mesoamerican PPB Program supported by the Norwegian Development Fund.
Number of Participants: 15 Males; 4 Females

Pulse CRSP Project: PI-UPR-1
Type of Training: Informal training of IIA technical personnel to identify bean diseases.
Description of Training Activity: : IIA technical personnel were trained in the field identification and disease severity evaluations of: Ascochyta leaf spot (Phoma exigua**)**, Angular leaf spot (*Phaeoisariopsise griseola*), Anthracnose **(**Colletotrichum lindemuthianum**),** Common bacterial leaf blight (*Xanthomonas axonopodis* pv. *phaseoli* and Bean Common Mosaic. Serological test for *Xanthomonas axonopodis* pv. *phaseoli* was carried out at the plant pathology laboratory in Chianga. Inmunostrips tests for bacterial and fungal diseases were also tested. These tests were complemented with isolations of fungal and bacterial diseases on artificial media with further morphological identification.
Location: Chianga, Angola
Beneficiaries: IIA technical personnel
Number of Participants: 5 Males; 3 Females

Pulse CRSP Project: PIII-TAMU-1
Type of Training: Technical
Description of Training Activity: Hands on training on use of modern equipment and laboratory techniques essential for the proposed project activities. Host Country PIs needed to familiarize themselves with the key techniques and equipment essential for accomplishing the project objectives to allow them to train their technical support staff to conduct experiments.
Location: University of Pretoria, South Africa; Egerton University, Kenya
Beneficiaries: Chitundu Kasase (Zambia PI), Abdul Faraj (Kenya PI), Alice Nderitu, Billy Kiprop, others
Number of Participants: 10 Male; 7 Female

C. Equipment for Host Country Capacity Building

The Dry Grain Pulses CRSP recognizes that for National Agriculture Research Systems (NARS) and agriculture universities to effectively address the challenges facing the pulse (bean, cowpea and related edible legume crops) sectors and to contribute to economic growth and food and nutritional security in their respective countries, these institutions need to build and maintain capacities in strategic areas of research, training and outreach. This requires investments in human resource development, scientific equipment, laboratory and field facilities, computer technology, and infrastructure.

The Management Office of the Dry Grain Pulses CRSP budgets, and competitively awards funds to Host Country institutions for capacity building. The intent is that these funds be utilized to address critical needs of Host Country (HC) collaborators which exceed the budgetary limits of the current projects, or to respond to the pulse program needs of agricultural research institutions in USAID priority countries which are projected as potential future collaborators.

In FY 2010, the Management Office (MO) in consultation with the Technical Management Advisory Committee (TMAC) approved the award of 3 supplemental activities totaling $76,180 that were considered to contribute to build capacity of host country institutions (See Annex 2). In addition, the Dry Grain Pulses CRSP MO supported the participation of 23 CRSP scientists and trainees in the World Cowpea Conference held in Saly, Senegal (27 September – 1 October, 2010). A total of $77,097 was committed for this purpose (See Annex 2).

The Dry Grain Pulses CRSP MO is currently seeking approval from the Technical Management Advisory Committee (TMAC) and from USAID for financial support ($100,000) of a workshop on ***"Enhancing pulse productivity on problem soils by smallholder farmers- Challenges and Opportunities"***. Penn State University would be the organizing and host institution for the workshop to be held on August 14-18, 2011 in State College, PA. CIAT and IITA have agreed to co-sponsor this workshop with the Dry Grain Pulses Pulse CRSP.

Annex 1: Status of degree training planned and executed in FY 2010

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PI-CU-1	Crispus Mugambi	Njeru	Kenya	M	Moi University	M.S.	Soil Science	Completed	Feb-08	Feb-10	Full
PI-CU-1	Belinda Akinyi	Weya	Kenya	F	Egerton University	M.S.	Soil Science	Active	Aug-08	Feb-11	Full
PI-CU-1	Jane Francisca	Lusweti	Kenya	F	University of Nairobi	M.S.	Plant Protection	Completed	Oct-07	Oct-09	Partial
PI-CU-1	Silvester	Odundo	Kenya	M	Moi University	M.S.	Soil Science	Active	2009	Feb-11	Full
PI-CU-1	Eunice	Onyango	Kenya	F	Moi University	M.S.	Applied Environmental & Social Science	Completed ??	2009	Sep-10	Full
PI-CU-1	Roselyne	Juma	Kenya	F	Moi University	M.S.	Plant Breeding/Evaluation	Active	2010	Mar-11	Full
PI-CU-1	Stanley	Onyango	Kenya	M	University of Nairobi	M.S.	Food Technology & Nutrition	Active	2010	Apr-11	Full
PI-CU-1	Caren	Oloo	Kenya	F	University of Nairobi	M.S.	Plant Protection	Withdrew	2009		Full
PI-ISU-1	Cyrille	Syanobe	Rwanda	M	Makerere University	M.S.	Food Science & Technology	Withdrew	Aug-08		
PI-ISU-1	Gerald	Sebuwufu	Uganda	M	Iowa State University	Ph.D.	Agronomy	Active	Aug-08	Aug-12	Partial
PI-ISU-1	Geoffrey Arijole	Nyakuni	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Canceled			
PI-ISU-1	Martin	Matambuka	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Active	Jan-09	May-12	Partial
PI-ISU-1	Aisha Nakitto	Musaazi	Uganda	F	Makerere University	M.S.	Food Science & Technology	Active	Aug-08	Dec-10	Partial
PI-ISU-1	Simon	Okiror	Uganda	M	Makerere University	M.S.	Agricultural Economics/Agribusiness	Active	Aug-08	Dec-10	Partial
P1-ISU-1	Catherine	Ndagire	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Active	Aug-09	Aug-11	Partial
PI-ISU-1	George	Jjagwe	Uganda	M	Makerere University	M.S.	Ag. Extension & Education	Active	Aug-10	Aug-12	Partial
PI-ISU-1	Rose	Kambabazi	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Delayed/Not Enrolled yet			Partial
PI-MSU-1	Gerardine	Mukeshimana	Rwanda	F	Michigan State University	Ph.D.	Plant Breeding and Genetics	Active	Aug-08	Aug-11	Full
PI-MSU-1	Krista	Isaacs	USA	F	Michigan State University	Ph.D.	Ecology and Nutrition	Active	Aug-08	Aug-11	Partial

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PI-MSU-2	Maria da Luz	Quinhentos	Mozambique	F	Michigan State University	M.S.	Agricultural Economics	Canceled			
PI-MSU-2	Ana Lidia	Gungulo	Mozambique	F	University of Pretoria, South Africa	M.S.	Agricultural Economics	Active	Feb-09	Dec-11	Full
PI-MSU-2	Estaveo	Chaves	Angola	M	University Federal Vicosa, Brazil	M.S.	Agricultural Economics	Active	Apr-09	Jun-11	Full
PI-PSU-1	Samuel	Camilo	Mozambique		Penn State	M.S.	Agronomy	Delayed			
PI-PSU-1	IIAM Scientist 2	TBD	Mozambique		Penn State	M.S.	Plant Nutrition	Delayed			
PI-UPR-1	Ronald	Dorcinvil	Haiti	M	University of Puerto Rico	M.S.	Soil Sciences	Completed	Aug-06	May-09	Partial
PI-UPR-1	Monica	Mbui Martins	Angola	F	University of Puerto Rico	M.S.	Plant breeding	Active	Aug-09	Aug-11	Full
PI-UCR-1	Manuel	Costa	Angola	M	University of Puerto Rico	M.S.	Plant Breeding/Pathology	Canceled			
PI-UCR-1	TBD	TBD	W Africa	F	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Delayed			
PI-UCR-1	Marti	Portorff	USA	M	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Active	Oct-08	Mar-11	Full
PI-UCR-1	Antonio	David	Angola	M	University of Puerto Rico	M.S.	Plant Breeding	Active	Aug-09	Aug-11	Full
PI-UIUC-1	Traore	Fousseni	Burkina Faso	M	University of Ouagadougou	M.S.	Entomology	Active	Sep-08	Aug-12	Full
PIII-ISU-1	Mercy	Kabahuma	Uganda	F	Iowa State University	M.S.	Crop Production/Physiology	Active	Aug-10	Aug-12	Full
PIII-ISU-1	Martha	Abwate	Uganda	F	Makerere University	M.S.	Soil Science	Active	Sep-10	Aug-12	Full
PIII-ISU-1	Peter	Ssenyonga	Uganda	M	Makerere University	M.S.	Soil Microbiology	Active	Sep-10	Aug-12	Full
PIII-ISU-1	Charles	Komba	Tanzania	M	Sokoine U. of Agriculture	M.S.	Agronomy	Active	Sep-10	Sep-12	Full
PIII-ISU-1	Beata	Khafa	Tanzania	F	Sokoine U. of Agriculture	M.S.	Plant Breeding	Active	Sep-10	Sep-12	Full
PIII-MSU-3	Amos	Nyangi	Tanzania	M	Sokoine U. of Agriculture	M.S.	Food Science	Active	Sep-09	Sep-11	Full
PIII-MSU-3	Sarah	Johnson	Tanzania	M	Sokoine U. of Agriculture	M.S.	Food Science	Active	Aug-09	Aug-11	Full
PIII-MSU-3	Rosemary	Marealle	Tanzania	M	Sokoine U. of Agriculture	M.S.	Nutrition	Active	Aug-09	Aug-11	Full

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/10**	Start date	Anticipated completion date	Type of CRSP support
PIII-TAMU-1	Twambo	Hachibamba	Zambia	F	University of Pretoria	Ph.D.	Food Science	Active	Aug-10	Jun-13	Full
PIII-TAMU-1	Alice	Nderitu	Kenya	F	University of Pretoria	Ph.D.	Food Science	Active	Aug-10	Jun-13	Full
PIII-TAMU-1	Leonard	Ojwang	Kenya	M	Texas A&M University	Ph.D.	Nutrition/Food Science	Active	Jan-10	Sep-12	Partial
PIII-TAMU-1	Archana	Gawde	???	F	Texas A&M University	Ph.D.	Molecular/Env. Plant Sci	Active	Jan-09	Sep-12	Partial
PIII-TAMU-1	Billy	Kiprop	Kenya	M	Egerton University	M.S.	Biochemistry	Active	Jan-10	Sep-11	Partial

Annex 2: Supplemental Funding awarded by the Dry Grain Pulses CRSP for Institutional Capacity Building in FY 2011

Awards to Enhance HC Institutional Capacity Building (Approved in 2010 for expenditure in FY2011)

Dry Grain Pulses CRSP

Proposal Overview

Project	Beneficiary Host Country Institution	Proposed Activity	Recommended funding
PII-UPR-1	Host Country Institution # 1: Instituto de Investigação Agronómica (IIA) Host Country Institution # 2: National Seed Program, Ministry of Agriculture, Haiti Host Country Institution # 3: Escuela Agrícola Panamericana (Zamorano0	This task will be accomplished through hands-on evaluation of inoculation trials previously planted at Zamorano. Trials will include greenhouse experiments with common beans inoculated with *Rhizobium leguminosarum, Rhizobium etli* and *Rhizobium tropici* strains and control treatments with and without nitrogen fertilizer. A field trial will be planted to demonstrate the response of common bean to inoculation with the more efficient Rhizobia strains UMR 1899 and UMR 632 compared with an un-inoculated control and nitrogen fertilization. Participants will return to their countries better prepared to train others of the benefits of biological nitrogen fixation. Participants will become familiar with applied scientific literature about nitrogen fixation and current inoculant production. Participants will also gain knowledge and awareness concerning the benefits of BNF and local production of inoculants, which can reduce the use and importation of N fertilizer. The workshop is designed to improve expertise concerning the use, production and storage of inoculants for beans. Because the use of inoculants is uncommon in developing countries, this workshop will provide participants with information and literature that will describe how inoculants can be successfully used. Because the workshop will include several host countries that currently share an interest in increasing BNF for bean production there is potential to create a network for future collaboration. The internet will be used to share research results and exchange information. Participants will be requested to prepare a presentation and a written document to provide a baseline of information concerning the potential of BNF in their country. This information will be used to discuss and prioritize research needs for the different countries as well as to identify gaps in human or fiscal resources that currently serve as barriers for BNF studies and inoculant production and utilization. As a precursor to participant presentations, some general information concerning biological control/integrated peat inoculants will be presented.	**$28,880.00**
PII-MSU-2	IIAM, Mozambique	Purchase of simple video equipment, including web camera and camcorder, as well as one laptop and needed sofware. Local specialists will be used to train the participants on using this simple technology to link video/audio to powerpoint and other presentation methods, creating low cost communication tools.	**$25,300.00**
PII-UIUC-1	INERA, Burkina Faso	An assessment of the availability of cell-phones among extension agents and farmers.	**$22,000.00**
PII- PSU-1	Workshop: "Enhancing Pulse Productivity on Problem soils by smallholders farmers- Challenges and Oppertunities". August 14-18, 2011 Pennsylvania State University.		**$100,000.00**
DGP CRSP MO	Sponsoring a total of 23 Lead US PIs, US PIs, and Host country PIs to attend the 5th annual "WORLD COWPEA CONFERENCE" held in Saly, Senegal		**$77,097.00**
		Total	**$253,277.00**

Annex 2: CRSP Scientists and Trainees Participating in the World Cowpea Conference

Funding Support provided by the Dry Grain Pulses CRSP

	Last Name	First Name	Institution	CRSP Project	Funds Approved
1	Navuana Odundo	Sylvester	KARI	CU-1	$3,100.00
2	Kiala Kilusinga	David	Univ. Agostinho Neto	MSU-2	$4,000.00
3	Crawford	Eric	MSU	MSU-4	$4,000.00
4	Awika	Joseph	TAMU	TAMU-1	$4,000.00
5	Duodu	Gyebi	University of Pretoria	TAMU-1	$3,663.00
6	Faraj	Abdul	Egerton University	TAMU-1	$4,000.00
7	Kasase	Chitundu	University of Zambia	TAMU-1	$4,000.00
8	Minnaar	Amanda	University of Pretoria	TAMU-1	$4,000.00
9	Singh	Bir	TAMU	TAMU-1	$4,000.00
10	Antonio	David	UPR/IIA	UCR-1	$3,000.00
11	Castame	Antonio	IIA	UCR-1	$3,243.00
12	Diop	Ndeye Ndack	UCR	UCR-1	$3,696.00
13	Drabo	Issa	INERA	UCR-1	$1,950.00
14	Ehlers	Jeff	UCR	UCR-1	$3,696.00
15	Muchero	Wellington	UCR	UCR-1	$3,696.00
16	Pottorff	Marti	UCR	UCR-1	$3,696.00
17	Roberts	Philip	UCR	UCR-1	$3,696.00
18	Tignegre	Jean Baptiste	INERA	UCR-1	$1,750.00
19	Ba	Malick	INERA	UIUC-1	$1,791.00
20	Baoua	Ibrahim	INRAN	UIUC-1	$2,420.00
21	N'diaye	Mamadou	IER-Mali	UIUC-1	$1,700.00
22	Pittendrigh	Barry	UIUC	UIUC-1	$4,000.00
23	Chicapa	Antonio	IIA	UPR-1	$4,000.00
	Total				**$77,097.00**

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