FY 2011 TECHNICAL PROGRESS REPORTS

October 1, 2010–September 30, 2011

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.

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

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Abstract of Research Achievements and Impacts
Activities during the past year have produced important achievements with regard to project research and development goals. In order to improve bean quality and yield (objective 1), adaptive research and trainings with farmers have focused on critical management practices and technologies: local community-based production and sale of quality seed; improved post-harvest storage through solarization and triple bagging; training in group dynamics and gender equity; strengthening group capacity and sustainability; and exchange visits with other farmer groups. Research continues on bean variety and fertilizer interactions that best increase yield. To be able to effectively consolidate learning and to disseminate management practices to new farmers, extension materials using various media are being refined and translated into local languages.

To enhance nutritional value, appeal and consumption of beans (objective 2), we have developed appealing bean-based products, and are teaching farmers about useful ways to prepare bean products. Research had been performed to determine the starch digestibility and the sensory acceptability of a bean-based porridge to be used as a weaning food which maximizes protein. Tests were also performed to evaluate the culinary and sensory characteristics of four local and five improved bean varieties. Farmers have been taught how to prepare the bean flour, how to use it in making soup, and how to use it to augment or substitute for other ingredients in cooking. To increase knowledge retention and accessibility, extension materials were developed on topics such as the basics of feeding young children, methods of preparing beans to reduce cooking time and increase nutrient availability, and how to prepare and use the bean-based flour.

In terms of increasing marketing and consumption of beans and bean products (objective 3), the focus has primarily been on strengthening farmers' groups for analyzing opportunities and constraints associated with collective marketing, and then implementation of strategic plans. Training sessions increased farmers' understanding of group dynamics and business management, and facilitated initial success in marketing collectively. Promotion of new ways of processing and consuming beans is ongoing in rural communities, and urban sales and use of bean-based products are advancing via partnerships with private sector businesses and NGOs.

Project Problem Statement and Justification

Agriculture in East Africa is characterized by women and men working in small scale, rainfed production on fields of poor soil fertility, 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, quality seed, technologies to improve yields and reduce post-harvest losses, and credit. Losses are very high throughout the bean value chain due to poor harvest and post-harvest practices and poor on-farm storage facilities. Beans on the market are typically poor quality and infested. Producers are not well linked to profitable markets, especially emerging sectors of domestic and regional markets. Traders operate on a small scale with limited investment capability. Availability and use of processed products remains very modest. Hunger and poverty are widespread.

The lack of value-added bean products having reduced preparation times makes bean preparation laborious with high fuel requirements; consumers tire of monotonous flavor, reducing their bean consumption despite documented high nutrient content and health benefits. Optimized processing (de-hulling, soaking, milling, fermentation and germination and cooking can enhance digestibility and nutritional value by reducing phytates and polyphenols that limit iron uptake, and can create value-added bean-based 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 understanding prospects for increasing demand for beans and agro-processed products through collaboration with private sector businesses.

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 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.

The objectives of our research, therefore, are to:

1. Improve harvested bean yields and quality.
2. Enhance Nutritional Value and Appeal of Beans through Appropriate Handling and Processing.
3. Identify solutions for constraints to increased marketing and consumption.
4. Increase the capacity, effectiveness and sustainability of agriculture research institutions that serve the bean sector in Uganda and Rwanda.

Results, Achievements and Outputs of Research

Objective 1: Improve harvested bean yields and quality.

Improve Yields and Quality through Evaluation of Better Production Practices

For seasons 2010B and 2011A, 12 trials were set up – two with each of the six farmers groups. For each season, trials were set up with different farmers in each group. Three varieties - K131, NABE 4, and Kanyebwa (farmers variety) were compared under four fertility treatments. The fertility treatments were: (1) Control - no fertilizer added, (2) FYM alone - (9 kg per plot- 10 T/ha), (3) Phosphorous alone - (36 g/plot - 40 kg/ha), and (4) FYM (4.5 kg/plot - 0.5 T/ha) and Phosphorous (18 g/plot - 20 kg/ha). The experiments were set in a randomized complete block design with two replicates. Each on-farm trail had 24 plots each 3 m x 3 m. For season 2011A, an additional 30 seed health trial plots each 3 x 3 m were set up with each of the six farmer groups. Comparative analyses from seed health experiments are ongoing. Similar trails were established for the second season (2011B) but with FYM and Phosphorous amendments as (7.5 kg and 15 kg per plot) and (54 g and 108 g per plot), respectively, because laboratory soil analysis indicated lower levels of both P and N for the six trial sites.

At physiological maturity, beans were harvested from each plot and the following data were collected: number of plants per plot, number of pods per plant determined from 20 randomly chosen plants per plot, number of seeds per pod from 20 randomly chosen pods per plot, total yield per plot, clean yield per plot (shriveled, discolored, cracked seed removed), 100 seed weight, and moisture content for seeds from the various plots was also determined. The seed weight/yield was standardized to 13% moisture content and yield adjusted to kg/ha. Data from each of the seasons were analyzed separately analyzed using PROC GLM in SAS.

Nitrogen and phosphorous are major nutrients required for good plant growth and development to achieve higher yields. Deficiency of both nutrients leads to stunting of bean plants, poor flowering, and flower abortion and, thus, low yields. Nitrogen and phosphorous were generally limiting in the soils used for the trials and their application was aimed at increasing their availability in the soil for plant utilization. The trials demonstrated to farmers the need for soil fertility improvement so as to get better yields. However, the modest increases in yield also demonstrated the complexity of getting consistent and dramatic increases in yield given the differences in trial management by farmers, local environments and trial sites.

For Season 2010B, Analysis of Variance showed that there were significant effects of variety ($p<0.0102$) and location ($p<0.0001$) on total yields of the three bean varieties tested. Variety by location ($p<0.0007$) and variety by fertility treatment ($p<0.0387$) interactions were also significant. Main effects of fertility treatment on yields were, however, not significant. ANOVA for clean yields had a similar pattern.

Across locations (farmer fields), K131 showed more stability in yield with average yields 365-668 kg/ha, and with 50% of total yields above the variety average of 499 kg/ha. This was followed by NABE4, with total average yields 201-562 kg/ha and 62.5% of the locations having average total yields above the variety average of 380 kg/ha. Variation in yields was greatest for Kanyebwa, with average total yields ranging from 36-570 kg/ha, and only 37.5% of the locations having average total yields above the variety average of 312 kg/ha.

Table 1: Effect of Fertility Treatment on Total and Clean Bean Yield - 2010B Season

Fertility Treatment	**Total Yield (Kg/ha)**			**Clean Yield (Kg/ha)**		
	Kanyebwa	**K131**	**NABE4**	**Kanyebwa**	**K131**	**NABE4**
Control	246B	487A	254B	152B	363B	158B
FYM	320AB	560A	406A	228AB	476A	279A
Phosphorous (P)	297AB	491A	424A	258AB	404AB	290A
FYM + P	401A	458A	443A	331A	322B	250AB

Data have been adjusted to kg/ha and standardized to 13% moisture content.
Means with the same letters down column are not significantly different at p=0.1.

Comparison of fertility treatment within varieties (Table 1) shows that application of fertilizers tended to increase the yields compared to the control. K131 had higher yields compared to the other two varieties. Within varieties, comparison of the highest fertility treatment yield to the control shows that NABE4 had the highest increase in total yield (43%), followed by Kanyebwa (38%) and K131 (13%), respectively.

For Season 2011A, analysis revealed significant location effects on plants per plot, pods per plant, seeds per pod, total yield, and clean yield. There were no significant variety effects on the total and clean yield. However, there were significant variety effects on the number of plants per plot, pods per plant and seeds per pod. Main effects of fertility treatment on yields were, however, not significant. This suggests that overall, the nutrients supplied were not sufficient to lead to significant increases in yields or other extraneous variables such as weed management, water stress, pest and diseases which may be more important. Interaction between variety and location was significant for pods per plant, seeds per pod, and total yield. Further, the variety by fertility treatment interaction was significant for total and clean yield.

Correlation analysis showed that the number of pods per plant (0.3, $p < 0.002$) and number of plants harvested per plot (0.26, $p < 0.1$) had significant positive effects on total yield.

Table 2: Effect of Fertility Treatment on Total and Clean Bean Yield - 2011A Season

Fertility Treatment	**Total Yield (kg/ha)**			**Clean Yield (kg/ha)**		
	Kanyebwa	**K131**	**NABE4**	**Kanyebwa**	**K131**	**NABE4**
Control	533AB	726AB	383A	366AB	373AB	201A
FYM	506AB	1010A	515A	359AB	560A	361A
Phosphorous (P)	444B	682B	532A	278B	486A	401.5A
FYM + P	733A	685B	596A	582A	202B	375A

Data adjusted to kg/ha and standardized to 13% moisture content.
Means with the same letters down column are not significantly different at p=0.10.

Overall, K131 yields were higher than the other varieties (Table 2). Application of farm yard manure together with phosphorous led to much higher yields for Kanyebwa, while application of farm yard manure alone led to much higher yields for K131 compared to the other treatments. There were positive though not significant differences in the yield of NABE4 due to the addition of manure. Within varieties, comparison of the highest fertility treatment yield to the control shows that NABE4 had the highest increase in total yield (36%), followed by K131 (28%) and Kanyebwa (27%), respectively. The modest increases in yields with manure indicate that the nutrients still were not sufficient to meet the full requirements of the plant during establishment and seed filling. Alternatively, other constraints such as pests, diseases, and drought may be responsible for limiting yield increases.

Overall, analyses of data from all the on-farm trials show that:

- Improved varieties used in the study had higher average and more stable yields across locations
- K131 yields were consistently higher that other varieties; this could be attributed to its better resistance to diseases and drought
- Improvement of soil fertility by application of manure and phosphorous has consistently led to moderately higher yields. This has demonstrated to farmers that soil improvements together with other good agronomic practices are necessary to obtain better yields.

With agronomic controls, a total of 180 plots were established for seed health experiment in the six farmer groups. Data collection in these experiments involved counting and classifying the number of pests observed on every plant and the data were entered using the recommended CIAT scale (CIAT 1987). The most common pests observed were bean beetles, aphids, thrips, whiteflies and bean pod borers. Two experiments were set up, each consisting of 30 plots per site. One experiment focused on assessing the effect of different seed sources on the yield with treatments being farmers seed from the market, better storage by VEDCO and farmers. The other treatment involved was NABE 4 from better storage by VEDCO and NACRRI, respectively.

The second experiment focused on the pathology and entomology of the most common bean variety in Kamuli (farmers seed). It also consisted of 30 plots. The treatments included five plots having seed with a seed dresser at planting, five plots sprayed with a pesticide, five plots with a fungicide, five plots with having a combination of the pesticide, fungicide and the seed dresser plus five plots serving as the control. Both experiments had three replications, each having five plots of 3 m x 3 m. All 67 farmers participated in this experiment. Analysis of data is pending.

Of the three bean varieties planted, K131 proved to be more tolerant to drought stress compared to farmers seed and NABE 4. In terms of yield per unit area, K131 still performed best with NABE 4 having the lowest yields. However, farmer seed was more susceptible to pests and diseases in the fields.

Of the six CRSP project farmer groups, five groups provided 10 kg each of beans that were used in the anaerobic storage technique. The materials used in this method were clean 10 liter jerrycans with no holes and with tightly fitting seals. There was a significant improvement in the storage of beans, with minimal pest multiplication and bean damage.

Support Community-Based Seed Production (CBSP) by Farmers Groups/Associations

CRSP farmer groups were able to plant 16 acres of beans in the 2011A season, well beyond the 6 acres that they cultivated during the previous season. Despite the April hailstorm which devastated some fields, most groups were able to achieve a good harvest. Group members are also cultivating expanded fields of beans on their own household plots. CRSP farmers were trained in group dynamics and business management by NaCRRI technicians and VEDCO staff to strengthen group cohesion for the challenges of producing quality seed. Farmers were encouraged to use their group constitutions when making decisions, which may range from sharing proceeds of a bumper harvest to disciplinary cases. Training covered major causes of group breakdowns such as not having regular meetings, inhibiting free sharing of views, not addressing issues, dominance within the group by particular individuals, lack of periodic democratic elections, and personal conflicts. Training also covered gender roles, gender equity, how gender roles interact with group dynamics and these interactions, in turn, may influence their efforts in development. These trainings enhance mutual respect and rational assignment of duties within the group, and maintain coherence in group activities. Refresher trainings on recommended management practices for proper bean production: use of approved seed at planting, timely weeding and pest control, drying of the beans on tarpaulins, and proper storage to avoid post-harvest bruchid damage. Business elements are discussed under objective 3 below.

All participating CRSP *farmers* were taken for a field exposure visit at the National Crops Resources Research Institute (NaCRRI) at Namulonge. The goal was to strengthen farmers' capacity in community based seed production. Farmers were taken to on-station bean research plots to understand clearly the recommended site selection and field layout. They also discussed criteria for selection of quality seed for planting.

All CRSP farmers were also taken to meet with members of the Gombe Seed Producers Farmers Association in Wakiso District (south of Kampala). During the visit, the farmers toured the bean fields of the hosts, and shared their knowledge, skills, and success stories for growing beans. Gombe seed producers use a hand driven seed dressing machine and pack their own seed for sale using low cost technology and system of seeds packed in small affordable quantities (0.5 kg, 1 kg, 2 kg) for ease of sale to institutions and other farmers. They have also been able to start an internal lending scheme with its source of capital being the beans.

Evaluate and Promote Adoption of Improved Post-Harvest Handling and Storage Methods

At Makerere University, researchers evaluated the impact of solarization and triple bagging on beans in bulk storage under Ugandan conditions. Of particular interest was reducing post-harvest losses of beans due to bruchid infestation. Also of interest are seed viability (germinability) and culinary properties of the beans. This involved determine the initial quality parameters of the beans, monitoring the temperature profile of the beans during solarization, assessing monthly the characteristics of the treated beans during a six month storage period, and re- determining the quality parameters after the storage, and determine the effect of treatments on seed germinability. Beans were obtained and dried to 12% moisture content. For each 100 kg of beans, the entire lot was divided into smaller lots by passing all the grain through the Boerner divider multiple times. Representative samples were drawn from the resulting lots.

Table 3: Methods of Determining Initial Characteristics of Beans and Their Viability

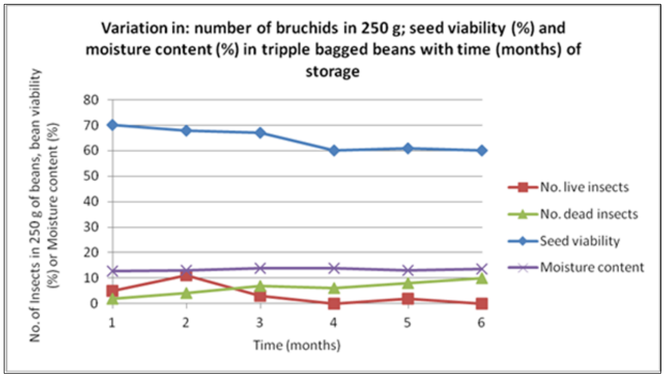
Characteristic	Units	Method
Moisture Content	%	Electronic hand-held moisture meter
Foreign Material	Weight %	Hand screening and weighing
Damage, Insect Damage, Splits Beans	Weight %	Visual inspection and weighing
Number of Live Insects	# per 250 g	Visual inspection and weighing
Number of Dead Insects	# per 250 g	Visual inspection and weighing

The bean samples were divided into three lots; the first lot was a control, the second was triple bagged, and the third was solarized and triple bagged.

Solarization was done by placing the beans on a tarpaulin laid on the grass (lawn). The beans were then covered with a transparent plastic film and left in the sun for 2 hours on a hot sunny day. Triple bagging was done using woven polyethylene sacks and HDPE sacks of thickness 80 microns that were free of holes. Two HDPE sacks were placed inside the woven sack, filled with beans and each of the sacks successively tied with sisal string, after eliminating all excess air. All three sample types were stored for a period of up to six months in a vermin proof store off the ground (on pallets) and away from the wall. Characteristics of the beans are being assessed at monthly intervals and the results recorded for subsequent analysis.

Beans and maize purchased from farmers shortly after harvesting were dried to 12% moisture content then solarized and then triple bagged. Control samples were stored in the conventional manner, single polypropylene bags. Samples were taken from the controls at one month intervals a different bag of each of the grain was opened at one month intervals and analyzed. Preliminary results indicate that the combination of solarization and triple bagging is effective for killing weevils in both beans and maize stored in bulk (75 kg bags). The control samples of both beans and maize, had increasing numbers of live weevils during a six month storage period. The number of live insects in beans that were triple bagged remained low throughout the six months storage period (see Figure 1).

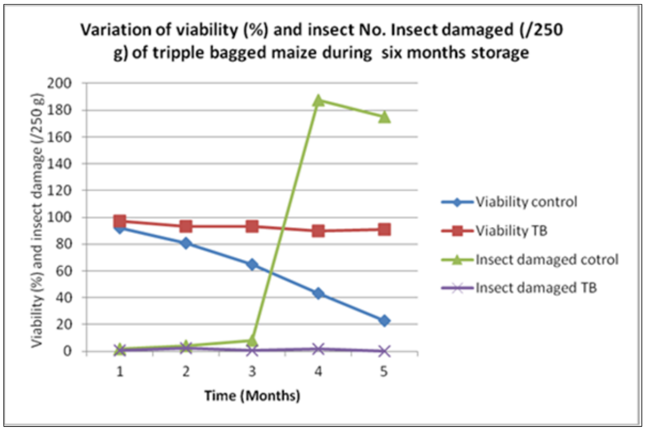
Figure 1 – *Live and Dead Bruchids, Seed Viability & Moisture Content in Triple Bagged Beans*



The moisture content of the triple bagged grains was maintained at the original level of about 12%. Triple bagging minimized moisture pick-up during the six month storage period.
The initial viability of the beans was rather low (60%), likely because the beans had been affected by drought, the harvest was generally poor and the beans were visibly of poor quality. The beans were not sorted but stored as obtained. The quality of the maize was better, and maize had a higher initial viability (>90%). Viability of both beans and maize remained high following solarization and subsequently during storage relative to the original quality of the grain, i.e., initial viability of the control sample. Changes of only about 10% were noted. Viability of poor quality beans that have been triple bagged beans is reduced by a maximum of 8% during six months storage period. The reduction is less in good quality beans, consistent with earlier experiments using better quality beans.

Beans were more resistant to insect damage and their viability was little affected. Triple bagging was also effective for protecting maize from insect damage and loss of viability (see Figure 2).

Figure 2 – *Seed Viability and Insect Damage of Triple Bagged Maize*



Experiments are on-going. Solarization experiments to profile temperature changes and evaluate mortality rate of insects were not successful due the uncharacteristically long rainy season. They will be repeated. The entire experiment is also being repeated to confirm previous observations (the control sample was stolen from the store room, which is now better secured).

Technicians from NACCRI with support from VEDCO staff trained all six groups regarding the roles of materials and procedures used during triple bagging and solarization. Demonstrations used both traditional interactive discussion and demonstrations, and animated videos. The solarization training involved digging a hole of 1.5 m length x 1 m width x 1 ft deep for demonstration purposes at all training venues. This was followed with measuring the percentage moisture content of the beans using a moisture tester. Seeds of the previous season from the group multiplication gardens were used for the demonstrations. Bean samples were collected prior to solarizing to conduct a germination test.

At the beginning of the harvesting period for 2011A when CRSP farmers had beans with which to demonstrate triple bagging and solarization, all received bags and three meters of black and clear polythene materials. Triple-bagged containers of beans were opened after six months and assessed for any bruchid survival and damage. Post-storage test documented 96% germination. Beans stored under these conditions were planted in farmers multiplication gardens during the 2011B growing season.

A potential hindrance to sustainable use of these materials may be cost. For example, each bag costs 3000 UGX (approximately $1.20 U.S.). The real cost declines when bags remain in good condition and are re-used; farmers are receiving follow up training on how to handle the bags and avoid puncturing or tearing them. The process is initially labor intensive, but ultimately significantly labor saving since it is done only once, in contrast to bi-weekly re-sunning the entire bean harvest when using traditional storage methods. Future training will focus on ensuring that proper solarization conditions are achieved and maintained, since farmers will not have thermometers and timers available.

Strengthen Farmers' Collective Capabilities to Learn and Share Innovative Practices

Following the field exposure visits to the National Crops Resources Research Institute (NaCRRI) at Namulonge and the Gombe Seed Producers Farmers Association in Wakiso, Kamuli CRSP farmers were impressed and inspired by the approach and accomplishments of their fellow farmers. Project farmers' capabilities in seed production have been strengthened. As result, CRSP farmers managed to cultivate 16 acres of beans in season 2011A compared to the 6 acres cultivated in 2010B.

Existing extension training materials for bean production and post-harvest management are continually being refined and translated in to Luganda. Topics include: proper site selection, plant and row spacing, weeding, pest management, harvesting, drying, threshing, moisture testing, sorting and seed selection, solarization, and storage (jerrycans and triple bagging). PowerPoint slides, posters, and video clips on various agronomic and post-harvest handling techniques have been developed to ensure quick and efficient knowledge transfer directly to the farmers. Those pertaining to post-harvest management and technologies will soon be tested hundreds of bean growers in Kamuli who have not previously participated in CRSP project activities. NaCRRI and VEDCO are currently exploring the potential for introducing some aspects of this research in other districts, especially the germination test and triple bagging.

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

Address Nutritional and Health Problems Among Vulnerable Individuals Through Increased Consumption of Beans, Bean Products, and Complementary Foods

Cold extruded bean flour based snack. 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. The following were the combinations indicated in Table 1 that were found to be acceptable. The preferred combinations were subjected to proximate analysis in the laboratory. Simultaneously storage stability studies were conducted at room temperature (20-25°C) for a period of four months to monitor the snack foods. Storage stability assessed by sensory evaluation showed no changes in terms of color, flavor and odor. The product was acceptable for consumption with no rancidity.

Table 4: Organoleptically Accepted Combinations of Bean Composite Flour

Sample	Bean Variety	Composition of Flour
1	Colta	100% Bean flour
2	Decelaya	70% Bean and 30% Maize
3	RWR 22-45	100% Bean Flour
4	White Beans	60% Bean and 40% Maize

A metallic hand operated extruder was used to cold press the dough before deep frying in hot cooking oil. It consists of a die, dough holder and dough presser. Dies are 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 extrusion was made directly into the hot cooking oil and deep fried.

Figure 3– *Elements of the Hand Held Cold Extruder*

Acceptability of these snack foods varied. For RWR22-45, the accepted blend was 100% and for White variety it was 60%:40% beans to maize. Though the blend of RWR22-45 was not acceptable, it may be used as a single flour in processing of snacks. This indicated that snacks from cereal - bean flour blends and bean flour alone can be processed.

In Uganda, a bean-based weaning food containing pre-processed (germinated and steamed) bean flour (40%), roasted grain amaranth (30%) and rice flour (30%) was developed. It was formulated to have protein and energy levels that contribute significantly to the Recommended Daily Allowances (RDAs) for children ages 2-5 years. A processing protocol aimed at reducing anti-nutrients and cooking time while improving protein and starch digestibility as well as the sensory acceptability for bean flour was developed. The protocol was optimized for minimizing anti-nutritional factors (phytic acid or phytate content and total polyphenol content), while maximizing protein and starch digestibility and overall sensory acceptability of a porridge prepared from the composite flour.

The bean-based composite porridge gave an acceptable viscosity of 2500–3000 cP at a high solid content of 15% compared to 8% for millet flour and 7% for maize flour. The composite porridge could supply 97% of the Estimated Energy Requirements (EER) for females ages 2-3 years compared to 50% from millet porridge and 42% from maize porridge with 3 servings daily (each serving = 500 ml of porridge). It could supply 84% of EER for males ages 2-3 compared to 43% from millet porridge and 37 % from maize porridge with 3 servings a day. For female children ages 4-5, the composite porridge could supply 53% of the EER compared to 27% from millet porridge and 23% from maize porridge with 3 servings a day. For male children ages 4-5, the composite porridge could supply 50% of the EER compared to 25% from millet porridge and 22% from maize porridge with 3 servings a day. Furthermore, the composite could meet 115% of the Recommended Daily Allowance (RDA) for protein of children ages 2-3 compared to 50% by millet and 38% by maize porridges with 1.5 servings per day. For children ages 4-5 years, the composite could meet 78% of the RDA for protein compared to 34% for millet and 26% for maize porridge with 1.5 servings per day. An optimized extruded bean flour protocol is being finalized and will complement this section, with all applicable nutritional evaluation.

In Rwanda, research was conducted to develop nutrient dense bean-based composite flour from bean and 6 other locally grown vegetables. This involved analyzing its nutritive value and functional properties, processing a sample soup from the developed flour, and assessing consumer acceptability of the soup through sensory evaluation. The study is part of the effort to provide affordable adequate nutrition for low income families. Fresh beans were subjected to a combined treatment of soaking, germination, de-hulling, parboiling, drying and milling into flour. For vegetables, the unit operations were: washing, size reduction, blanching, drying and milling. Flours obtained were mixed to different proportions. The mix was termed CRSP/KIST PANAMIX. Four samples (A, B, C, and D) of the composite flour were formulated using bean, moringa leaves, potato, tomato, carrots, leeks and garlic flours in the ratios of 70:10:8:4:4:2:2 (A), 60:20:8:4:4:2:2 (B), 50:30:8:4:4:2:2 (C), and 40:40:8:4:4:2:2 (D). Four samples of soups were developed from theses composite flours; and 15 trained panelists rated the prepared soups. Preliminary sensory evaluation showed that soups processed from samples A and B were the most acceptable.

Then, the two samples underwent laboratory analysis of selected functional properties and nutrients. The functional properties analyzed were bulk density, pH, oil absorption capacity; water absorption capacity and wettability. For PANAMIX No.1 (Sample A), the results obtained were 0.88 g/cc, 5.67 pH, 2.4 ml/g, 5.8 ml/g and 50.6 seconds, respectively. For PANAMIX No.2 (Sample B), the results were 0.86 g/cc, 5.45 pH, 2.65 ml/g, 6.5 ml/g and 53 seconds,

respectively. Appropriate methods of analysis were used to determine the proximate chemical composition of the two first accepted samples, PANAMIX No.1 and PANAMIX No.2.
The results indicated that ash, β-carotene, calcium, carbohydrate, crude fat, crude protein, total energy, crude fiber and moisture content were 10.26%, 79.12 mg/100 g, 0.875%, 51.40%, 7.1%, 11.98%, 317.47 Kcal/g, 13.9% and 5.34%, respectively, for PANAMIX No.1. It was 9.12%, 173.56 mg/100g, 1.06%, 46.26%, 11.00%, 13.825%, 339.34 Kcal/g, 12.42%, and 7.37%, respectively, for PANAMIX No.2. The results from the second sensory evaluation revealed that there was no significant difference between the two samples, PANAMIX No. 1 and PANAMIX No.2 ($p<0.05$). Generally, both composite flours were nutrient dense, but the latter was found to be high in β-carotene, calcium, crude fat, crude protein and total energy when compared to PANAMIX No.1.

Table 5: Nutritional Value of PANAMIX in 100g

Sample	Nutrients	Composition of Flour
1	Carbohydrates (g)	51.4
2	Crude fats (g)	7.1
3	Crude protein (g)	11.98
4	Energy (Kcal)	303.27
5	Fiber (g)	13.9
6	Moisture (g)	5.34
7	β – carotene (mg)	79.12
8	Calcium (g)	0.87

Three topics were identified for which extension materials have been developed:

- Basics of feeding children aged 6-59 months
- Methods of preparing beans that reduce cooking time and enhance nutrient bio-availability
- Preparation of bean-based composite flour and utilizing the flour in porridge

The content is available in two forms; a summary training outline and a detailed training manual. It will soon be translated into local languages and illustrations added.

In Rwanda, two KIST lecturers (Hilda Vasanthakaalam and Aurelia Larry) and five students traveled to Rukomo sector, Nyagatare district, Eastern Rwanda to demonstrate and conduct trainings. They explained and demonstrated processing the CRSP/KIST PANAMIX, and discussed the nutrient content in 100g of the product. Villagers were encouraged to substitute 15–20% of the mix for wheat in cake, biscuit and bread making. They also explained and demonstrated preparation of the bean based soup, and the cold extrusion method. In addition to 60 farmers who registered, several village leaders also participated. Moreover, many other farmers joined the event after being invited by the excited farmers who were registered.

Figure 4 - *Demonstrating Cold Extrusion of Bean Snack*

Soup preparation was also demonstrated. It involves mixing 100 g of PANAMIX with 200 ml of water, which is then added to 750 ml of boiling water. To this is added 15 ml of cooking oil, salt to taste, and everything is boiled for 10 minutes until it thickens and can be served hot.

Figure 5 - *Demonstrating Preparation of Bean Based Soup*

Participants indicated that it could nourish vulnerable segments of the population (children, mothers, sick, and the elderly). Local officials forwarded two significant recommendations following the demonstration. Training 60 health counselors in the district was proposed by the Executive Secretary of Rukomo sector. Demonstrating the techniques to farmers and village authorities in Mimuri sector is also on the agenda; this could not be accomplished during this trip due to the overwhelming number at Rukomo who participated in the demonstration and training.
Farmers in Kamuli District were also trained in preparation of the cold extruded bean snack as well as methods (soaking and sprouting) to enhance nutritional quality of bean dishes fed to children aged less than five years. Grace Nkundabombi from KIST and Catherine Ndagire from

Makerere conducted the training. Sensory evaluation sessions of dishes prepared with soaked and sprouted beans were also carried out to evaluate acceptability of the foods.

Rapid appraisal of the basic knowledge of feeding infants and young children and the extent and use of beans were assessed, and training materials for utilization of beans to improve the quality of meals served to infants and young children in Kamuli were piloted. In Rwanda, arrangements have been made with two NGOs (Africare and World Vision) to assist in this activity. This was determined as a more appropriate initial activity than documentation of nutrition status.

Analyze Culinary Properties, Sensory Characteristics, and Consumer Acceptability of Improved Varieties of Beans

A protocol for rapid screening of culinary properties of pulses was obtained from Prof. Amanda Minnaar, Department of Food Science, at the University of Pretoria. The protocol determines the following characteristics of beans: the water absorption capacity during soaking (g/kg); cooking water absorption (g/kg); seed coat splitting (%); cotyledon splitting (%); soluble solids content (º Brix) and pigment leaching. The protocol also includes a method for screening pulses for sensory characteristics through sensory evaluation. The characteristics for evaluation include: seed aroma; cooked legume aroma; texture (tactile); broth aroma and broth appearance.

In Uganda, this protocol is being used at Makerere University to evaluate culinary and sensory characteristics of local and improved bean varieties. To date, four local and five improved varieties have been analyzed. Preliminary data shows that all the varieties so far analyzed are short cooking, i.e., take less than 120 minutes to cook. Further analysis is underway to determine the variation of cooking times among the varieties. More varieties will be analyzed in the future.

The Department of Food Science and Technology at KIST received for analysis the 16 new bean varieties released by Institut des Sciences Agronomiques du *Rwanda (ISAR)*. Three KIST students conducted preliminary assessment of culinary properties. Complete assessment has been delayed by the government's prohibition of lightweight non-biodegradable plastic bags, such as zip-lock bags that are needed for this assessment. Currently, biodegradable plastics are now available but not of the desired thickness (density) that can withstand boiling. An alternative approach of using basmati rice bags will be used in the near future by KIST students.

The culinary properties of eight local and six improved bean varieties are being analyzed. The beans were purchased from the open market. Their moisture content was determined followed by drying the beans to approximately 12% moisture and storing them in the layers of zip-lock bags. Samples are drawn and subjected to cooking experiments to determine the time required to cook, i.e., being easily crushed between two fingers. After cooking times are confirmed, the different bean varieties will be cooked for the time determined to be adequate and subjected to sensory acceptability testing, using untrained consumer panels. This work was delayed by the 1.5 month closure of Makerere University in August-September.

Incorporate Insights from Analysis of Private Food Processing Industry Regarding Development and Commercialization of Bean-based Products

Four types of incubators were identified: local economic development incubators; academic and scientific incubators; corporate incubators and private investor incubators. The four differed in their goals, main activities, objectives, targets, constraints and trends. As a public institution engaged in research and development (R&D), the academic and scientific type of incubator is most suitable for activities of the Makerere University Food Technology and Business Incubation Centre (Mak-FTBIC). Mak-TFBIC objectives are emblematic of academic and scientific incubators, including: commercialization of technologies generated by R&D activities; developing an entrepreneur spirit among graduates; fulfilling the public University's mandate of outreach to the public and building a positive image by making a positive contribution to national development; the Center and its activities are supported by a grant from the government of Uganda.

Mak-FTBIC targets projects generated out of internal research activities (technology development projects) as well as external projects, including satellite incubation activities in which private sector businesses are provided technical support in their premises outside of the Mak-FTBIC. The services offered by Mak-FTBIC include: concept testing (internally referred to as technology development projects - in which promising research findings are refined, up-scaled and market tested, in partnership with a private sector businesses); providing technical advice and support to incubatees in areas of business and financial management, design and implementation of quality management systems; and providing advice on intellectual property management. Mak-FTBIC management has currently engaged a consulting firm to undertake a diagnostic study of incubatee businesses to access 'business mentors'/coaches, and attract investments to facilitate 'hatching' of the businesses.

The academic and research incubator type is working well with eight incubatee companies and 12 technology development projects. Undergraduate students are inspired to undertake research projects with prospects for incubation and commercialization, while graduates are gainfully employed and have the opportunity to be entrepreneurs.

Bean processing into value added products has so far been very limited in Uganda and the East African Community (EAC). This project is contributing to its establishment. Experiences from elsewhere in Africa, Europe and North America, highlight the potential of the bean industry in Uganda. The most common processing of beans is canning and is an important industry in developed countries and in South Africa. Asian countries, especially India, sell pre-cooked bean curries and sauces in sachets. Such products have potential for the urban market in Uganda for working families with limited time for meal preparation.

During a visit to the University of Pretoria, Drs. Nakimbugwe and Vasanthakaalam visited the South African Bean Council offices and bean processing facilities in Pretoria. The Bean Council is involved in coordinating bean production, post-harvest handling, including pre-cleaning, sorting and packaging of dry raw beans in consumer packs that are sold in supermarkets. In addition, the bean council collaborates with research organizations to select, produce and multiply bean seeds sold all over the country and beyond. South Africa also has a bean canning industry which constitutes a steady market for beans. The above experiences highlighted the potential market for beans in Uganda, Rwanda and other countries in the East African Community. Currently, there is market for all grains within the EAC, especially Southern Sudan, for which the expanding market can benefit well organized farmers groups engaged in collective marketing. Nutreal Limited is a company currently involved in producing and marketing nutrient-enhanced foods, including a bean-based product up-scaled from a protocol developed as part of this research project. The company is utilizing increasing amounts of dry beans which will serve as a key market for farmers when production is up-scaled.

Experience with Nutreal Limited to up-scale production of the bean-based composite flour developed from this project indicates that the following are important:

- First and foremost, the technology developed should be compatible with the private company's mission and objectives. In this case, a protocol for a nutrient-enhanced food was developed and fitted very well into Nutreal's mission to produce and market nutrient-enhanced foods.
- R&D-based technologies are valued, as they increase the chances of products' market success; being associated with an R&D institution is also viewed very positively.
- Continued technical support and involvement of the R&D personnel from the institution is key; private sector businesses want to be assured of it.
- The availability of a University-based R&D and business incubation facility encourages private sector involvement as it reduced their initial risks and allows for extensive market testing before heavy investments are made into manufacturing infrastructure.

The collaborative relationship between MAK, NaCRRI and VEDCO provides an ideal framework for linking farmers' groups to industry. Both NaCRRI and VEDCO work with farmers and farmers' groups and are in position to link backwards to production and forward to R&D and processing. The partners already provide technical support to farmers' groups with regard to enhancing production and productivity and improving post-harvest handling and storage, factors that are important for access to markets. The partners also train farmers' groups to improve their nutrition security by using improved preparation and simple processing methods for better health which, in turn, enhances productivity.

Makerere University's Food Technology and Incubation Centre (FTBIC) has provided opportunity for linking farmers' associations to private industries to be suppliers of raw materials. This is already the case for grain amaranth, which is being supplied to processors working in the FTBIC by farmers' groups in Kamuli and other districts. A similar market already exists for beans once production is up-scaled. The FTBIC frequently receives inquiries on possible markets for agricultural products, so producers are aware of the potential.

Nutreal Limited, a private company working in MAK-FTBIC is currently collaborating with our research group to increase the bean-based product range and utilization of pre-processed bean flour. Composite flours, including pre-processed beans, are being developed for food use. Trials to incorporate pre-processed bean flour into baked products are also underway.

Kubumwe Enterprises in Rwanda has discussed collaborating with the Department of Food Science and Technology at Kigali Institute of Science and Technology

Objective 3: Identify solutions for constraints to increased marketing and consumption.

Assess Capabilities and Needs of Farmer Groups and Associations

Farmers in Kamuli own and cultivate an average of 2-2½ acres, and one-half borrow or rent land (averaging 1 acre) for their agricultural activities. Most were growing maize and beans, but only

15% of those farmers were harvesting at least 50 kg of beans. Other important crops are cassava, sweet potatoes, bananas, groundnuts, soybeans, millet, rice, and grain amaranth. Many also raise poultry, goats, and/or pigs, as well as some cattle, for both food security and income. Most households sell some agricultural produce (averaging 1-2 crops), and sold almost exclusively on an individual basis to traders (only 5% sold collectively). One-half of all households engage in one or more of a diverse array of non-agricultural income earning activities in the formal or informal sector. More than one-half borrowed money during the previous year.

Participating in the CRSP project has enhanced farmers' assets and capabilities, both individually and collectively. While the number of farmers participating directly in CRSP activities has not increased due to the nature of training and support required for the array of field experiments, these farmers are all part of larger groups. Their social capital has been enhanced through strengthening their groups and connections made with other groups locally (when others inquire about their new ways of cultivating and handing beans) and through exchange visits. Their human capital has been enhanced through gaining technical knowledge and experience in applying it. Their political capital has been enhanced locally through leadership roles are carried out by members democratically elected by their colleagues for one year term, and externally through awareness of their interests and rights and capabilities of lobbying local government officials for support of their initiatives, particularly regarding marketing. A significant impact on cultural capital - in terms of gender roles - is that five of six groups are currently headed by women. Their natural capital has been enhanced through increasing the amount of land cultivated in response to new opportunities presented by growing and selling beans. Their physical capital has been enhanced through acquiring improved bean varieties that are high yielding and tolerant to environmental stresses, and some groups have acquired oxen and an ox plough. As farmers grow more beans, group members are very interested in labor saving production technologies (threshers, larger scale storage, etc.) that will lessen their work in large scale production, storage and bulking centers for improved marketing and increased access to microfinance services.

Strengthen Farmers' Successful Engagement in Value Chain Development

Farmer groups were trained and supported in various aspects of collective marketing of beans. This involved: improving farmers' understanding of market price variation (among traders, markets, and seasons); enhancing their ability to manage harvested grain to obtain increased prices through loss-minimizing storage, negotiation skills, and coordination of collective marketing; and business planning, record keeping, and analysis. Results to date include:

- project farmers responded successfully to an 'Invitation for Bids' for puchase of beans
- the project team created a two page negotiated contract for all six groups
- 1000+ kg of two varieties were purchased from project farmers for scaling up
- plans to purchase 2 MT from CRSP project farmers when current season is completed

Figures 6 – *Invitation to Bid*

INVITATION FOR BIDS

Bids are invited from competent VEDCO CRSP farmers' groups to bid for supply of quality bean seed in Kamuli district.

Qualification Requirements include:

- The beans **MUST** have a germination percentage not less than 90%
- The beans should have moisture content below 14% and with a very good uniform color.
- Beans should be of good quality (Very clean , well sorted and with no broken/ damaged grains)
- The bidder should have the capacity to collectively supply to a tune of 1000kgs for both NABE 4 and K132 varieties.

Deadline of submission of quotations is 24th/06/2011 before 4:00pm

Figure 7 – *Agreement Form*

AGREEMENT FORM

This agreement is made on this ___________day of ________________
between ……………………………………………… Of………………
……………………………………………..(village, sub county, District)
and Volunteer Efforts for Development Concerns (VEDCO) in respect
to supply …………………………………………………………….....

Under the Collaborative Research Support Project (CRSP) at a cost of
Ushs…………………………(words)……………………………………
…………………………………………………………………to be paid
in……………………………………………………………………….

Signature:___________________	Signature:___________________
Name:______________________	Name:______________________
On behalf of the farmers group	**On behalf of VEDCO**

The CRSP project, in coordination with the CSRL program in Kamuli, has provided initial training and two varieties of improved bean seeds to 348 farmers to each plant 1/3rd acre of beans in 2011A, and an additional 200 farmers to each plant 1/6th acre of beans in 2011B. Thus, the project is already making excellent progress in scaling up bean production and management practices. Additional training sessions are planned, particularly regarding post-harvest practices.

Assessment of farmer groups interests, capabilities, and needs has led to continued mentoring and support for the bean value chain stakeholders forum which was established in late 2010. This included sharing insights from experiences of collective marketing by farmers associations in Masaka and Rakai, southwest of Kampala, and in Kapchorwa in northeastern Uganda.

Partner meetings were organized in two sub-counties (Butansi and Bugulumbya) in Kamuli district and facilitated by team members from Makerere University and VEDCO to analyze anticipated opportunities and constraints for participatory marketing from the farmers' point of view. They also discussed strategies to achieve successful participatory marketing and prioritize activities, and draft the activity road map. Farmers identified establishment of storage centers as a key factor in helping them obtain better prices for their beans when bulking and selling collectively. They also identified limited access to microfinance and agro-inputs (pesticides and herbicides) as key constraints to boosting their production.

Detailed value chain analysis for bean enterprises is currently being conducted by a Makerere University M.Sc. student in Agricultural Extension and Innovation, George Jjagwe. His interviews with farmers cover extension services accessed, participation in group activities, production inputs and activities, crop and livestock diversity, production costs, sources and credibility of market and price information, crop and livestock sales, income earned, household assets, and food security. He is also conducting interviews with input suppliers, traders, and consumers in district towns. The results of George's work will be very useful for making significant progress in value chain development and farmers livelihoods.

Objective 4: Increase the capacity, effectiveness and sustainability of agriculture research institutions that serve the bean sector in Uganda and Rwanda.

At the Master's level, Catherine Ndagire, M.Sc. student in Human Nutrition at Makerere University, has completed coursework and most of her research. She is currently finalizing her laboratory work and preparing to pilot test in Kamuli District the extension materials that have been developed through her work. George Jjagwe, M.Sc. student in Agricultural Extension and Innovation Studies, has also completed his courses, developed tools for data collection and has embarked on data collection. Grace Nkundabombi, M.Sc. student in Food Technology (from KIST in Rwanda) started her studies at Makerere University during the current academic year. M.Sc. student in Applied Human Nutrition at Makerere University (Aisha Nakitto Musaazi) completed and submitted her thesis for review, and will defend it during the current academic year. Simon Okiror, Agricultural Economics, successfully defended his thesis and graduated. The first manuscript from his thesis is being finalized for submission to a peer-reviewed journal.

At the Ph.D. level, Martin Mutambuka, Ph.D. student from Uganda in Food Science and Human Nutrition at Iowa State University, has passed preliminary exams, is nearing completion of lab research at ISU, will travel to Uganda in December 2011 to conduct sensory evaluation studies and continue writing the dissertation, and return to ISU in April to defend his dissertation and graduate in May 2012. Gerald Sebuwufu, Ph.D. student from Uganda in Crop Physiology and Sustainable Agriculture at Iowa State University, is taking preliminary exams, and progressing well in his field and lab research at ISU. During Spring 2012, he will write dissertation chapters. He will defend his dissertation and graduate in August 2012.

Collaboration among the three Ugandan institutions (VEDCO, NACRRI and MAK) has allowed for inter-organization learning fostering stronger partnership and linkages. Involvement of students in the three organization has also made this learning possible. Collaborators continue to jointly conduct activities and jointly learn. A KIST student who developed a cold extruded bean product demonstrated the method in Kamuli, Uganda, assisted by a Makerere University student and coordinated by VEDCO.

Project findings to date have been disseminated in various contexts during the past year:

- Mazur RE (2011). “Value Chains - How Can They Achieve Food and Nutrition Security Goals?” West Africa CAADP Nutrition Program Development Workshop. Dakar, Senegal. Nov. 9-12.
- Mazur RE, Musoke H, Nakimbugwe D, Ugen M (2011) “Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda.” Conference Note 1 for International Conference on ‘Leveraging Agriculture for Improving Nutrition and Health’ in New Delhi. Washington, DC: International Food Policy Research Institute.
- Mazur RE, Ugen M, Bwambale N, Sebuwufu G, Nakimbugwe D (2011). “Disseminating Improved Bean Production Management Practices and Technologies and Strengthening Marketing Capabilities.” Poster presented at USAID-Collaborative Research Support Programs Council Meeting: Research to Feed the Future in East Africa. Kampala, Uganda. July 25.
- Mutambuka M, Murphy PA, Hendrich S, Reddy MB (2011). “Effect of extraction buffer pH on ferritin yield from common beans (*Phaseolus vulgaris*).” Poster presented at the Annual Meeting of the Institute of Food Technology. New Orleans, LA: June 11-14.
- Sebuwufu G, Mazur RE, Westgate M, Bwambale N, Ugen M (2011) “Improving Common Bean Yields for Rural Development in Uganda.” Poster presented at USAID-Collaborative Research Support Programs Council Meeting: Research to Feed the Future in East Africa. Kampala, Uganda. July 25.
- Vasanthakaalam H (2011) Adding Value to Grains – Science, Nutrition and Technology. (includes chapter “The Cold Extrusion Process” (pp. 109-111). Germany: Lambert Academic Publishing, 188 pages. ISBN-10: 3845438479, ISBN-13: 978-3845438474.

Degree Training

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 2011: full-time student
Type of CRSP Support (full, partial or indirect): Partial

<u>Trainee #2</u>
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
Training Status during Fiscal Year 2011: full-time student
Type of CRSP Support (full, partial or indirect): Partial

<u>Trainee #3</u>
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 2012
Training Status during Fiscal Year 2011: full-time student
Type of CRSP Support (full, partial or indirect): Partial

<u>Trainee #4</u>
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
Training Status during Fiscal Year 2011: full-time student
Type of CRSP Support (full, partial or indirect): Partial

Trainee #5
First and given names: Marie Grace
Last name: Nkundabombi
Citizenship: Rwandan
Gender: Female
Degree: M.Sc.
Discipline: Food Technology & Nutrition
Host Country Institution to benefit: Kigali Institute of Science and Technology, Rwanda
Training Location: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe (Co-PI Hilda Vasanthakaalam)
Start date: August 2011
Project completion date: August 2012
Training Status during Fiscal Year 2011: full-time student
Type of CRSP Support (full, partial or indirect): Partial

Explanation for Changes

Rapid appraisal of the basic knowledge of feeding infants and young children and the extent and use of beans were assessed, and training materials for utilization of beans to improve the quality of meals served to infants and young children in Kamuli were piloted. In Rwanda, arrangements have been made with two NGOs (Africare and World Vision) to assist in this activity. This was determined as a more appropriate initial activity than documentation of nutrition status.

Networking and Linkages with Stakeholders

NaCRRI has been multiplying more than 200 nutri-bean lines (lines high in iron, zinc and protein) recently received from the University of Nairobi through CIAT. Through the Material Transfer Agreement (MTA) signed between CIAT-Colombia and Iowa State University, ISU has been receiving 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, the work of Ph.D. student Gerald Sebuwufu. NaCRRI researchers Michael Otim (entomologist) and Pamella Paparu (pathologist) have been conducting research to quantify the incidence of insect pests (bean aphids, thrips, bean stem maggot and flower beetles) and diseases (bean root rot, web blight, and bean rust). Findings will guide advanced training of farmers in pest and disease control to reduce crop losses.

VEDCO holds biannual community review meetings in its areas of operation; CRSP project partners and farmers participate in these review and planning meetings. VEDCO organized the first value chain stakeholder workshop in Kamuli in late 2010, involved 25 participants from 15 organizations (farmer marketing groups and associations, government agencies, non-governmental organizations, private sector traders, transporters, distributors, and processors). Ongoing research on value chain development for beans and maize corresponds to VEDCO's commitment to continue playing a facilitative role.

Visits to ISU by Co-PI from Makerere University (Uganda) resulted in further learning about parallel and complementary research interests, and bases for long term collaboration. ISU faculty members visited Uganda – bringing expertise in agricultural and biosystems engineering, agronomy, development communications, human nutrition, and sociology.

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

Scholarly Activities and Accomplishments

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

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

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

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

Musaazi, Aisha Nakitto. 2011. "Developing a quick-cooking bean flour." Final thesis for M.S. degree. Department of Food Science and Technology. Kampala, Uganda: Makerere University.
Mutambuka Martin, Murphy PA, Hendrich S, Reddy MB (2011). "Effect of extraction buffer pH on ferritin yield from common beans (*Phaseolus vulgaris*)." Poster presented at the Annual Meeting of the Institute of Food Technology. New Orleans, LA: June 11-14.

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

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

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Coulter JP & Mcgrath P (1994) “Economics of grain handling and storage in developing countries.” In: *Grain Storage Techniques: Evolution and Trends in Developing Countries*. *FAO Agricultural Services Bulletin.* 109(1-24).

Murdock LL & Shade RE (1991). “Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpeas by solar heating.” *American Entomologist* 37(228-231).

Murdock LL, Seck RE, Ntoukam G, Kitch L, Shade RE (2003) “Preservation of cowpea grain in sub-Saharan Africa - Bean/Cowpea CRSP contributions.” *Field Crops Research* 82(169-178).

Van Schoonhoven, A. and M.A. Pastor-Corrales (compilers) (1987). *Standard System for the Evaluation of Beans from CIAT.* Cali, Colombia: Centro Internacional de Agricultura Tropical.

Vasanthakaalam H (2011) The Cold Extrusion Process” (pp. 109-111) in *Adding Value to Grains – Science, Nutrition and Technology*. Germany: Lambert Academic Publishing, 188 pages. ISBN-10: 3845438479, ISBN-13: 978-3845438474.

VEDCO (2011) *Annual Report 2010*. Kampala, Uganda: Volunteer Efforts for Development Concerns.

Contribution of Project to Target USAID Performance Indicators

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

Cumulatively, we have been mentoring 20 students for degree training, seven at graduate level (of whom three are female) and 13 at B.S. level (of whom seven are female). We have exceeded our original estimate due to the efforts of Co-PI Vasanthakaalam and Co-PI Nakimbugwe who actively involve B.S. students in the CRSP project while they undertake research for their 4th year projects at KIST and Makerere University, respectively.

With regard to short term training, 67 farmers (58 women and 9 men) have participated in a series of short-term trainings 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. During 2011A, bean crop management practices and technologies have been disseminated to an additional 90 farmers (47 women and 43 men) during 2011A. During FY12, we plan to disseminate applicable management practices and technologies to more farmers, monitoring and evaluating the process and impacts to identify any barriers and most effective strategies.

We have progressed well in terms of the number of technologies and management practices that are under research (5), and under field testing (3), and ready to be made available for transfer (9) – slightly more than anticipated. The number of additional hectares under improved technologies or management practices (138) exceeds what was originally anticipated (115).

Farmers marketing associations in two sub-counties are directly benefitting from project activities. We are providing technical assistance directly to 51 community based organizations

(CBOs), slightly more than planned. Women constitute the majority of members in these CBOs. There are four host country partner organizations benefitting, as planned.

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. The discussion between Kubumwe Enterprises the Department of Food Science and Technology at Kigali Institute of Science & Technology in Rwanda in may also lead to effective collaboration.

Contribution to Gender Equity Goal

Among the team of research scientists and professional practitioners, there are six women and six men. As noted above, we have been mentoring three female graduate students and seven female undergraduate students; comparable data for males are four and six, respectively. Of the 30 farmers participating directly in the field experiments, 24 are women; similarly, most (58 of 67) farmers participating in project training sessions are women. Approximately ¾ of the additional 548 farmers receiving training and improved bean seeds during 2011 are women.

Progress Report on Activities Funded Through Supplemental Funds

Supplemental funds received in previous years for work in food science and technology at Makerere University and Kigali Institute of Science and Technology have been instrumental in advancing research and development activities addressing objective 2 and parts of objective 1:

- travel to Sokoine University and University of Pretoria (MAK and KIST Co-PIs)
- rapid nutrient analyzer at KIST (2008)
- single screw extruder and supplies at KIST (late 2009)
- degree (M.Sc.) training for KIST staff member at Makerere University
- short term training of M.Sc. graduate student (Catherine Ndagire) from Makerere University at Iowa State University in mid-2010

Recently awarded FY12 funding will support technology dissemination, research, and training:

- Development of new training media (print and video) and materials for improved management practices and technologies to be utilized in training 800 farmers in 20 demonstration sites
- Implementation and evaluation of six combinations of media and methods in training and demonstration: (a) interactive training, (b) animated video, and (c) farmer acted video. One-half of the farmers in each method/combination will receive ‘take home’ printed flyers.
- Capacity building of VEDCO’s Kamuli staff in advanced methods of farmer learning facilitation.

This final supplemental funding will strengthen capacity in our key project implementation partner, VEDCO, as well as Makerere University and Iowa State University faculty and students. It will also consolidate ongoing work that will be useful in future efforts to scale up innovative management practices and technologies to wider populations in Uganda and Rwanda.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Yield and Quality*														
1a. Variety performance and fertility responses analyzed	0			0			0			0			0		
1a. Biological & agronomic controls for pests & diseases initiated	0			0			0			0			0		
1a. Variety perform., fertility respon., bio. & agron. controls analyzed	X	X		0			X			0			0		
1a. Best performing bean varieties reported to breeders	X	X		0			X			X			0		
1a. Seeds provided for post-harvest storage studies	0			0			X			X			0		
1b. Training in group dynamics & mgmt. practices for quality seed	0			0			0			0			0		
1b. Exchange visits to established seed production programs	0			0			0			0			0		
1b. Extension guide for bean CBSP initiated and tested	0			0			0			0			0		
1b. Linkages establ. for breeders, seed processors, marketers	0			0			X			X			0		
1b. Seed storage facilities established	0			0			X			X			0		
1c. Effects of solarization on germination and storage evaluated	0			0			0			0			0		
1c. Farmers trained in effective use of solarization technique	0			0			0			0			0		
1c. Polyethylene for solarization distributed to farmers groups	0			0			0			0			0		
1c. Barriers to adoption of solarization identified and resolved	0			0			0			0			0		
1c. Storage techniques evaluated for pest control and germination	X	X		0			X			X			0		
1c. Farmers trained in new solar techniques	0			0			X			X			0		
1c. Storage materials produced and distributed to farmers	0			0			X			X			0		
1c. Training in mananging bulking facilities completed	0			0			X			X			0		
1d. Exchange visits of other farmer groups conducted	0			0			0			0			0		
1d. Contacts establ. w/ districts to scale technologies & practices	0			0			X			X			0		
1d. Stakeholder workshop to review bean prod. training materials	X	X		0			X			X			0		
1d. Extension materials translated and published	0			0			X			X			0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Cold extruded bean products & process developed at KIST	0			0			0			0			0		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X	X		X			0			0			X		
2a. Extension approaches indentifed and content developed	X	X		X			0			X			X		
2a. Farmers trained in bean cold extrusion processing	0			0			0			0			X		
2a. Baseline nutritional status established for feeding studies	X		X	X			0			0			X		
2b. Analysis protocol for culinary properties obtained	0			0			0			0			0		
2b. Analysis of desirable culinary traits of current varities initiated	0			0			0			0			0		
2b. Culinary traits & sensory char. of current varieties documented	X	X		X			0			0			X		

2b. Analysis of culinary traits & sensory char. of improv. var. initiated	0			X			0			0			X		
2c. Tech. incubation & transfer models identified and modifed	0			X			0			0			0		
2c. Local & int'l industries as potential markets for beans identified	0			X			0			0			0		
2c. Private industry interest/conditions to adopt bean tech. evaluated	0			X			0			0			0		
2c. Links establ. btw. farmers' assoc. & private industries	0			X			X			X			0		
2c. Protocols for value-addition w/ private sector partners initiated	0			X			0			0			0		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
3a. Farmer groups' composition, roles, assets, capabilites identified	0			0			0			0			0		
3a. Farmer groups' needs determined and prioritized	X	X		0			0			X			0		
3b. Farmers trained in group/assoc. dynamics and gender equity	0			0			0			0			0		
3b. Partner meetings held in two sub-counties	0			0			0			0			0		
3b. Participatory market research groups formed	0			0			0			0			0		
3b. Market chain analysis for bean enterprises conducted	X	X		X			0			X			0		
3b. Market information sources assessed	X	X		X			0			X			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
4. Training M.S. (FST and AgEcon) at MAK on-going	0			0			0			0			0		
4. Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
4. Training M.S. students at Makerere University completed	0			X			0			0			X		
4. Training Ph.D. students at Iowa State University ongoing	X	X		0			0			0			0		
4. Inter-organizational learning fostered	X	X		X			X			X			X		
4. Prelim. results disseminated (conf., public., websites)	X	X		X			X			X			X		

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

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

M Mazur
Signature

9-28-11
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: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Yield and Quality*														
1a. Variety performance and fertility responses analyzed	0			0			0			0			0		
1a. Biological & agronomic controls for pests & diseases initiated	0			0			0			0			0		
1a. Variety perform., fertility respon., bio. & agron. controls analyzed	X			0			X			0			0		
1a. Best performing bean varieties reported to breeders	X			0			X			X			0		
1a. Seeds provided for post-harvest storage studies	0			0			X			X			0		
1b. Training in group dynamics & mgmt. practices for quality seed	0			0			0			0			0		
1b. Exchange visits to established seed production programs	0			0			0			0			0		
1b. Extension guide for bean CBSP initiated and tested	0			0			0			0			0		
1b. Linkages establ. for breeders, seed processors, marketers	0			0			X			X			0		
1b. Seed storage facilities established	0			0			X			X			0		
1c. Effects of solarization on germination and storage evaluated	0			0			0			0			0		
1c. Farmers trained in effective use of solarization technique	0			0			0			0			0		
1c. Polyethylene for solarization distributed to farmers groups	0			0			0			0			0		
1c. Barriers to adoption of solarization identified and resolved	0			0			0			0			0		
1c. Storage techniques evaluated for pest control and germination	X			0			X			X			0		
1c. Farmers trained in new solar techniques	0			0			X			X			0		
1c. Storage materials produced and distributed to farmers	0			0			X			X			0		
1c. Training in mananging bulking facilities completed	0			0			X			X			0		
1d. Exchange visits of other farmer groups conducted	0			0			0			0			0		
1d. Contacts establ. w/ districts to scale technologies & practices	0			0			X			X			0		
1d. Stakeholder workshop to review bean prod. training materials	X			0			X			X			0		
1d. Extension materials translated and published	0			0			X			X			0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Cold extruded bean products & process developed at KIST	0			0			0			0			0		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X			X	X		0			0			X		
2a. Extension approaches indentifed and content developed	X			X	X		0			X			X		
2a. Farmers trained in bean cold extrusion processing	0			0			0			0			X		
2a. Baseline nutritional status established for feeding studies	X			X		X	0			0			X		
2b. Analysis protocol for culinary properties obtained	0			0			0			0			0		
2b. Analysis of desirable culinary traits of current varities initiated	0			0			0			0			0		
2b. Culinary traits & sensory char. of current varieties documented	X			X	X		0			0			X		

2b. Analysis of culinary traits & sensory char. of improv. var. initiated	0			X	X		0			0			X		
2c. Tech. incubation & transfer models identified and modifed	0			X	X		0			0			0		
2c. Local & int'l industries as potential markets for beans identified	0			X	X		0			0			0		
2c. Private industry interest/conditions to adopt bean tech. evaluated	0			X	X		0			0			0		
2c. Links establ. btw. farmers' assoc. & private industries	0			X	X		X			X			0		
2c. Protocols for value-addition w/ private sector partners initiated	0			X	X		0			0			0		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
3a. Farmer groups' composition, roles, assets, capabilites identified	0			0			0			0			0		
3a. Farmer groups' needs determined and prioritized	X			0			0			X			0		
3b. Farmers trained in group/assoc. dynamics and gender equity	0			0			0			0			0		
3b. Partner meetings held in two sub-counties	0			0			0			0			0		
3b. Participatory market research groups formed	0			0			0			0			0		
3b. Market chain analysis for bean enterprises conducted	X			X	X		0			X			0		
3b. Market information sources assessed	X			X	X		0			X			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
4. Training M.S. (FST and AgEcon) at MAK on-going	0			0			0			0			0		
4. Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
4. Training M.S. students at Makerere University completed	0			X	X		0			0			X		
4. Training Ph.D. students at Iowa State University ongoing	X			0			0			0			0		
4. Inter-organizational learning fostered	X			X	X		X			X			X		
4. Prelim. results disseminated (conf., public., websites)	X			X	X		X			X			X		

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

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

[signature]
Signature

30th Sept 2011
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: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	***Improve Bean Yield and Quality***														
1a. Variety performance and fertility responses analyzed	0			0			0			0			0		
1a. Biological & agronomic controls for pests & diseases initiated	0			0			0			0			0		
1a. Variety perform., fertility respon., bio. & agron. controls analyzed	X			0			X	√		0			0		
1a. Best performing bean varieties reported to breeders	X			0			X	√		X			0		
1a. Seeds provided for post-harvest storage studies	0			0			X	√		X			0		
1b. Training in group dynamics & mgmt. practices for quality seed	0			0			0			0			0		
1b. Exchange visits to established seed production programs	0			0			0			0			0		
1b. Extension guide for bean CBSP initiated and tested	0			0			0			0			0		
1b. Linkages establ. for breeders, seed processors, marketers	0			0			X	√		X			0		
1b. Seed storage facilities established	0			0			X	√		X			0		
1c. Effects of solarization on germination and storage evaluated	0			0			0			0			0		
1c. Farmers trained in effective use of solarization technique	0			0			0			0			0		
1c. Polyethylene for solarization distributed to farmers groups	0			0			0			0			0		
1c. Barriers to adoption of solarization identified and resolved	0			0			0			0			0		
1c. Storage techniques evaluated for pest control and germination	X			0			X	√		X			0		
1c. Farmers trained in new solar techniques	0			0			X	√		X			0		
1c. Storage materials produced and distributed to farmers	0			0			X	√		X			0		
1c. Training in mananging bulking facilities completed	0			0			X	√		X			0		
1d. Exchange visits of other farmer groups conducted	0			0			0			0			0		
1d. Contacts establ. w/ districts to scale technologies & practices	0			0			X	√		X			0		
1d. Stakeholder workshop to review bean prod. training materials	X			0			X	√		X			0		
1d. Extension materials translated and published	0			0			X	√		X			0		
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
2a. Cold extruded bean products & process developed at KIST	0			0			0			0			0		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X			X			0			0			X		
2a. Extension approaches indentifed and content developed	X			X			0			X			X		
2a. Farmers trained in bean cold extrusion processing	0			0			0			0			X		
2a. Baseline nutritional status established for feeding studies	X			X			0			0			X		
2b. Analysis protocol for culinary properties obtained	0			0			0			0			0		
2b. Analysis of desirable culinary traits of current varities initiated	0			0			0			0			0		
2b. Culinary traits & sensory char. of current varieties documented	X			X			0			0			X		

2b. Analysis of culinary traits & sensory char. of improv. var. initiated	0			X			0			0			X		
2c. Tech. incubation & transfer models identified and modifed	0			X			0			0			0		
2c. Local & int'l industries as potential markets for beans identified	0			X			0			0			0		
2c. Private industry interest/conditions to adopt bean tech. evaluated	0			X			0			0			0		
2c. Links establ. btw. farmers' assoc. & private industries	0			X			X	√		X			0		
2c. Protocols for value-addition w/ private sector partners initiated	0			X			0			0			0		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
3a. Farmer groups' composition, roles, assets, capabilites identified	0			0			0			0			0		
3a. Farmer groups' needs determined and prioritized	X			0			0			X			0		
3b. Farmers trained in group/assoc. dynamics and gender equity	0			0			0			0			0		
3b. Partner meetings held in two sub-counties	0			0			0			0			0		
3b. Participatory market research groups formed	0			0			0			0			0		
3b. Market chain analysis for bean enterprises conducted	X			X			0			X			0		
3b. Market information sources assessed	X			X			0			X			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
4. Training M.S. (FST and AgEcon) at MAK on-going	0			0			0			0			0		
4. Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
4. Training M.S. students at Makerere University completed	0			X			0			0			X		
4. Training Ph.D. students at Iowa State University ongoing	X			0			0			0			0		
4. Inter-organizational learning fostered	X			X			X	√		X			X		
4. Prelim. results disseminated (conf., public., websites)	X			X			X	√		X			X		

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

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: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	*Improve Bean Yield and Quality*														
1a. Variety performance and fertility responses analyzed	0			0			0			0			0		
1a. Biological & agronomic controls for pests & diseases initiated	0			0			0			0			0		
1a. Variety perform., fertility respon., bio. & agron. controls analyzed	X			0			X			0			0		
1a. Best performing bean varieties reported to breeders	X			0			X			X	√		0		
1a. Seeds provided for post-harvest storage studies	0			0			X			X	√		0		
1b. Training in group dynamics & mgmt. practices for quality seed	0			0			0			0			0		
1b. Exchange visits to established seed production programs	0			0			0			0			0		
1b. Extension guide for bean CBSP initiated and tested	0			0			0			0			0		
1b. Linkages establ. for breeders, seed processors, marketers	0			0			X			X	√		0		
1b. Seed storage facilities established	0			0			X			X	√		0		
1c. Effects of solarization on germination and storage evaluated	0			0			0			0			0		
1c. Farmers trained in effective use of solarization technique	0			0			0			0			0		
1c. Polyethylene for solarization distributed to farmers groups	0			0			0			0			0		
1c. Barriers to adoption of solarization identified and resolved	0			0			0			0			0		
1c. Storage techniques evaluated for pest control and germination	X			0			X			X	√		0		
1c. Farmers trained in new solar techniques	0			0			X			X	√		0		
1c. Storage materials produced and distributed to farmers	0			0			X			X	√		0		
1c. Training in mananging bulking facilities completed	0			0			X			X	√		0		
1d. Exchange visits of other farmer groups conducted	0			0			0			0			0		
1d. Contacts establ. w/ districts to scale technologies & practices	0			0			X			X	√		0		
1d. Stakeholder workshop to review bean prod. training materials	X			0			X			X	√		0		
1d. Extension materials translated and published	0			0			X			X	√		0		
Objective 2	*Enhance the Nutritional Value and Appeal of Beans*														
2a. Cold extruded bean products & process developed at KIST	0			0			0			0			0		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X			X			0			0			X		
2a. Extension approaches indentifed and content developed	X			X			0			X	√		X		
2a. Farmers trained in bean cold extrusion processing	0			0			0			0			X		
2a. Baseline nutritional status established for feeding studies	X			X			0			0			X		
2b. Analysis protocol for culinary properties obtained	0			0			0			0			0		
2b. Analysis of desirable culinary traits of current varities initiated	0			0			0			0			0		
2b. Culinary traits & sensory char. of current varieties documented	X			X			0			0			X		

2b. Analysis of culinary traits & sensory char. of improv. var. initiated	0			X			0			0			X		
2c. Tech. incubation & transfer models identified and modifed	0			X			0			0			0		
2c. Local & int'l industries as potential markets for beans identified	0			X			0			0			0		
2c. Private industry interest/conditions to adopt bean tech. evaluated	0			X			0			0			0		
2c. Links establ. btw. farmers' assoc. & private industries	0			X			X			X	√		0		
2c. Protocols for value-addition w/ private sector partners initiated	0			X			0			0			0		
Objective 3	*Increase Marketing and Consumption of Beans and Bean Products*														
3a. Farmer groups' composition, roles, assets, capabilites identified	0			0			0			0			0		
3a. Farmer groups' needs determined and prioritized	X			0			0			X	√		0		
3b. Farmers trained in group/assoc. dynamics and gender equity	0			0			0			0			0		
3b. Partner meetings held in two sub-counties	0			0			0			0			0		
3b. Participatory market research groups formed	0			0			0			0			0		
3b. Market chain analysis for bean enterprises conducted	X			X			0			X	√		0		
3b. Market information sources assessed	X			X			0			X	√		0		
Objective 4	*Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.*														
4. Training M.S. (FST and AgEcon) at MAK on-going	0			0			0			0			0		
4. Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
4. Training M.S. students at Makerere University completed	0			X			0			0			X		
4. Training Ph.D. students at Iowa State University ongoing	X			0			0			0			0		
4. Inter-organizational learning fostered	X			X			X			X	√		X		
4. Prelim. results disseminated (conf., public., websites)	X			X			X			X	√		X		

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

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

	30/09/2011
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: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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	Abbreviated name of institutions														
	Iowa State			Makerere			NaCRRI			VEDCO			KIST		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1	***Improve Bean Yield and Quality***														
1a. Variety performance and fertility responses analyzed	0			0			0			0			0		
1a. Biological & agronomic controls for pests & diseases initiated	0			0			0			0			0		
1a. Variety perform., fertility respon., bio. & agron. controls analyzed	X			0			X			0			0		
1a. Best performing bean varieties reported to breeders	X			0			X			X			0		
1a. Seeds provided for post-harvest storage studies	0			0			X			X			0		
1b. Training in group dynamics & mgmt. practices for quality seed	0			0			0			0			0		
1b. Exchange visits to established seed production programs	0			0			0			0			0		
1b. Extension guide for bean CBSP initiated and tested	0			0			0			0			0		
1b. Linkages establ. for breeders, seed processors, marketers	0			0			X			X			0		
1b. Seed storage facilities established	0			0			X			X			0		
1c. Effects of solarization on germination and storage evaluated	0			0			0			0			0		
1c. Farmers trained in effective use of solarization technique	0			0			0			0			0		
1c. Polyethylene for solarization distributed to farmers groups	0			0			0			0			0		
1c. Barriers to adoption of solarization identified and resolved	0			0			0			0			0		
1c. Storage techniques evaluated for pest control and germination	X			0			X			X			0		
1c. Farmers trained in new solar techniques	0			0			X			X			0		
1c. Storage materials produced and distributed to farmers	0			0			X			X			0		
1c. Training in mananging bulking facilities completed	0			0			X			X			0		
1d. Exchange visits of other farmer groups conducted	0			0			0			0			0		
1d. Contacts establ. w/ districts to scale technologies & practices	0			0			X			X			0		
1d. Stakeholder workshop to review bean prod. training materials	X			0			X			X			0		
1d. Extension materials translated and published	0			0			X			X			0		
Objective 2	***Enhance the Nutritional Value and Appeal of Beans***														
2a. Cold extruded bean products & process developed at KIST	0			0			0			0			0		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X			X			0			0			X	X	
2a. Extension approaches indentifed and content developed	X			X			0			X			X	X	
2a. Farmers trained in bean cold extrusion processing	0			0			0			0			X	X	
2a. Baseline nutritional status established for feeding studies	X			X			0			0			X		X
2b. Analysis protocol for culinary properties obtained	0			0			0			0			0		
2b. Analysis of desirable culinary traits of current varities initiated	0			0			0			0			0		
2b. Culinary traits & sensory char. of current varieties documented	X			X			0			0			X	X	

2b. Analysis of culinary traits & sensory char. of improv. var. initiated	0			X			0			0			X	X	
2c. Tech. incubation & transfer models identified and modifed	0			X			0			0			0		
2c. Local & int'l industries as potential markets for beans identified	0			X			0			0			0		
2c. Private industry interest/conditions to adopt bean tech. evaluated	0			X			0			0			0		
2c. Links establ. btw. farmers' assoc. & private industries	0			X			X			X			0		
2c. Protocols for value-addition w/ private sector partners initiated	0			X			0			0			0		
Objective 3	***Increase Marketing and Consumption of Beans and Bean Products***														
3a. Farmer groups' composition, roles, assets, capabilites identified	0			0			0			0			0		
3a. Farmer groups' needs determined and prioritized	X			0			0			X			0		
3b. Farmers trained in group/assoc. dynamics and gender equity	0			0			0			0			0		
3b. Partner meetings held in two sub-counties	0			0			0			0			0		
3b. Participatory market research groups formed	0			0			0			0			0		
3b. Market chain analysis for bean enterprises conducted	X			X			0			X			0		
3b. Market information sources assessed	X			X			0			X			0		
Objective 4	***Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.***														
4. Training M.S. (FST and AgEcon) at MAK on-going	0			0			0			0			0		
4. Training M.S. student in FST from Rwanda on-going	0			0			0			0			0		
4. Training M.S. students at Makerere University completed	0			X			0			0			X	X	
4. Training Ph.D. students at Iowa State University ongoing	X			0			0			0			0		
4. Inter-organizational learning fostered	X			X			X			X			X	X	
4. Prelim. results disseminated (conf., public., websites)	X			X			X			X			X	X	
Name of the PI reporting on benchmarks by institution	**Robert Mazur**			**Dorothy Nakimbugwe**			**Michael Ugen**			**Henry Kizito Musoke**			**Hilda Vasanthakaalam**		

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

Hilda Vasanthakaalam
Signature

29/Sept/2011
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, 2010 - September 30, 2011)

FY 2011 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 Mazur, Iowa State University
Host Country(s): Uganda, Rwanda

Output Indicators	2011 Target	2011 Actual
	(Oct. 1, 2010 - Sept. 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	2	3
Number of men	3	3
Short-term Training: Number of individuals who received short-term training		
Number of women	75	105
Number of men	48	52
Technologies and Policies		
Number of technologies and management practices under research	5	5
Number of technologies and management practices under field testing	5	3
Number of technologies and management practices made available for transfer	5	9
Number of policy studies undertaken	0	0
Beneficiaries:		
Number of rural households benefiting directly	467	615
Number of agricultural firms/enterprises benefiting	3	3
Number of producer and/or community-based organizations receiving technical assistance	50	51
Number of women organizations receiving technical assistance	50	51
Number of HC partner organizations/institutions benefiting	4	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	115	138

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

Principal Investigator
James D. Kelly, Michigan State University, USA

Collaborating Scientists
Louis Butare, Rwanda Agriculture Board, Rwanda
Eduardo Peralta, INIAP, Ecuador
George Abawi, Cornell University, USA
Sieg Snapp, Michigan State University, USA

Abstract of Research Achievements and Impacts

The bean breeding program at MSU released a new vine cranberry bean variety Bellagio. The variety has improved plant structure, uniform maturity, resistance to anthracnose and bean common mosaic virus and excellent seed quality for canning. In statewide trials in 2011 it outperformed the commercial variety Chianti and the new variety should help recover cranberry bean acreage in the state. The breeding program continues to evaluate black, navy, red, pink, pinto, great northern and kidney lines for yield and 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 northern valleys. INIAP 483 Intag is a large-seeded red mottled type and INIAP 482 AfroAndino is a small black-seeded variety released for canning industry. The new red mottled variety Intag is the first to possess resistance to three important diseases (rust, anthracnose and angular leaf spot) and it is making impact into a broad area of the Intag Valley supported by the substantial outreach component of the program and the interest and need for new bean varieties in the region. The varieties were released through the process of evaluation and participatory selection with members of the CIALs in the provinces of Carchi, Imbabura and Intag. Ten tons of basic seed of five varieties was produced for distribution to growers in the region and the program continues to refine its non-conventional seed production in the Mira and Chota Valleys working with specialized seed growers. In Rwanda, the breeding expanded crossing program and successfully produced 10 ton of breeder and pre-basis seed of bush and climbing beans that was distributed to NGO partners and seed companies for additional seed multiplication and distribution in small quantities to small farmers. Four climbing bean varieties for high altitude zones are under consideration for release in Rwanda in 2012. The lines are white, red, and red mottled seeded types and have high yield potential (>3 t/ha) and the red line has over 90 ppm seed Fe. Two doctoral students conducted field research in Rwanda in 201; one was screening genetic populations for drought tolerance and the other was evaluating participatory cropping systems in grower fields comparing inter-planting of climbing bean varieties with and without maize. Bulletins, promotional materials and booklets were produced in both countries to disseminate information on new bean varieties and bean production systems.

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.

Progress on Project Activities for the Report Period by Objectives

<u>Objective 1</u>: 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.

<u>Approaches and Methods</u>

1. Continue to select parental breeding materials for crossing in Ecuador, Rwanda and U.S.
2. Expand group of lines from Rwandan breeding for crossing with new introduced differential lines from Ecuador, MSU, UPR and CIAT/PABRA-interchange.
3. Cross Rwandan sources of resistance for bean common mosaic virus (BCMV), angular leaf spot (ALS), rust, anthracnose, Fusarium wilt and Pythium and major foliar pathogens into large seeded lines with contrasting colors.
4. Confirm resistance of selected parental lines to target root pathogen(s) including Macrophomina in screenhouse/greenhouse tests, as 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 (Rubona) in Rwanda.
7. Initiate selection for diseases resistance under screenhouse inoculation condition at Rubona.
8. Yield evaluation of advanced lines in range of seed types in Ecuador, Rwanda and U.S. and continue to exchange most promising materials among the three breeding programs.
9. Initiate characterization of biofortified lines for Fe and Zn for use as parents in Ecuador and in Rwanda.

10. Evaluate lines and varieties for canning industry in both the field and lab in Ecuador.
11. Continue seed increase of most promising lines in all three countries.
12. Expand on farm trials with advanced lines in Rwanda and Ecuador.
13. Release elite climbing and bush beans bean varieties in different 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

- Foundation seed increases of the new vine cranberry bean variety Bellagio, released by the MSU breeding program, were produced in the western US in 2011. Bellagio is full-season variety with resistance to anthracnose and mosaic virus. The plant type is less decumbent than the current vine varieties, and its produces a large (55g) round seed with excellent canning quality. The seed type would have commercial appeal in both Ecuador and Rwanda. A group of anthracnose resistant cranberry breeding lines from MSU was sent to Rwanda and Angola for testing in 2011.
- A total of 5600 plots were harvested for yield and over 2600 single plant selections were made in the early generation nurseries as part of the MSU breeding program activities in 2011. Three new lines in three different market classes (pink, pinto, white kidney) are under consideration for release in 2012; based on continued high performance of upright full-season pinto line P07863 with white mold avoidance, early-season white kidney K08961; and an upright pink line S08418 with good seed color. Sources of common blight resistance were identified in advanced kidney and cranberry bean lines.
- Research continues to develop a stable transformation system for common bean. Progress has been slow and the research is no longer being handled as a student project and has been fully assigned to the Plant Transformation Center as a research objective.
- The bean breeding program in the Rwanda Agriculture Board (RAB, formerly ISAR) increased the number of crosses in 2011. More than 200 single and backcross crosses were made during this reporting period to incorporate multiple resistances to anthracnose, angular leaf spot, bean common mosaic virus and/or micro-nutrients, Fe and Zn. The populations were created using some of the differential cultivars as sources of resistance against bean rust, angular leaf spot (MEX 54), anthracnose (G2333) and BCMNV (USCR-7, USCR-9).
- In other cross combinations, 10 crosses with novel and unadapted Fe sources that were acquired through CIAT were developed. 150 F1/BC1 simple, double and 3-way crosses were initiated. An evaluation of new high iron bean populations introduced from CIAT headquarters last year and further screening of rich micronutrients (Fe and Zn) advanced lines were undertaken at Rubona, Rwerere, and Karama stations.
- Different lines have been evaluated as high iron content at different sites both on RAB research stations and farmer fields. These trials were set in two groups. The first group include preliminary yield trials (PYT) with an evaluation of 104 biofortified bush bean lines introduced from CIAT at Rubona station; an evaluation of 182 biofortified climbing beans introduced also from CIAT (under observation nursery) both in Rubona and Rwerere station; the second group that include an evaluation of 13 advanced high iron content bush bean types. 28 high Fe content and drought resistant varieties were evaluated in a preliminary yield trial (PYT) at Rubona station. Among these lines 14 lines were selected in the advanced yield trial (Phase I) in this cropping season (2012A) at three sites.
- The phenotypic evaluation of 125 RIL population from the cross of SEA5 x CAL96 was

conducted by Gerardine Mukeshimana in Rwanda for two growing seasons (Nov., 2010 to March 2011 and April to July, 2011). The experiments were located in dry-land research stations at Karama and Nyagatare. Both irrigated versus non- irrigated treatments were applied at both locations. Experiments in Nyagatare were lost due to necrotic strains of BCMNV and root rot diseases. Geometric yields ranged from 428 to 2342 kg/ha and phenological and harvest index data were also collected for use in QTL analysis.

- The same RIL population is being genotyped at MSU with Simple Sequence repeat (SSR) markers with the goal of mapping QTL associated with drought resistance in beans. Parents were screened with 460 SSR markers of which 148 were polymorphic representing a polymorphism level of 32 % between the parents. The genotyping of the entire mapping population is being conducted. The population has already been evaluated with74 polymorphic primers.
- Thirty-five bush bean lines for canning were introduced from CIAT Kawanda (Uganda) and evaluated at Rubona for adaptability and further seed increase. These lines are under test this season at two new sites, Mutara and Bugesera. Confirmation of their canning quality will be done later when sufficient quantity of seeds needed for the test will be available. We are waiting to receive the working collection of traditional canning (navy beans) from Ethiopia to be evaluated in Rwanda.
- The characteristics of the four new varieties (RWV3316, RWV3006, RWV2872, and RWV236) planned for released in Rwanda in 2012 are shown on table 1. They are well adapted to highland of Rwanda, their yield potential is high (>3.4 tons per ha) and they meet farmer preferences in terms of seed size and color. Results from two different labs showed that some of the advanced lines and will be released in 2012 B season as high iron content lines. The best line based on the iron contain was RWV3316. This variety was generated from a cross (CAB2 x LAS400) of CAB2 (white seeded) and LAS400 (a large seeded red bean variety). The micronutrient concentrations of RWV3316 are 93.0 ppm for iron and 31 ppm for zinc.
- Increasing seed of bush and climbing beans identified as micronutrient (Fe and Zn) rich lines among the ISAR improved varieties was planned to facilitate the dissemination of these new bean varieties. The lines involved in this seed increase were RWV3316, RWV3006, RWV2872, RWV2361, RWV1129, MAC44, and RWR2245. The target for seed micronutrients is over 70 ppm for iron, and over 30 ppm zinc.
- The program identified three bean varieties (MAC44, SER 16, and SER30) with moderate levels of drought resistance from among the 15 recently released lines (Listed in table 1. in 2010 annual report). About 150 kg of breeder seed have been produced for each variety this cropping season in Nyagatare. At the three research stations (Nyagatare, Karama and Ngoma) the program produced about 1,000 kg of foundation seed for each variety to be distributed to farmer associations involved in seed multiplication.
- On May 31, 2011 the National Grain Legume (PRONALEG-GA) team in INIAP, Ecuador launched the first bush black bean variety Afroandino – INIAP 482 in Tumbatú (Carchi) Chota Valley. Afroandino is a small seeded black bean that originates as the CIAT line A55 (INT272 x INT244). 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.

- The new large seeded red-mottled variety INIAP 483 INTAG with resistance to three foliar diseases was released by INIAP in 2011. Intag was derived from the backcross (Concepción */ G916) made in 2003 at the Experimental Farm Tumbaco. In the F2 generation selection was made from eight individual plants and the best three progenies were selected in the F3. In 2005, the three F4 lines were evaluated and the line Concepción */ G916 -1 was selected as the most promising. In 2006, the F5 line was evaluated in adaptation and performance tests, and was selected for long pods and large red-mottled seed. In 2008 and 2010 the line was evaluated for resistance to angular leaf spot and rust in the valley of Intag, Tumbaco and Concepción. The line was resistant to the two pathogens in all locations, while the control variety Concepción was susceptible to angular leaf spot and intermediate resistance to rust. In addition the Concepción */ G916 -1 line produced an average yield of 1.6t / ha greater than the control with 1.0t / ha. In 2007 and 2008 the same line was selected by the participatory Local Agricultural Research Committee (CIAL) in Intag (Imbabura). During 2009 and 2010, seed of this line was increased by the same CIAL and on September 9, 2011 in a field day "Tollo Intag" the variety was officially handed over bush bean producers in the area of Intag as the improved variety of bush bean variety INIAP 483 named Intag. Two leaflets describing the new varieties available for distribution and the pdf file can be viewed @http:// www.iniap.gob.ec
- The breeding program in Ecuador continues to combine resistance to rust, anthracnose, angular leaf (ALS) and Fusarium wilt in all new breeding materials, using double and triple crosses combined with cyclic selection in a range of selection environments, both on station and in growers' fields. Crosses were made using varieties and promising lines of commercial seed and parents of Mesoamerican origin for resistance to rust, anthracnose and ALS. At harvest, individual F2 plants were selected and 66 F3 progenies derived from crosses for resistance to *Fusarium oxysporum*, (derived from resistance sources CMR 27, CMR 20 and TP6), were combined with susceptible varieties Portilla, Concepción, and Paragachi Andino. At harvest, 23 progenies were selected that exceeded the controls in plant vigor, resistance to rust, pod load and performance. In the next cycle, the 23 progenies were re evaluated and eight lines were selected for resistance to rust, *Fusarium oxysporum* and *Empoasca*, good vigor of growth, overall yield and grain quality. In addition to selecting bush types, selections with type II growth habit in red mottled seed color were identified with high levels of resistance to rust and anthracnose and to Empoasca, good pod load, seed quality and yield.
- Seed increases were initiated on the following promising red seeded bush bean lines: BRB 195, ICA QUIMBAYA, INIAP 402, DRK BRB 194 and 105; black seeded Condor, and AFROANDINO; red mottled line; S143 (Yunguilla x POA 10) -3; and four top promising lines with multiple disease resistance (AMPR3XCAL143) 1F2-1F4 (AMPR3XCAL143) 1F2-3PF4, (AMPR5XCAL143) 4F2-1F4 and (AMPR5XG916) 2F2-7PF4. Seed of all new and old varieties: Intag, Portilla, Paragachi Andino, Chota, Rocha, Rojo del Valle, Guarandeño and Conception continues to be multiplied for distribution to the CIALs.
- In the Department of Nutrition and Quality at INIAP twelve bush bean genotypes were assessed for the canning process by applying heat treatment and evaluation based on physical parameters, nutritional and sensory properties. Based on analysis of crude seed, Condor had the lowest hardness (3.6 mm) and the highest protein content (30.0%); NSL had the highest starch content (74.5%); G21212 the highest content of anthocyanins (534 mg /100g beans)

and the higher iron content (89.2 ppm); BRB 195 the lowest tannin content (139 mg/100 g beans); and ICA Quimbaya had the highest zinc content (46.9 ppm). Soaking in the trial determined that the rate of hydration was related to seed size. The very small size took 2 to 3 hours to reach the proper moisture ratio (1.8) to start the thermal seed processing. Small seeds required between 3 to 5 hours, the medium from 5 to 7 hours and large-seeded genotypes reached optimal hydration ratio of 6 to 8 hours. At the end of soak period, the seed reached between 49 to 55% humidity. The thermally processed grain was characterized for physical, chemical and sensory properties. Canning brine with $CaCl_2$ produced the best seed size characteristics, greater hardness, better color characteristics, lower viscosity and solids suspended in the liquid of lesser degrees of failure and degree of agglomeration of the seed, lower drained weight, higher protein content, starch, anthocyanins, tannins, iron and zinc, lower moisture content. Brine without Ca exhibited opposite characteristics. Acceptability analysis revealed that genotype BRB 194 showed the highest preference among the panelists. This material also had the highest total weighted score required for canning. An economic analysis of pilot plant level, determined that the unit cost of producing each unit of processed product is equal to $ 1.03. The calculated return on equity was 17.8% and 10.7% of total investment.

- Flour quality of six bean genotypes was assessed in three stages: first, the milling quality was assessed using three pre-treatments (toasted, seed conditioning and seed coat removal) in order to determine the best yielding bean flour; the functional and rehydration properties of the flours with higher extraction rate were assessed; and quality parameters of various formulations with different levels of substitution in flour-based bean biscuits. The pre-treatment with the higher flour yield (67 - 75%) came from the preparation, in which the bean seeds were soaked at 50 ° C for a period of two hours, steam cooked for 5 minutes, dried at 60 ° C to 14% moisture and subjected to milling. Flour was selected from Portilla after analyzing the functional and hydration properties of flour. The flour contains 25.7% protein, 10.6% amylose and 89.3 % amylopectin with high falling number greater than 400 seconds. Bean flour mixtures with different levels (5, 10, 15, 25 and 50%) of substitution with cereals were tested to produce biscuits. All formulations showed a pseudoplastic behavior so the sensory analysis of biscuits was made from mixtures with higher content of bean flour. Levels of 25 and 50% did not significantly alter the color and aroma of the biscuit, while substitutions above 25% produced noticeable changes in flavor and texture.

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. Evaluate specific populations developed at CIAT and MSU/Ecuador at two sites for reaction to drought and non-stress in Rwanda.
2. Continue with the selection of lines with tolerance to drought and root rots in Ecuador
3. Evaluate sub-set of best drought tolerant lines from thesis study of Louis Butare at two locations in Rwanda; and from other sources.
4. Continue characterization of new local traditional lines (bush, climbers) collected from growers in Ecuador to determine level of drought tolerance and root rot in Tumbaco.
5. Complete survey to identify field sites 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.

6. Field trials and greenhouse screening will be conducted to identify root rot resistance sources in Ecuador and Rwanda.
7. Characterize germplasm for reaction to individual root pathogens at Cornell using selected promising germplasm for Rwanda, Ecuador, MSU and TARS (UPR).

Results, Achievements and Outputs of Research

- 100 Recombinant Inbred Lines (RILs) from an interspecific cross of common and runner bean for drought and aluminum toxicity resistance were introduced in Rwanda in 2010. The material originated as part of Louis Butare's doctoral research at CIAT headquarters. The RILs were evaluated several times at Rubona and Nyamagabe research stations, and selected lines have now been evaluated in PYTs.
- From 15 lines (Mesoamerican bean genotypes, small red) in another trial evaluated in 2011B cropping season at Karama station, siz varieties (SER51, SER101, NCB275, SAB659, SER83, and SER111) were selected and submitted to further evaluation using on farm Participatory Variety Selection (PVS) approach in multi-location trials. Phenotypic description of these six lines will be undertaken and their potential yields on farmer field conditions will be determined.
- Greenhouse experiments at MSU conducted by Gerardine Mukeshimana to identify bean lines with higher levels of drought tolerance in the shoot were concluded in 2011. The test used small pots to restrict root growth in order to identify those genotypes with tolerance in the shoot. 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.
- The mapping population (CONCEPCIÓN * 2/RAB651) was sent to Rwanda for an initial seed increase. The population will be evaluated under moisture stress in Rwanda in 2012 to identify QTL for drought tolerance. Problems with BCMNV are not expected to compromise this study of this population in the field in Rwanda as the dominant I gene may be protected in this cross. In the interim, genotyping of the parental lines with SSR markers continues.
- Field evaluation of bean breeding lines and germplasm for root rot resistance in New York: A replicated field trial consisting of 34 advanced materials provided primarily by Drs. J. Kelly and T. Porch were established in the bean root rot nursery at the Vegetable Research Farm, NYSAES, Cornell University near Geneva, NY. Twenty of the materials included in the 2011 evaluation were included for the first time, whereas the others were advanced from the previous evaluations. These bean lines differed significantly in their reaction to root rot pathogens when determined at the full flowering stage. For example, the average root rot severity ratings of CLR Kidney, TARS-RR-2011-5, TARS-RR-2011-2, B04554 (Zorro), and P07863 (pinto being considered for release) were 6.0, 3.4, 3.6, 3.4, and 3.4, respectively on a scale of 1 (no disease symptoms, healthy) to 9 (>75% of root and stem tissues affected and at later stages of decay). These results were similar to those obtained from the 2010 field trial

(BIC 54: 142 – 143). The tested lines also exhibited significant differences in their reactions to common bacterial blight and vigor. Seed yield of a number of the promising lines is currently been completed and summarized.

- Cover crops for managing root diseases of beans and other agronomic crops: An on-going collaborative project is assessing the efficacy of selected cover crops (rye grain + hairy vetch, oat, sudex, forage radish, red clover, rapeseed, buckwheat, wheat, and a fallow check) in suppressing root pathogens, including *Fusarium*, *Pythium*, *Rhizoctonia*, *Thielaviopsis*, *Pratylenchus* and *Meloidogyne*) and improving yield as well as soil health and quality. The replicated cover crop treatments are arranged in large strips (4.5 x 60 m) and replicated 3 times per evaluation field. Four fields with different previous management histories and root disease pressure were been used in this investigation. Bean cv. Caprice was machine planted in all the cover crop plots in early June 2011. In general root rot severity was lowest and yield of bean was highest in the field with the highest soil quality and lowest disease pressure. In this field, bean yield was highest in the rye+vetch cover crop and lowest in the buckwheat cover crop plots. All the cover crop treatments were re-established in Sep. 2011 for another cycle of evaluations in 2012.
- Long-term tillage, rotation, and cover crop trail (soil health site): this collaborative site of the Cornell soil health team was planted to beans in 2011. The trial consists of about 14 acres divided into a total of 72 plots (18 treatments replicated 4 times). The treatments are represented by three tillage systems (no-till/ridge-till, zone-till, and plow/conventional-till), three cover crops (no cover, rye grain, and vetch), and two rotations. One rotation includes primarily high value vegetable crops (R-1), whereas the second rotation also includes season long soil building crops (R-2). The no-till system is converted to a ridge system whenever the plots are planted to direct seeded vegetable crop in R-1. The 2011 season was characterized by a very wet spring that delayed planting, a very dry mid-season (June-July) and then a very wet late season/fall. Interestingly, we were able to machine harvest beans in the zone-till and no-till plots without much difficulty, but not the plow-till plots? We had to hand-harvest a number of the beans in the plow-till plots, as the harvester was getting stuck and extremely rutting and compacting the soil. The latter clearly indicated the benefit of the reduced tillage systems under such wet weather conditions. The data is still been analyzed, but the yield of beans was highest in the ridge-till system, in rotation R-2, and after vetch. The trial is continuing and data will be collected on root health, soil health indicators, and other parameters.
- Evaluation of selected pea varieties for resistance to root pathogens: Root rot diseases of peas are prevalent and damaging to peas. In recent years, disease symptoms commonly observed on roots of infected plants in New York were those of Fusarium-root rot and less frequently symptoms of Fusarium-wilt. However, symptoms of infections caused by *Thielaviopsis, Pythium* and *Aschochyta* were also observed at times. Recently, large number of varieties and promising lines were evaluated in commercial fields with known histories of severe disease incidence and also in greenhouse tests using naturally infested soil. In 2011, a total of 47 varieties and lines were again evaluated in the greenhouse. Root rot severity ratings varied greatly among the peas tested, ranging from 8.8 to 3.3 on the 1 (healthy) to 9 (most severe, dead) evaluation scale. June, Marias, BSC 3048 generally exhibit the most susceptible reaction, whereas Boogie, Pendleton, and Lil'mo were among the most tolerant.
- Thirteen RILs previously selected under normal irrigation were evaluated for pod load growth and reaction to rust, Empoasca and seed quality. The same selected RILs plus two

checks were evaluated under two treatments with and without drought stress. The trial under drought stress was watering every 15 days and no stress test was normal watering every eight days. Vigor data were taken and pod load at harvest number of pods per plant, number of grains per pod and dry grain yield. Under drought stress, obtained yields 10 lines between 1.7 and 2.0 t / ha while the Portilla and Concepción checks yielded 1.6t / ha. Under normal watering every week there was no difference in performance between the lines and the control.

- Twenty-eight black bean lines were subjected to terminal drought (drought stress from pod-filling). Pod load data were collected, plant health and seed yield. Under these parameters 10 lines were selected for high performance and plant health, superior to the control Afroandino. All 10 lines were superior in performance to the check Afroandino. They were also resistant to *F. oxysporum* and drought tolerant. Five lines were selected based on superior performance, rust resistance and vigor.

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

<u>Approaches and Methods</u>

1. Continue surveys to diagnose major root diseases in Rwanda and collect isolates of root pathogens for additional characterization.
2. Maintain the collection of root rot isolates previously collected in different production zones of Ecuador.
3. Further characterization of root rot isolates collected previously in both Northern and Southern production regions of Ecuador at Cornell and/or Ecuador.
4. Phenotypic evaluation of Rwandan germplasm for resistance to local isolates of anthracnose, ALS and BCMV under field conditions, screenhouse and MAS.
5. Continue the collection of isolates of anthracnose, and ALS in Rwanda and Ecuador from diverse agro-ecological zones for race typing.
6. Increase seed of the differentials for anthracnose, ALS and rust in Rwanda; and continue characterization of ALS in Ecuador. Continue 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, 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 2011. 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. New navy and black bean lines with resistance to anthracnose are currently being evaluated in yield trials.

- 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. A new rust strain was recently reported in the high Great Plains region of Colorado and Nebraska, but no information on race type is currently available.
- 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. To date races 27 and 55 have been confirmed and race 3 is a tentative observation.
- Four new races of anthracnose (256, 300, 384, and 387) collected in the localities of Urcuquí, Mira and Pimampiro were characterized and the *Co-4*^{2} and *Co-5* genes offer good levels of resistance to these races. A single race of angular leaf spot 62:0 was collected at three locations in Urcuquí, and Intag. This a highly virulent race on Andean beans, but it can be controlled with Mesoamerican germplasm.
- Fusarium wilt is becoming increasingly serious disease in many bean production areas of Ecuador. In addition some of the most recently released varieties such as Portillo 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. The program continues to make good progress in selection for resistance to Fusarium wilt. The program has identified a hot screening site at Tumbaco where high levels of soil borne pathogen exist and allows for early generation screening to detect resistance.
- 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.
- Since rust and ALS are highly variable pathogens, testing must be conducted at different locations in Ecuador to confirm resistance and identify new sources of resistance. Testing of 31 sources of resistance to ALS and rust using natural inoculation was conducted in the town of Peñaherrera (1800 m) in the Intag valley (new production area). The nursery was made up of Andean lines and varieties generated by the breeding program and CIAT. Eleven lines generated by the breeding program and 15 from CIAT were highly resistant to ALS, and 18 lines were resistant to rust with reactions from 1 to 3 on a scale of 1 to 9=S.
- The inheritance of resistance to rust in the JeMa cultivar was evaluated in a population of 165 F2 seeds derived from cross with AND277 (susceptible to rust) inoculated with rust race 0:61. The results suggest the presence of a single gene based on 130 resistant and 35

susceptible individuals. In order to confirm the 3:1 segregation ratio, F3 families will be evaluated and additional crosses with JeMa/ Red Small Garden(S) will be tested.

- Six promising lines were selected with combined resistance to rust, anthracnose and angular leaf spot in Ecuador. Angular leaf spot was evaluated in the field (La Concepcion, Carchi) and confirmed in greenhouse tests along with reaction to specific races of anthracnose; and rust was evaluated in the field at Tumbaco. The selected lines showed high genetic resistance to all the three diseases in comparison with the check Portilla which was susceptible to angular leaf spot and had an intermediate resistance to rust.
- Another objective of the visit to Rwanda in May, 2011 was to expand the survey to access the major soilborne pathogens and other pests impacting bean production in Rwanda in collaboration with the members of the national bean team. Again, the bean fly and BCMV were observed predominately during this trip, suggesting the need to devote more efforts for their management. Root diseases observed in the various research sites and growers fields visited were primarily Fusarium-cortical rot, Pythium-root rot, root-galling by the root-knot nematode, and a low incidence of Scleotium-rot. In-country evaluations of bean germplasm against these pathogens and those observed previously (Macrophomina and Rhizoctonia) were suggested.

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. 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, initiate trials in 2011 and terminate in 2012.
   - On-farm assessment of promising lines conducted in sole crop and intercrop on-farm trials at 8 sites in 2011/12.
2. Evaluation of 17 tests with 17 CIALs each growing cycle in Ecuador.
3. Expand non-conventional and conventional seed production in Ecuador and Rwanda.
4. Release two bush beans and one climbing bean in Ecuador using farmer participatory approach.
5. Continue to provide seed of elite and new varieties for post harvest quality evaluation at KIST.
6. Continue with farmer participatory approaches to identify appropriate and cost-effective innovations for staking climbing beans that would enhance the adoption in Rwanda.
7. Organize a visit of scientist(s) from Ecuador to Rwanda 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. (Depending on additional funding from CRSP).
8. Initiate interchange of experience in Rwanda on participatory methods and seed production for local community use with smallholder farmer members anticipated date Feb 2012. Training of trainers (extension, research technicians, NGO staff, expert farmers, seed company technicians) on seed and farming system production, and work with progressive farmers.

9. Draft a manuscript by August 2012 for review at Rwanda workshop and circulate for comment and input by collaborators. Based on initial on-farm assessment in Rwanda and literature review outlining strengths and challenges associated with sole crop vs. intercrop bean based cropping systems, in terms of plant breeding approaches and addressing farm family nutrition.

Results, Achievements and Outputs of Research

- Experimental research on cropping systems and bean varieties were conducted in northern Rwanda using a mother-baby-grandbaby trial system. In season 2011B (Feb-July) two on-station genotype by cropping system x environment "mother" trials were planted in northern Rwanda at ISAR Station Musanze and ISAR Station Rwerere with the objective of determining how genotypes perform differently under different cropping systems across different environments. Each on-station trial had four replications. Eight more single replications, or "baby" trials were planted on farmer fields with farmer associations in the sectors of Gakenke, Burera, and Muko for a total of 24 replications. One replication consisted of 14 plots. Bean genotypes RWV 3006, RWV 2070, RWV 3316, Gasirida, and double controls of Ngwinurare and a local mixture were each planted as sole beans and intercropped with PL9A maize variety. A plot of sole maize and a plot combining the local mixture and maize in a traditional mixture were also included. Data on yield, agronomic traits, leaf area index, canopy cover, and soil samples were collected at each site and plant biomass for total N analysis was collected from the research station trials.
- On-farm trials had the additional objective of understanding farmers' preferences for cropping systems and bean varieties in a given system. At each farmer field site participatory variety selection was used near the end of season B to evaluate cropping systems and bean varieties under monocropping and intercropping. Approximately 105 farmers (71 women, 34 men) participated.
- In season 2012A (Sep 2011-Feb-2012) the same trials were replicated on-station and on-farm. Data collection is ongoing. Farmer discussions and evaluations from the first season indicated farmers were not satisfied with the design of the intercropping system. As a result we initiated the "grandbaby" phase of the trials with the objective of encouraging farmers to experiment and identify satisfactory cropping system designs. After discussions on experimentation with six associations, farmers chose two bean varieties from our baby trial to plant in an intercrop and a monocrop. They also planted a monocrop with the local mixture. Approximately 70 farmers participated. Design and yield data will be collected with farmers from each grandbaby site and participatory evaluation of the trials will be carried out at the end of the season.
- Survey and short structured interviews are being carried out in Season 2012A to collect data on the grandbaby trials, farmer preferences for cropping systems and bean varieties, socioeconomic status, and the effect of land use policies on farmers' ability to experiment.
- A participatory workshop will be carried out at the end of season A with practioners in plant breeding and agronomy. Participants will gain an understanding of theory, and new methodologies in participatory breeding and agronomy for improved bean-based farming systems. Focus areas will include: Trial designs, focus groups and practical tools that take into account livelihoods and sustainable production, including conservation and nutrition aspects of client–oriented research.
- About 44 lines combining drought and heat tolerance resistance with high mineral density

and high yield potential were subjected to participatory variety selection (PVS) in Rwanda. These lines were evaluated in two separate Genotype x Environment (GxE) trials. Twenty-one biofortified bush bean lines introduced from CIAT Kawanda evaluated for the first time in Rubona (season 2011A) on two more sites including the Districts of Muhanga and Ngoma. Another GXE evaluation was conducted with 23 climbing bean lines at Rubona, Muhanga, Rwerere, and Karama. For all these Genotype x Environment interaction evaluations, farmers were invited to participate using their criteria of preference in this selection process.

- Two field screening trials under drought stress were conducted to evaluate advanced bean varieties for yield potential through participatory plant breeding process at Karama research station. The total number of lines tested was 29, and from this set six lines were selected to be tested under multi-location trials on stations and on farm (Karama, Nyagatare, and Ngoma).
- To enhance the availability of seed and adoption of new improved varieties by farmers in Nyagatare, Gatsibo and Kabarore Districts in Umutara (Eastern Province), more than six tons of new bush bean varieties (RWR 1668, RWR 2245, RWR 1180, RWK 10) that are adapted to the region for their early maturity, desirable seed types and high yields (2.0 – 2.5 ton ha^{-1}) were multiplied. They were distributed to farmers in the districts directly by RAB or through RAB NGO partners based in the region, such as ADRA or through farmers' cooperatives. By using the small packaging of seed and loan distribution strategies, an estimated 6,000 farmers benefited from this seed multiplication and distribution exercise. Further seed quantities were used for secondary multiplication by the partners for eventual distribution to more producers.
- In all RAB stations, about 10 tons of breeder and pre-basic seed of the pre-released and released bush and climbing beans mentioned above were produced on research stations. Seed was sold and distributed to farmers and farmers cooperatives; NGOs such as ADRA and Seed companies: Win-Win and RWASCO, Urugaga-IMBARAGA, DRD, DERN, AFRICARE, CARITAS, COAMV, UNR (Facagro), TUBURA (Local Ngos) and PADAB partners for secondary seed multiplication and distribution to more producers.
- Evaluation and participatory selection of bush bean germplasm with local CIALs continued in Ecuador. In the town of La Concepción, eight lines with resistance to three diseases (rust, anthracnose and angular leaf spot) plus four checks (two resistant and two susceptible) were evaluated by members of the CIAL for plant and seed traits. Farmers selected four lines for planting in various fields in the next cycle. In the next cycle, CIAL members selected lines (X AMPR3 CAL143) - 1F2 - 1F4 (X AMPR3 CAL143) - 1F2 - 3PF4 and (X AMPR5 CAL143) - 4F2 - 1F4 and it is expected that the best single line for variety release will be identified in the next cycle.
- In the two growing cycles 10 t of basic seed of five varieties was produced. Six seed-producing CIALs in the Mira and Chota Valleys, multiplied seed of four bush bean varieties: Portilla (4500kg), Conception (450kg) AfroAndino (2835 kg) and Paragachi Andino (495kg); and the CIAL in the Intag Valley produced seed of the new Intag (1530 kg) variety.
- In Huigra (1300 m), Chimborazo, 10 bush bean varieties were planted at the request of the Grower Association Lucmas. Participatory assessments were performed on the plants, and most of the varieties were superior to the local controls. This was the first time that local farmers were introduced to INIAP varieties and researchers.
- In Cañar, five quintals each of Portilla and Rocha varieties were planted and evaluated at pod filling. Varieties showed good adaptability and farmers were content for the reintroduction of beans after 16 years since the crop disappeared from this region. Seed of bush varieties was

planted, multiplied and distributed to farmers in the province of Loja in the south (Zapotillo Farm).

- The important health benefits of beans were promoted during the preparation of the world's largest stew in San Miguel de Porotos (Cañar) following a 10 K road race where the prize was the bean stew. Seed of bush beans was sent to low-lying areas and next year a bean fair is planned to exhibit agricultural biodiversity and help with the recovery of climbing bean material that was lost due to drought and habit of consuming in these regions

Objective 5: Training

Degree Training

First and Other Given Names: Doctoral 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 was conducted in Rwanda. (Research progress reported herein). She successfully completed her comprehensive examination and conduct field trials in Rwanda in two seasons 2010-2011. She was successful in securing a Borlaug LEAP fellowship which will provide her support to travel and conduct additional research work at CIAT and in Rwanda in 2011-2012. Expected conclusion date – Sept 2012.
- 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 successfully concluded her comprehensive examination and travelled to Rwanda in Jan 2011 to initiate field work – partial support from Fulbright fellowship. (Research progress reported herein). She plans on concluding two field seasons in March 2012 and will graduate later in 2012.

Non-degree Training – Extension Activities

- A booklet with promotional materials has been developed and 5,000 copies printed and distributed to Rwandan farmers and other related producers. The booklet promotes the bean production chain.
- Training on seed multiplication (for 28 participants including researchers and technicians from RAB research and extension programs) have been conducted in order to build their capacity in seed multiplication, increase the qualities of seed produced, and build a common understanding of some guidelines in the domain. Those technicians are supposed to train farmers and other technicians from collaborators institutions and Community based organization (CBOs).
- A bean stakeholder meeting was organized in Rwanda as a starting point in the establishment of an innovation platform for bean producers and traders. Participants from different organizations attended the meeting including privates sectors working in seed production and commercialization (RWASECO and Win-Win), International and local NGOs (Africare, DERN, DRD, CSC). Farmer associations and individual farmers were also represented. Key speakers for this workshop were CIAT scientists including Claude RUBYOGO, Eliud BIRASHI, David WETAKA Wozemba; and Senior scientists from RAB, Grace Akao (Seed specialist), and Enock (AGRA seed specialist). Discussions were focused on the following themes: Updates on bean breeding in Rwanda, seed system, role of ISAR seed program in promoting improved seed uptake and linkages with stakeholders in the seed industry; updates

on Rwanda and regional markets; small packs in dissemination of improved bean varieties; and update on Agriculture Extension and policies in Rwanda by Raphaël Rurangwa (MINAGRI, Planning Director General). Three working groups were formed to elaborate recommendations: Group1: Roles and responsibilities in technology development and dissemination; Group 2: Accessibility of information on improved bean production and commercialization technologies to potential users; and Group 3: Seed increase of improved varieties and wide dissemination.

- The Southern Agriculture Zone Division of RAB recently received from Harvest-Plus project a XRF machine that assists in bean seed analysis for micronutrient concentration. Technicians from Rwanda and DRC were trained in its use and they will contribute in future in mineral analysis of beans for both Harvest-Plus, Bio-Innovate, and CRSP projects.
- Trip to Rwanda during May 9-23, 2011: Drs. J. Kelly and G. Abawi travelled to Rwanda to meet with collaborators at ISAR, review research activities, visit field research sites around the country and presented a 3-day workshop on bean pathology (major root and foliar diseases) and breeding – genetics of beans to the ISAR technical staff. A complete list of 23 participants and topics discussed was provided in an earlier trip report. Visual aids and powerpoint information was distributed to the participants.
- Dr. Snapp joined the trip in mid-May and we visited the research plots of Krista Isaacs and hosted the ISU CRSP team during their stay in Rwanda. In addition, we attended HarvestPlus field day activities at Muko near Musanze.
- Sara Jablonski, a MS student at MSU travelled to Ecuador for 6-week period in 2011 to conduct thesis research on "The nature of participation in Ecuador's participatory bean improvement program." The three main questions she attempted to address in interviews with CIAL members were: How do farmers and scientists participate in the selection and production of new bean varieties? What is the relationship between the CIALs engaged in varietal selection and their respective communities? What have been the results of this participation for target communities in northern Ecuador? Ms. Jablonski will graduate in 2012 and present her findings in her Master's thesis.
- Research on canning and physical properties of 12 bean genotypes (reported herein) was conducted as part of the thesis study of a graduate in the Agribusiness National Polytechnic School in Quito.

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

Engagement of USAID Field Mission(s)

Past visits were made to USAID Mission in Kigali on two occasions in 2008 and 2009 to discuss the role and work of the PULSE CRSP in Rwanda and introduce HC partners. 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

- The project also forged closer collaboration with Kigali Institute of Science and Technology (KIST). RAB provided KIST with 20 newly released varieties for post harvest and processing studies under CRSP MSU/ISU collaboration. 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 RAB.
- RAB, farmers' cooperatives, and seed production agencies worked together to further dissemination of bean technologies. NGOs such as World Vision, AFRICARE, ADRA, CARITIUS, Catholic Relief Services, DERN; farmers organizations, COAMV in the North; RDO in the East; Iterambere ry'Abahinzi Borozi Muhanga (IABM) (South), and local Government Extension Agents (Country-wide), Musasu Watershed (south), Sogwe Watershed farmers Cooperatives (South), Gakiragi Watershed Cooperative (East), Umutara Polytechnic University (East), IMBARAGA (Umbrera farmer organization in the country), DERN, DRD, TIN, CSC, Rwanda Seed Company (RWASCO), AGRA Climbing Bean, N2 Africa, CIALCA, and individual farmers were also involved in promoting bean technology. Government institutions such as KIST, and Higher Training Institute of Agriculture and Livestock (ISAE) were among partners with RAB in scaled-up programs.
- 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.

Leveraging of CRSP Resources

- In addition to the Dry Grain Pulse CRSP project, funding was secured through Nitrogen fixation CRSP project with Iowa State University to the bean breeding program in Rwanda, AGRA (Alliance for a Green Revolution in Africa), Harvest-Plus, Bio-Innovate, ASARECA, ACTESA/COMESA, and PABRA network. Support from the Government also was provided to the bean program for both variety selection and further seed increase. Support from Borlaug LEAP fellowship for additional training of doctoral CRSP candidate.
- 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.

Scholarly Activities and Accomplishments

List of Publications

Abawi, G. S., T. G. Porch, and J. D. Kelly. 2011. Field and greenhouse evaluation of bean germplasm for root rot and other diseases in New York, 2010. BIC 54: 142-143.

Brisco, E.I., T. G. Porch, and J.D. Kelly. 2011. Comparison of choice versus no-choice tests of a dry bean IBL population for resistance to potato leafhopper. Annu. Rep. Bean Improv. Coop. 54:88-89.

Mkwaila, W., and J. D. Kelly. 2011. Heritability estimates and phenotypic correlations for white mold resistance and agronomic traits in pinto bean. Annu. Rep. Bean Improv. Coop. 54:134-135.

Mkwaila, W., K.A. Terpstra, M. Ender, and J.D. Kelly. 2011. Identification of QTL for resistance to white mold in wild and landrace germplasm of common bean. Plant Breeding 130:665-672.

Miklas, P.N., S. P. Singh, H. Terán, J. D. Kelly, and J. R. Smith. 2011. Registration of common bacterial blight resistant cranberry dry bean germplasm line USCR-CBB-20. J. Plant Reg. 5:98-102.

Roman-Avilés, B., J.M. Lewis and J.D. Kelly. 2011. Fusarium Genetic Control: A Long Term Strategy. In: Control of Fusarium Diseases, Editors: Fernando M. Alves-Santos and Julio J. Diez. 2011:000-000 ISBN: 978-81-308-0470-5.

Wright, E.M., and J.D. Kelly. 2011. Mapping QTL for seed yield and canning quality following processing of black bean (*Phaseolus vulgaris* L.). Euphytica 179:471–484.

A booklet with promotional materials has been developed and 5,000 copies printed and distributed to Rwandan farmers and other related producers. The booklet promotes the bean production chain. Extension publications were published on new varieties in the US; in Spanish in Ecuador and in Kinyarwanda in Rwanda. Two leaflets describing the new varieties available for distribution in Ecuador and the pdf file can be viewed @http:// www.iniap.gob.ec

Professional Recognition, Awards and Accomplishments

Plant Variety Protection Certificate No. 201000268 was issued for 'Zorro' black bean variety on 8/18/2011.

Plant Variety Protection Certificate No. 201000269 was issued for 'Santa Fe' pinto bean variety on 8/18/2011.

Tables/Figures

Table #1: New Climbing Bean Varieties to be released 2012, their phenology, seed characteristics and yield potential.

Varieties	Days to Flowering	Days to maturity	Seed color	Seed size	Yield (Kg per ha)
RWV3006	58	110	White	Large	3,560
RWV2872	56	108	Red-mottled	Large	3,939
RWV2361	57	108	Red-mottled	Medium	3,485
RWV3316	58	110	Red	Large	4,000

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2010 – September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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

	Abbreviated name of institutions											
	MSU			Cornell			Ecuador			Rwanda		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	10/1/11	Y	N*	10/1/11	Y	N*	10/1/11	Y	N*	10/1/11	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	
Biofortification for Fe, Zn							x		x	x	x	
Canning and quality evaluation	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				
Characterize CIAT resistance sources										x	x	
Increase, characterize local germplasm							x	x				
Evaluation for drought and root rot				x	x		x	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		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												
Evaluation of climbing beans				x	x	x	x	x		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		

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 **Date**

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

MSU: pathogens being collected in Rwanda were retained in country due to quarantine concerns

Cornell: Characerization of isolates and germplasm evaluation is continuing and need to be done in Rwanda too.

Ecuador: Work with biofortified lines is not being continued with CIAT, no funding for interchange of scientists betwee
Rwanda and Ecuador

Rwanda:

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	2008 Target	2008 Actual	2009 Target	2009 Actual	2010 Target	2010 Actual	2011 Target	2011 Actual	2012 Target	2012 Actual
	(Apr 1-Sept 30, 2008)		(Oct 1 2008-Sept 30, 2009)		(Oct 1 2009-Sept 30, 2010)		(Oct 1 2010-Sept 30, 2011)		Oct 1 2011-Sept 30, 2012	
Degree Training: Number of individuals who have received degree training										
Number of women	1			1	2	2	2	2	2	
Number of men			1		1	0	1	1	1	
Short-term Training: Number of individuals who have received short-term training										
Number of women			1	1	2	0	4	6	8	
Number of men			2	3	2	2	4	4	8	
Technologies and Policies										
Number of technologies and management practices under research	8	4	8	14	19	17	17	20	14	
Number of technologies and management practices under field testing	4	3	4	10	10	11	14	14	11	
Number of technologies and management practices made available for transfer	8	2	8	12	11	8	16	16	23	
Number of policy studies undertaken										
Beneficiaries										
Number of rural households benefiting directly	3000	2400	3100	8300	8000	10500	8800	17,000	8000	
Number of agricultural firms/enterprises benefiting	9	2	9	19	20	12	27	29	37	
Number of producer and/or community-based organizations receiving technical assistance	54	15	54	110	75	61	117	167	219	
Number of women organizations receiving technical assistance	8		8	15	13	21	51	31	102	
Number of HC partner organizations/institutions benefiting	18	8	18	38	38	30	40	40	47	
Developmental outcomes:										
Number of additional hectares under improved technologies or management practices	5400	1200	7000	14000	16000	18200	20500	29,000	27000	
"Number of public-private sector partnerships formed as a result of USAID assistar				8						

Rwanda: More than 200 T of seed of improved varieties has gone to farmers through ISAR and main partners (RADA, NGOs, CBOs and Farmers)
Ecuador: Over 250 T of seed of improved varieties has gone to farmers through INIAP- new varieity INIAP INTAG released to growers
MSU & Cornell: Established active collaboration with USDA-ARS Mayaguez to evaluate root rot germplasm at Geneva NY
MSU & UPR: Established active collaboration with UPR and USDA-ARS Mayaguez to evaluate MSU germplasm in Angola

Change in rural households - Discrepancy between Target and Actual Nos in 2011
No changes for Ecuador - as values for target and actual numbers coincide quite well
Changes apply only to the Rwandan figures
The target number of household in Rwanda should have been 4000 not 1000 reported, Typo.
The total number of households for both countries should have been 8,800 not 5,800 reported
The reason for the dramatic change from 8,800 to 17,000 is based on changes in land policy in Rwanda
In Rwanda the current actual agricultural policies support consolidation and crop intensification.
As a result, the program reaches many more households with new technologies that are being tested or demonstrated on these larger land holdings.
The consolidation and crop intensification program make it easier to reach more end-users in the same location at the same time- rather than a few households as in the past
Farmer grow the same crop on a larger area - not the smaller diversified cropping patterns in the past, so the program
works directly with a larger number of househ and is able to disseminate more than one technology more easily as more households are benefiting.

As a result, the program reaches many more households, producers and community based organizations with new technologies that are being tested or demonstrated on these large land holdings.

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

Principal Investigators
Richard H. Bernsten (lead), Michigan State University, USA
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Abstract of Research Achievements and Impacts

In Angola, semi-structured interviews of small scale traders were conducted in common beans markets in Huambo and Londimbuali. Preliminary research on bean markets indicate a preference for local over imported beans, yet smallholder farmers in the Planalto region lack marketing strategies to reach those markets and trade organization appears weak, implying high transaction costs. Txocaine's research identified the margins for traders in key common bean marketing channels and found that bean farmers are interested in improved production technologies, but wait for projects to ensure the inputs. While high transport costs restrict marketing, some farmers are able to transport to regional markets. Interviews with farmer groups found that most farmers sell into local markets or to traders arriving in the village, even when farmers associations exist. For market information, farmers listen to the new radio programs broadcasting prices, but indicated that these prices were not "reliable", as they found different prices when they went to sell in the market. Phase II rapid appraisal market research on cowpeas markets in two provinces found that the peak sales months vary among markets. Almost all cowpea traders are women--many both grow and trade cowpeas. Traders identified various transport problems. In rainy season, some areas remain inaccessible. Price information for cowpeas (and beans) is limited to word of mouth, as cell phones function only in selected areas. Where phones function, traders used them to obtain price and other trading information. Traders identified quality as a key constraint to greater marketing--cowpeas is mixed, with different varieties and sizes in the bags and are infested with insects. While IDA distributed cowpea seeds in the region, IDA extension agents believed that many farmers ate the seeds. In the future, IIA and IDA need to do more to ensure adequate supplies of seeds, and develop delivery systems for inputs at the farm level. Estevao Chaves completed his MS thesis, using Mozambican data as Angolan time series price data were not available.

In Mozambique, semi-structured interviews were conducted with 109 traders (54 cowpeas, 55 beans traders) in northern/central Mozambique and Maputo's wholesale market (15 traders). The market rapid appraisal by SIMA found that cowpea traders were more likely to sell to large warehouse agents (LWA), whereas bean traders were likely to sell to retailers—likely due to the developing value chain for cowpea processing/export. As LWA establish longer term links with local traders, cowpea traders are more local and less likely than common bean traders to work in more than one district. This value chain may lend itself more to developing targeted actions to

improve quality/post-harvest handling, since wholesalers can be a more easily organized. For beans, traders are informal and sell directly to retailers as there are few processors and organized bean traders. Market prices follow each other across the country's markets. Currently, there are few processors and organized bean traders. CRSP research to evaluate cowpea markets and producer activities in southern Mozambique will provide insight into how cowpea production/marketing might be improved. Interviews with market traders in Maputo found that they sourced beans depending on relative prices and availability--sometimes importing from Swaziland/South Africa. Supermarkets, import beans due to poor quality of Mozambique's beans, but also buy beans in the main production zones. Research under PABREN focused on enhancing farmer access to appropriate information on markets, including varietal choices and prices. This research in the northern bean areas is completed and in 2012 researchers will meet with farmer focus groups in the southern production areas. The database on cowpeas/bean prices has been created and is revised weekly, based on weekly SIMA price collection. SIMA continues to disseminate the data via radio, television, newspaper, and e-mail. Farmer focus groups for beans were conducted in the north in collaboration with PABREN. Currently farmer focus groups are being conducted in the south for cowpeas. Research on bean trade between Mozambique and South Africa (SA) found .that import parity prices from SA were important in determining bean prices in Mozambique. Reducing transport and other transaction costs were identified as actions needed to ensure competitiveness of local beans throughout the year, since SA beans appear in markets in the off-season, while local beans are more available during the production seasons. Donovan worked USAID/Mozambique mission to develop the Feed the Future Strategy, which will include pulses. The project collaborated with the NSI to use cellphone technology for price information dissemination, but the system has suffered delays due to contracting issues .While 2007 Population Census data showed only 1% of rural households had cellphones, there has been rapid growth in rural cellular networks, cellphone-based information will be useful to traders and better off farmers.

In Honduras, strategies for managing the bean crops using organic fertilizers and household items and plant were tested in on-farm trials and demonstrate in farmers' fields in collaboration with CIALs; and *Rhizobium* inoculation trials were conducted. At least 100 CIALs farmers are using organic fertilizer and pest control practices produced locally, and at least 50% are capable of producing their own organic fertilizer/pest control products at their own farms. Results from *Rhizobium* inoculant tests on farmer fields indicate the usefulness and potential adoption of this practice by small-scale bean producers. Technical assistance has been provided in stages. First, technical personnel and CIAL leaders are trained on production of organic fertilizer/pest control products at Zamorano's Organic Agriculture Unit. Then, technicians and farmer leaders train other farmers at the local level; facilities were established producing organic fertilizer/pest control products at PRR and FIPAH and practical training courses/demonstration were carried Field trials/demonstration plots were used to promote adoption of these products. Periodical visits of NGOs technicians and farmer extensionists were conducted to follow up production/use of organic products at farm level. More than 50 farmers from CIAL received training at the local level and are producing/utilizing organic products on their commercial bean plots. Organic products are sold by PRR and FIPAH facilities and by farmer from CIALs locally. More than 15 NGO technicians/CIAL leaders have been trained on the production/use of organic fertilizers/ organic pest control products. During FY 2011, 15 young farmers were trained in 5 practical modules including one on organic agriculture. The use of plant extract as insect repellent and foliar organic fertilizers on bean crops by CIALs farmers is quite common. Currently, the *Rhizobium* inoculant technology is in the farmer field testing stage. During the Primera 2011, inoculated and non-inoculated treatments were compared in farmer bean commercial production plots and more than 12 farmers were trained on the use of inoculants on beans. IMO staff was contacted to obtain third-party fairtrade certification for the farmer association. The IMO agreed to provide fair trade certification (pending the outcome of an audit visit) for the association and Whole Food Markets (WFM) guaranteed that it would purchase 20 MT of beans from the farmers at a farmgate price of $ 0.60/lb, if the association obtained fairtrade certification from the IMO. In March 2011 the PIs met with association leaders to discuss IMO certification requirements and sales to WFM and with other supply chain participants. While in early 2011 the farmers agreed to accept WFM's price, because the local bean price had increased, they now wanted $0.75/lb. Upon returning to the US, Bernsten visited WFM's office to provide background information about the farmers and request a higher price. While WFM agreed to pay $0.75/lb, when Rosas later contacted the farmers to confirm that they would accept WFM's new price, the farmers wanted $ 0.85/lb—the price that local traders were now paying farmers. Subsequently, Bernsten contacted WFM to discuss options. As WFM could not pay the price that the farmers now wanted, we agree to postpone finalizing a purchase contract and wait until early 2012 to see if the local price declined to a price level that WFM was willing to pay. If the local price declined, WFM agreed to reconsider purchasing 20 MT of small red beans for delivery in mid- or late-2012. Consequently, plans to get IMO certification and export to WFM were postponed.

Project Problem Statement and Justification

Angola

Common beans and cowpeas are important crops for smallholder farmers in Angola, with approximately 36% of households in a recent survey indicating that common beans were the most important source of cash income from crops. About two-thirds of household production was sold, for those households growing beans.

However, marketing constraints are clearly found in household surveys in the Planalto region of the country, such that farmers tend to sell from farmgate or in local markets due to ease of trading. Sales period is strictly based on harvesting period, rather than strategic considerations of storage and pricing. Looking more specifically at common beans, we find that many farmers sell into the local markets at harvest time simply because of convenience. Farmers who sell in more distant markets (27% of farmers in the region, based on survey estimates) indicate that they choose those markets in order to get higher prices, but they have transport expenses, as well as information constraints, making marketing more costly. Some 28 percent of farmers determine when to sell their beans based on price, yet the information available to help guide this choice is limited to mostly friends, family, and local traders.

A key question is whether or not there are areas for greater efficiency in the marketing system that would enable Angolan farmers to contribute greater amounts, substituting for imported beans as well as meeting unmet needs in the urban areas for the quality of beans demanded. Phase II of the research and training identified the costs associated with the marketing channels. Txocaine's thesis provides evidence that intermediaries gain fairly high marketing margins. There are opportunities for farmers to increase their profits by selling into regional rather than local markets, but a minority of farmers is organized to market in the larger, more distant markets. Additional work with World Vision and other local organizations is needed to ameliorate the information gaps which are reducing profitability and overall volumes marketed for beans.

Cowpea cultivation in Angola is more dispersed and marketing seasons more varied than for common beans. There is basically no information on cowpea producers and their marketing channels, and thus research will begin to fill in the gaps of information on cowpeas to assess potential.

Mozambique

In Mozambique, both cowpeas and common beans are marketed by smallholder producers, and the local market information system (SIMA) shows high seasonality in prices for the common bean, whereas cowpeas tend to have less dramatic variability, with more flexibility in planting seasons and locations. Cowpeas and common beans have different marketing channels. Wholesale common bean traders do not work with cowpeas or other legumes and prefer to specialize. Cowpea markets tend to be more localized, but recent developments suggest that new markets for processing may be arising, along with pigeon peas. IIAM researchers with SIMA have begun to identify some of the new initiatives in processing of cowpeas and pigeon peas for use in dhal for export to Southeast Asia.

The costs occurring through the various channels, both for cowpeas and common beans, were determined in the earlier rapid appraisal survey and traders have identified ways to minimize their costs using banking and cell phone technology. The current trading structure of common beans is primarily informal sector and does not lend itself easily to the formation of a bean task force. In July 2011, Pulse CRSP researchers helped TradeHub and AGRIFuturo to organize travel by South African traders and processors into the bean production zones of Mozambique, looking into possible linkages. Organizing farmers and assuring quality product were seen as critical.

Phase I research has identified the basic marketing channels for common beans, and work has only just begun on the marketing channels for cowpeas. Cowpeas are generally grown in different agro ecological zones compared to common beans, and cowpeas have a lower overall marketed volume.

Honduras

Common beans, the second most important food crop (95,000 ha) after maize, are an important source of food and cash income for smallholders. However, input costs are rising—which reduces farmers' profits—and 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 technologies (i.e., organic alternatives to fertilizer and pesticides) that will enable them to reduce their input costs. In addition, they need access to new markets that will add value to their crop. This project focuses on testing organic crop management practices and developing new market opportunities for smallholders by producing and exporting fairtrade beans (small reds) to the US food retail market.

Results, Achievements and Output of Research
In all three countries, this research focuses on identifying potential market enhancements for smallholders in Angola, Honduras and Mozambique.

Angola and Mozambique
During Phase I, research in both Mozambique and Angola sought to describe and understand bean producers and their relationship to markets. Most recent efforts in Mozambique have involved evaluating the cowpea value chain, although there is still work to be completed to prepare a research report. Existing analysis for farmers and trading systems in Mozambique and in Angola has highlighted some key features of bean production and marketing, as well as cowpea marketing. Beans are seen as a cash crop by many farmers; trade networks are responsive to change; traders travel long distances and may specialize in beans; traders are adapting to new technologies and services (for example, cell phones and automatic teller machines at banks); and farmers make investments in improved varieties.

In both Mozambique and Angola, training workshops and guidance on value chain research for common beans and cowpeas has included price analysis and future training will include partial budgeting on technologies, survey research methods, and cost benefit analysis. One MS student has finished his study program and the second will finish in late 2011. Each will help to provide skills to their institutions.

Objective 1: Angola
Identify efficiency in marketing channels and leverage points to increase farmer profits and trader volumes.

Approaches and Methods
Semi-structured interviews were conducted in common beans markets in Huambo and Londimbuali.

Cowpea market research used a survey type called "Inquerito da Janela", developed in Mozambique by SIMA. The method consisted in sampling at random interviewees. A semi-structural questionnaire comprises of 4 sections with different headings was elaborated and submitted to 36 volunteers small scale traders. It was also pre-determined the direction of the survey (Huambo-Bengela-Huambo).

Results
Preliminary market research on bean markets indicated a preference for local beans over imported beans, yet smallholder farmers in the Planalto region lack marketing strategies to reach those markets and trade organization appears weak, implying high transaction costs. There are three key marketing months for beans: January, February, and June. Txocaine’s research was able to identify the margins for traders in key common bean marketing channels for Londimbuali. On the supply side, research by Txocaine showed that bean farmers are interested in improved production technologies, yet tend to wait for projects to ensure the inputs. The high cost of transport is a key factor restricting marketing, yet some farmers with higher levels of production are able to arrange transport to regional markets. Interviews with farmer groups of

World Vision found that most farmers continue to sell into local markets or to traders arriving in the village, even when farmers associations exist. For market information, farmers were listening to the new radio programs broadcasting prices, but farmers indicated that the prices were not "reliable" and that they found other prices when they went to the market, not the radio announced prices. This reflects a challenge for the market information system to train farmers on competition and markets, as farmers had been accustomed to government controlled prices and were confused, thinking that the radio prices were government announced prices.

Dr. Kiala, Artur Paulino (a student), and other UJES students focused Phase II rapid appraisal market research on cowpeas in markets of Benguela and Huambo Provinces. In some markets, December and January are the peak months for sales, whereas in other markets, June was the peak month, with various markets trading throughout the period January through June. The traders of cowpeas are almost entirely women, and many of them both grow and trade cowpeas. Traders identified various transport problems, having to use motorcycles or whatever is available to transport cowpeas to markets. In rainy season, some production areas remain inaccessible. As with common beans, price information for cowpeas is mostly limited to word of mouth and cell phones function only in selected areas. Where phones do function, traders were interested in using them for price and other trading information. Overall the traders identified quality problems as a key constraint to greater marketing, as the cowpeas are mixed, with different varieties and sizes in the bags, and there are problems of insect infestations, with inadequate post-harvest handling. IDA had distributed cowpea seeds in the region, but the IDA extension agent believed that farmers ate many of the seeds distributed, rather than planting them. This points to the need in the future for IIA and IDA to do more work to ensure adequate supplies of seeds, as well as to develop delivery systems for inputs at the farm level. Paulino will be following up with farmers receiving the IDA seeds in the coming months.

Estevao Chaves completed his MS thesis in August 2011, which was to contribute to diagnosis under this objective. However, due to the lack of time series data for Angola, he developed his thesis using Mozambican data. The analysis applied there will be useful in Angola, when time series price information is available.

<u>Outputs</u>

Artur Paulino, "Potencial comercial de feijão macunde em Angola" (Commercial potential for Cowpeas in Angola). 2011. Thesis for UJES.

Estevao Chaves. Interdependência dos Preços de Feijão-Vulgar entre Cinco dos Principais Mercados em Moçambique. (Interdependence of common bean prices among fice ket markets in Mozambique). MS Thesis, the University of Vicosa, Brazil.

David Kiala Kilusinga. Progress Report on Cowpea the Research. Project. September 2011.

<u>Collaborators</u>

David Tunga, Food Security Department (DSA), MINAGRI
Moises Lima and Fabio da Cruz, World Vision PRORENDA project, Huambo

Objective 2: Mozambique

2.1 Identify efficiency in marketing channels and leverage points to increase farmer profits and trader volumes.

Approaches and Methods

Semi-structured interviews were conducted with 109 traders (54 with cowpeas and 55 with common beans) in the northern and central parts of Mozambique during the rapid appraisal Windshield Survey. Additional interviews were conducted in the main Maputo wholesale market with another 15 traders.

Analysis of price data uses weekly data from selected markets within the SIMA system at wholesale and retail levels.

Results

The most recent market rapid appraisal by SIMA found that cowpea traders were much more likely to sell to large warehouse agents, whereas the common bean traders were more likely to sell to retailers. This difference is believed to be related to the developing value chain for cowpea processing and export, an area of future research. Large warehousing agents establish longer term links with local traders, and thus the cowpea traders tend to be more local and are less likely than common bean traders to work in more than one district. This value chain, at least in northern and central Mozambique, may lend itself more to developing targeted actions to improve quality and post-harvest handling, since wholesalers can be a more easily organized interest group. For common beans, the traders are generally informal and tend to sell directly to retailers in other markets. As one large-scale trader recently said, 'the common bean traders get the job done and there is less potential for profitable actions" for large-scale private sector involvement. As figure 1 below indicates, market prices tend to follow each other across the markets of south, center, and north. Currently in Mozambique, there are very few processors and relatively few organized common bean traders.

There is ongoing IIAM research through the Pulse CRSP in association with PABREN to evaluate cowpea markets and producer activities in southern Mozambique. This will help provide insight into how cowpea production and marketing might be improved in southern areas. IIAM/CESE researcher Isabel Cachomba interviewed market traders in Maputo and found that they source beans depending on relative prices and availability. At times they purchase beans in Swaziland or South Africa, importing them informally to avoid import duties. This is more likely to happen around the end of the year, near the holidays. Formal sector stores, such as supermarkets, also tend to source beans from elsewhere in the region due to poor quality of Mozambique's beans and the drying processes used. Otherwise they work with partners to buy beans in the main production zones. Various traders indicated that the quality of beans in the Linchinga area was the best, as farmers tended to dry the beans more for sales. Another advantage of the imported beans is that the beans are sorted, without the mixing as is found in sales of local beans.

Phase II Pulse CRSP activities are linked with PABREN network activities to enhance farmer access to appropriate information on markets, including varietal choices and prices in different key markets. Under the PABREN effort, IIAM researchers are evaluating farmers' preferences for varietal choice. The research on the northern bean-producing areas has been completed and the research results will be shared. Pulse CRSP funding will enable CESE researchers to go to the southern production areas to talk to farmer focus groups on varietal choice, early in FY 2012.

The database on cowpeas and common prices is available and is continually being revised, based on weekly SIMA price collection. SIMA continues its efforts to disseminate the data via radio, television, newspaper, and e-mail. The Ministry of Agriculture website (http://www.minag.gov.mz) is currently under reconstruction and will begin posting the Quente Quente weekly bulletin on a regular basis. Estevao Chaves from Angola used the SIMA price series to look at interdependence of prices among five key markets.

Farmer focus groups concerning common beans were conducted in the north in collaboration with PABREN. Currently farmer focus groups are being conducted in the south for cowpeas, so this work is still ongoing.

Ms. Gungulo, a CRSP student at University of Pretoria, developed a research paper on trade in dry beans between Mozambique and South Africa. Preliminary results suggest that import parity prices from South Africa were important in determining bean prices for farmers in Mozambique. Reducing transport and other transaction costs were identified as actions needed to ensure competitiveness of local beans throughout the year, since South African beans tend to appear in southern markets in the off-season, whereas domestic dry beans are more available in the production seasons.

Moving into the bean marketing season, there will be more forward progress on the market research, assuming that the vehicle is available soon. There have been several activities which complement the CRSP activities in Mozambique. Donovan met with TradeHub Legumes specialist Cuan Opperman, as well as with the McKinsey team working with the USAID Mozambique mission, to develop the Feed the Future Strategy. Pulses will be an area of investment under the FTF strategy, although we are waiting to see if pulses will be considered of primary or secondary importance under the final version. The team seemed to focus more on the pigeon peas and cowpeas due to export potential to India and elsewhere for dhal production.

Outputs

Isabel Chachomba, Report on Marketing of Common beans in Bazuka Market (Comercialização de Feijões no Mercado Basuka) 19/04/2011.

Ana Lidia Gungulo, Trade Analysis Dry Beans Market in Mozambique, November 2011. Draft Report.

Collaborators

Jill Findeis, Pennsylvania State University; Arlindo Miguel and staff at the Agricultural Market Information System (SIMA), MINAG; Alda Tomo and Isabel Cachomba , IIAM/CESE

2.2 Develop cell phone-based information system for beans, to link farmers and traders to market prices and availability.

Approaches and Methods
Collaborative work will be implemented with the National Statistics Institute, involving farmer focus groups for pre-testing messages and instructions and providing enumerator with Short-Term in-service training on SMS system use.

Results
Regarding the cellphone technology for price information dissemination, the system has suffered delays due to contracting issues between the National Statistics Institute and the private firm providing the service, Syslog. Those issues have been resolved and SIMA is waiting for INE to resolve further technical issues with them.

The 2007 Population Census showed only 1% of rural households had cellphones, however, there has been rapid growth in rural cellular networks, so it is believed to be much higher.[1] At least for now, cellphone information availability will be useful for a high percentage of the traders and better off farmers when it gets out.

Outputs
Draft SMS system in operation, but with data transfer complications to be resolved.

Collaborators
Arlindo Miguel and staff at the Agricultural Market Information System (SIMA), MINAG; Helder Vicente, Provincial Directorate of Agriculture, Zambézia; Balthazar de Brouwer, WFP P4P program; D. Cantor, SCIP project in Mozambique; and S. Nhane, the webmaster of the National Statistics Institute.

Objective 3: **Honduras**

3.1 Conduct on-farm trials to validated organic bean production practices, including organic fertilizers and pesticides based on extracts from local plants.

Approaches and Methods
Integrated approaches for management of bean crops using organic fertilizers (bokashi, compost, chicken manure, crop residues and others) and household items (e.g., detergent, oil, ethanol) and plant extracts (e.g., Gliricidia, nim, hot pepper, onion, garlic, parsley) that have proven to be effective in reducing insect pests and disease incidence and damage continue to be tested and demonstrated in bean farmer plots, in the Yojoa Lake, Yorito-Sulaco-Victoria, Vallecillo, and F. Morazán regions in collaboration with CIALs (local research committees) and NGOs. In addition, *Rhizobium* inoculation trials are conducted with the participation of farmer CIALs from the same regions and in the western bean production region in collaboration with the FAO-Seed for Development Project and in southern Honduras with the CARE/CIAT Project.

[1] MSU is currently conducting a survey of farm households in most of Zambezi and Nampula Provinces and will be able to indicate cell phone ownership with the results of that survey in early 2012

<u>Results</u>
Farmers from participating CIALs of the Yojoa Lake, Yorito-Sulaco-Victoria and Vallecillo regions have implemented the use of organic fertilizers and pest control practices produced locally. The majority of these farmers are capable to elaborate their own organic products in their farms after received practical training. *Rhizobium* inoculant tests on bean farmer fields were conducted this year in several regions of Honduras.

<u>Outputs</u>
At least 100 farmers from participating CIALs are using organic fertilizer and pest control practices produced locally, and at least 50% of these farmers are capable of producing their own organic fertilizer and pest control products at their own farms. Results from *Rhizobium* inoculant tests on farmer fields indicate the usefulness and potential adoption of this practice by small-scale bean producers.

<u>Collaborators</u>
The Honduran NGOs Programa de Reconstrucción Rural (PRR) and Fundación para la Investigación Participativa con Agricultores de Honduras (FIPAH); and farmers organized as CIALs from Yojoa Lake (several municipalities in the departments of Comayagua and Santa Bárbara), Yorito-Sulaco-Victoria (municipalities in the Yoro department) and Vallecillo municipality (department of F. Morazan). At the regional level, the project collaborates with the Participatory Plant Breeding Program for the Mesoamerican Region (FPMA in Spanish), supported by the Norwegian Development Fund, on training and exchange activities related to agro-ecological management of the bean and maize crops.

3.2 Provide technical assistance to farmer groups interested in establishing commercial organic bean plots.

<u>Approaches and Methods</u>
Technical assistance has been provided in stages. First, technical personnel and farmer CIAL leaders received training on production of organic fertilizer and pest control products at the Organic Agriculture Unit at Zamorano. Then, technicians and farmer leaders trained other farmers at local level; facilities for production of organic fertilizer and pest control products at PRR and FIPAH were established and practical courses and demonstration were carried out for training. Organic products are sold at these facilities. Field trials and demonstration plots are used to promote the utilization of these products. Periodical visits of NGOs technicians and farmer extensionists are conducted to follow up the production and utilization of organic products at farm level.

<u>Results</u>
NGOs technical personnel and farmer leaders from Honduras and Central America have received training at Zamorano, in production and use of organic fertilizers and plant extracts for pest control. More than 50 farmers from CIAL received training at local level and are producing and utilizing organic products on their commercial bean plots. In addition, organic products are sold by PRR and FIPAH facilities and by farmer from CIALs locally.

Outputs

More than 15 NGO technicians and farmers CIAL leaders have been trained on production and utilization of organic fertilizers and organic pest control products in Honduras and Central America. During the present year, 15 young farmers (including 6 women) were trained in five practical modules including one on organic agriculture. The use of different plant extract (nim. onions, garlic, hot pepper and others) as insect repellent and the application of foliar organic fertilizers based on earthworm humus, compost, and other organic source of nutrients on bean crops by farmers from CIALs is quite common at the present. Currently, the *Rhizobium* inoculant technology is on the farmer field testing stage. During the Primera season of 2011, inoculated and non-inoculated treatments were compared in farmer bean commercial production plots and more than 12 farmers were trained on the use of inoculants in beans.

Collaborators

Same as in Objective 3.1.

3.3 Assist farmer groups to obtain fair trade certification.

Approaches and Methods

The objective of this sub-component is to work with a Honduran farmer association to produce and export fairtrade-certified beans to a US food retailer (e.g., Whole Food Markets, WFM). However, to sell beans and other commodities as fairtrade products, the producers must be fairtrade certified by a third party. Initially, we planned to obtain third-party fairtrade certification from the Fairtrade Labeling Organization (FLO-CERT), but this proved to be problematic. Since FLO had never previously certified dry beans, they had not set "standards" for this commodity and would not initiate the 6-9 month process to set "standards" and a "fairtrade price" (i.e., a price that covers costs of production plus a profit margin of 10%) unless there existed evidence (a buyer contract) that there was a demand for the product. And, without prior certification (including a fairtrade price), it was impossible to negotiate a contract with a US buyer. While certification by the Rainforest Alliance (RA) was an option, we decided not to pursue this because RA certification is not widely recognized in the US retail food market. Thus, following WFM's suggestion, we decided to seek certification from the International Marketing Organization (IMO). Because the IMO certifies farmer groups, rather than commodities, the process for obtaining certification is more straightforward. After being contacted, the IMO confirmed that they could certify the farmers in Honduras. Subsequently, after completing the IMO's preliminary application (which the IMO approved), the IMO sent an invoice (cost estimate for a certification audit/visit) and documents (100+ pages) describing the requirements that the farmers had to meet to be certified. Subsequently, Dr. Rosas met with the farmer association (ASOCIALAYO) to discuss the IMO's requirements. However, before scheduling a certification audit visit by the IMO (which would cost $2,500), we needed confirmation from WFM that they would purchase the beans at a price acceptable to the farmers.

Results

The IMO agreed to provide fair trade certification (pending the outcome of the audit visit) for the farmer association and, as discussed below, WFM guaranteed that it would purchase 20 MT of fairtrade beans from the farmer at a farmgate price of $ 0.60/lb, if the farmer association obtained fairtrade certification from the IMO. However, after initially agreeing to this price, the farmers decided that they wanted a higher price—a price that WFM was unable to meet. Consequently, the IMO's certification (audit) visit was postponed until the farmers agreed to sell their beans at a price that was acceptable to WFM.

Outputs

While we did not pursue securing fairtrade certification, cost of production data were collected, as required by the IMO for determining a "fair" price. Thus, having established contact with the IMO and having estimated the costs of bean production, if in the future the farmers agree to sell their beans at a price acceptable to WFM, protocols are in place to schedule an IMO certification (audit) visit.

Collaborators

US: The principal buyers of bulk commodities at WFM's US headquarters in Austin TX and the person in charge of fairtrade certification at the IMO, based in San Francisco, CA.
Honduras: The elected leaders of the members of the farmer association (ASOCIALAYO).

3.4 Export fair-trade beans to a US retailer.

Approaches and Methods

Prior to being able to contract farmers to produce beans for export to a US food retailer as fairtrade beans, it is necessary to: 1) obtain fairtrade certification for the farmer association, 2) document the links in the supply chain from the farmgate to the US port of entry, 3) estimate the costs associated with each stage of the supply chain (i.e., fairtrade certification, production, transporting a container to the village, cleaning/packing the beans, fumigation, transporting the container to the port, obtaining a Honduran export permit, Aphis inspection charges, US customs clearance charges, shipping to the US/Houston TX, and the broker's service charges), 4) identify a broker who could be contracted to transport the beans from the farmgate to the Honduran export port and complete the required export-related paperwork, 5) identify a US food retailer who would purchase the beans and provide a purchasing contract, 6) identify a price that was acceptable to the US retailer and the farmer association, 7) obtain an export permit (due to supply shortages, the government frequently place an embargo on exports), and 8) provide the farmers with a contract specifying the quantity and quality standards required by the buyer.

Results

Throughout the year, many phone and e-mail contact were made with WFM's bulk commodity buyers to update them on the project and negotiate a purchase price. In early March 2011, Whole Food Markets (WFM) agreed to purchase 20 MT of small red beans (under its *Global certified Trade Program*) for delivery in January 2012 at a farmgate price (US$ 0.60/lb) that the farmers had agreed to in early 2011. After adding supply chain costs, this farmgate price translated to a price of US$ 0.87/lb delivered to the US port at Houston, TX. In late March, Rosas and Bernsten met with the leaders of the leaders of the farmer association to discuss logistics (e.g., production costs, production schedule, and purchasing arrangements), collected data from the farmers to estimate their bean production costs in order to document that the price offered by WFM was a "fair price" (these data are require by the IMO). In addition, we met with 1) a bean broker to discuss logistics and costs related to collecting the beans at the farmgate and transporting them to

Honduras' export port and 2) Honduran government official to obtain information regarding the process for applying for an export permit.

However, since early 2011, the local price of beans had increased substantially, due to production shortfalls in the previous Primera and Postrera seasons. Thus, at the March meeting with the leaders of the farmer association, they requested a higher price (US$ 0.75) than WFM had originally agreed to pay. After returning from Honduras in April, Bernsten visited WFM in Austin TX to meet with the bulk commodity purchasing staff to negotiate a higher bean price. At this meeting, Bernsten made a PowerPoint presentation which provided an overview of the project, including its history, photos of the farmers in their bean fields, the supply chain costs, and the reasons the farmer wanted a higher price than WFM originally offered. While WFM agreed to the new price that the farmers wanted (US$ 0.75), the local bean price continued to increase. Thus, when Rosas met again with the farmers to offer them WFM's new price (US$ 0.75/lb), the farmers noted that the retail price was now US$ 1.00/lb and local traders were currently offering farmers US$ 0.85/lb. Furthermore, the farmers expected that the local bean price would continue to remain high. Subsequently, Bernsten contacted WFM to discuss options. As WFM could not offer the farmers the price that they now wanted, we agree to postpone finalizing the purchase contract and wait until early 2012 to see if the local price declined to a price level that WFM was willing to pay. If the local price declined, WFM agreed to reconsider purchasing 20 MT of small red beans for delivery in mid- or late-2012.

This situation highlights the challenge of getting farmers to agree to contract their bean production at a future price, when local price of beans is highly volatile and the buyer (WFM) is only willing to pay a price at which it estimates consumers will be willing to pay at its retail stores. Farmers are used to selling their beans on the spot market price, rather than contracting at a future price. Because farmers correctly or incorrectly expected that the price of beans would continue to be close to $ 0.85/lb in January 2012, they were unwilling to contract for a lower price in May 2011--7 months prior to when they would be selling to WFM.

Given that the initiative to sell fair trade beans to a WFM is on hold, Bernsten postponed completing the research paper on constraints and opportunities for exporting fair trade beans until after the above described situation is resolved.

Outputs

Documentation of the supply chain and costs associated with each component of the supply chain.

Documentation of the costs of bean production.

Collaborators

US: The principal bulk commodities buyers at WFM's US headquarters in Austin
Honduras: The elected leaders of the leaders of the farmer association (ASOCIALAYO), a bean broker, and government officials responsible for issuing an expert permit.

Objective 4: Institutional capacity building

Degree Training

First Names: Ana Lidia
Last Name: Gungulo
Citizenship: Mozambique
Gender: Female
Degree: MS
Discipline: Agricultural Economics
Host Country Institution to Benefit from Training: IIAM
Training Location: University of Pretoria, South Africa
Supervising CRSP PI: Cynthia Donovan
Start Date of Degree Program: January 2009
Program Completion Date: December 2011
Training status during Fiscal Year 2011: Active
Type of CRSP Support (full, partial or indirect): Full

First Names: Estevao
Last Name: Chaves
Citizenship: Angola
Gender: Male
Degree: MS
Discipline: Agricultural Economics
Host Country Institution to Benefit from Training: University of Agostinho Neto, Angola
Training Location: Federal University of Vicosa, Brazil
Supervising CRSP PI: Cynthia Donovan
Start Date of Degree Program: January 2009
Program Completion Date: July 2011
Training Status during Fiscal Year 2011: Completed
Type of CRSP Support (full, partial or indirect): Full

Short-Term Training: Mozambique

Type of Training: Analysis of market price data
Description of Training Activity: Participants will work with data from SIMA and complete analysis to understand analytical methods and research issues related to market prices
Status of this Activity as of September 31, 2011: Completed in November
When did the Short-Term Training Activity occur?: November 2011
Location of Short-Term Training: Maputo, Mozambique
Who benefited from the Short-Term Training Activity?: 12 staff (2 from UAN/Angola, 5 from IIAM, and 5 from Directorate of Economics/MINAG, which includes SIMA
Numbers of Beneficiaries by Gender: Male 6, Female 6, Total 12

Short-Term Training: Mozambique

Type of Training: Camtasia screen recording software
Description of Training Activity: Taught participants how to use Camtasia software
Status of this Activity as of September 30, 2011: Completed
When did the Short-Term Training Activity occur?: May

Location of Short-Term Training: IIAM, Maputo, Mozambique
Who benefitted from this Short-Term Training Activity? IIAM and UJES
Number of Beneficiaries by Gender: Male-2,Female-0,Total-2

Short-Term Training: Mozambique
Type of Training: Survey research methods
Description of Training Activity: Participants will work with specific aspects of survey methods and evaluate existing survey instruments and methods in exercises
Status of this Activity as of September 30, 2011: Not completed
When did the Short-Term Training Activity occur?: Postponed until early 2012
Location of Short-Term Training: Maputo, Mozambique
If Training was not completed as planned, provide a rationale: R. Bernsten was unable to travel to the region until early 2012.
Who (anticipated) benefitted from this Short-Term Training Activity: CESE analysts (9) and DAP (6) staff will benefit
Numbers (anticipated) of Beneficiaries by Gender: 6 women and 9 men

Short-Term Training: Mozambique
Type of Training: Cost Benefit Analysis
Description of Training Activity: Participants will attend sessions to understand the development and use of cost benefit analysis. This will be applied training.
Status of this Activity as of September 30, 2011: Not completed
When did the Short-Term Training Activity occur?: Postponed until early/mid 2012
Location of Short-Term Training: Maputo, Mozambique
If Training was not completed as planned, provide a rationale: E. Crawford was unable to travel to the region until early/mid 2012.
Who (anticipated) benefitted from this Short-Term Training Activity: CESE analysts (9) and DAP (6) staff will benefit
Numbers (anticipated) of Beneficiaries by Gender: 6 women and 9 men

Short-Term Training: Mozambique
Type of Training: Intensive English Course
Description of Training Activity: One CESE analyst will live with a family in South Africa and study English intensively, with 30 sessions per week for 8 weeks
Status of this Activity as of September 30, 2011: Not completed
When did the Short-Term Training Activity occur?: Postponed
Location of Short-Term Training: Capetown, South Africa
If Training was not completed as planned, provide a rationale: F. Mazuze indicated that the English training needs to be associated with future studies and no CESE staff have yet been accepted into graduate programs.to take advantage of this training.
Who (anticipated) benefitted from this Short-Term Training?: IAMA staff
Number (anticipated) Beneficiaries by Gender: Male 1, Female 0, Total 1

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

Type of Training: Analysis of market price data
Description of Training Activity: Participants will work with data from DSA or elsewhere and complete analysis to understand analytical methods and research issues related to market prices
Status of this Activity as of September 30, 2011: Not completed
When did the Short-Term Training Activity occur? Postponed until December 2011
Location of Short-Term Training: Luanda, Angola
If Training was not completed as planned, provide a rationale: Due to scheduling issues, we were unable to conduct this training as planned. The next window of opportunity is in December 2011.
Who (anticipated) benefitted from this Short-Term Training?: UAN/Angola staff (10) and possibly DAS staff (5-10)
Number (anticipated) of Beneficiaries by Gender: Male 8, Female 12, total 20

List of Equipment Costing >$5,000

<u>Mozambique</u>

Four wheel drive, double cabin pickup truck
Given the multiple foci of bean production and the lack of transport at the Northwestern Zonal Research Center, market and farmer research requires transport facilities. Note with earlier research, vehicles from other zonal research centers were made available, but it has become a major limiting factor.

IIAM/CESE received funds for purchase in late September 2011 and is in the process of finalizing the purchase in October 2011. IIAM will cover the costs of a driver, maintenance, and other operational costs. $40,000 was been budgeted for the purchase.

Explanation for Changes

<u>Angola: Objective 1</u>

Donovan gave a price seminar to undergraduate students while in Angola in late 2010, but still pending is the more extensive, Excel based training for analysts and more advanced students. Angola price training was to be conducted in March 2011, while Donovan was in Angola for other work, but the timing did not work for UJES. Planning is underway for training in December 2011 or February 2012. Scheduling has been a major challenge.

Attempts to time travel with the PIs of other Pulse CRSP projects in Angola have proven unsuccessful. December 2012 presents the next opportunity and we are working on that. Unfortunately, student final exams are scheduled during the next travel period for UPR researchers.

Database development has waited for Estevao Chaves to return to Angola, which only occurred in August of 2011. He will be working with UJES colleagues on this with World Vision staff in early FY 2012.

<u>Mozambique: Objective 2</u>

The cellphone technology for distributing price information has once again been delayed for SIMA due to reliance on the partnership with the National Statistical Institute (INE). As indicated above, INE delayed in establishing a contract with the service provider. Bean farmers will be among the first to be trained in using the technology once it is functioning and the Farmer Focus groups on this technology will be conducted then.

The authorization for the purchase of a vehicle has yet to be approved by USAID/Washington and it is constraining all of the field work, given the scarcity of vehicles with MINAG. The overall report and outreach are still pending, with Ana Lidia Gungulo due back in late 2011.

Survey research training with Dr. Bernsten has been postponed into early 2012 due to scheduling issues. Cost benefit training with Dr. Crawford has also been difficult to schedule and will be in early 2012, as there is high demand for this training. The PIs are concerned about training delays, with training pushed until FY2012.

As indicated above, the vehicle purchase for early FY2011 was delayed as we waited for USAID. Further delays occurred as new paperwork was needed for the funds transfer. The funds transfer was completed in late September of FY 2011, and the vehicle purchased finalized in Oct 2011.

<u>Honduras: Objective 3</u>

Scheduling a IMO certification (audit) site visit, the final step in obtaining IMO certification, was postponed, given that the farmers would not agree to the price that WFM was willing to pay for their beans.

The production and export of fair trade beans was postponed, given that the farmers would not agree to the price that WFM was willing to pay for their beans.

Achievements in the period April 1, 2011 – September 30, 2011:
Objectives/Activities planned and not achieved

<u>Objective 1: Angola:</u>

Farmer focus groups were postponed. With Estevao Chaves back in Angola, UJES and MSU look forward to working with World Vision colleagues to organize these meetings. Estevao will also need to pull together the database, using World Vision prices, as there is still no national price data collection.

<u>Objective 2: Mozambique</u>

Farmer focus groups concerning common beans were conducted in the north in collaboration with PABREN. Currently farmer focus groups are being conducted in the south for cowpeas, so this work is still ongoing. The authorization for the purchase of a vehicle has yet to be approved by USAID/Washington and it is constraining all of the field work, given scarcity of vehicles with MINAG. The overall report and outreach are still pending, with Ana Lidia Gungulo due back in late 2011.
Focus groups with farmers on the cell phone potential were also postponed due to scheduling conflicts with the SIMA staff.

<u>Objective 3: Honduras</u>

In early March 2011, Whole Food Markets (WFM) agreed to purchase 20 MT of small red beans for delivery in January 2012 at the price that the farmers had agreed to in early 2011. In late

March, Rosas and Bernsten met with representatives of the farmer group to finalize the purchasing arrangements and meet with an exporter/broker to finalize exporting arrangements. In addition, confirmed with the farmers their production costs to document that the price offered by WFM is a "fair price" (these data are require by the IMO, the third party certifier who agreed to certify the farmers beans as meeting fair trade standards). However, since early 2011, the local price of beans increased substantially, due to production shortfalls in the previous Primera and Postrera seasons. Thus, at the meeting with the farmer group, the farmers requested a higher price than WFM had originally agreed to pay. In early April, Bernsten visited with the purchasing agents at WFM's Austin, Texas headquarters to negotiate a higher price for the farmers. While WFM agreed to the price that the farmers wanted, the local bean price continued to increase. Thus, when Rosas met with the farmers to offer the higher price, the farmers noted that local traders were currently paying a higher price (nearly $1/lb) than Bernsten had renegotiated with WFM. Subsequently, Bernsten contacted WFM to discuss options. As WFM could not offer the farmers the price that they now wanted, we agree to postpone finalizing the purchase contract and wait until early 2012 to see if the local price declined to a price level that WFM was willing to pay. If the local price declined, WFM agreed to reconsider purchasing 20 MT of small red beans for delivery in mid or late 2012.

This situation highlights the challenge of getting farmers to agree to contract their bean production at a future price, when local price of beans is highly volatile and the buyer (WFM) is only willing to pay a price at which it estimates consumers will be willing to pay at its retail stores. Farmers are used to selling their beans at the spot market price, rather than contracting at a future price. Because farmers correctly or incorrectly expected that the price of beans would continue to be close to $1/lb in January 2012, they were unwilling to contract for a lower price in May 2011, 6 months prior to when they would be selling to WFM.

Given that the initiative to sell fair trade beans to a WFM is on hold, Bernsten postponed completing the research paper on constraints and opportunities for exporting fair trade beans until after the above described situation is resolved.

Objective 4: Capacity Building

Angola price training was to be conducted in March 2011, but the timing did not work for UJES. Planning is underway for training in December 2011. Scheduling has been a major challenge. Donovan did give a price seminar to undergraduate students while in Angola in late 2010, but there is still pending the more extensive, Excel based training for analysts and more advanced students.

Mozambique: Survey research training with Dr. Bernsten has been postponed into early 2012 due to scheduling issues. Cost benefit training with Dr. Crawford has also been difficult to schedule and will be in late 2011 or early 2012 as there is high demand for this training.

Networking and Linkages with Stakeholders

Angola

The project PIs met in Huambo with World Vision, a key development agency involved in farmer productivity and market extension activities with its ProRenda project. Donovan worked with their marketing officer to modify data collection and dissemination aspects. Students will have access to the database of prices as it develops, but it is still of short duration and limited usefulness for analysis. The links of this work with that project also enables outreach directly to farmer associations in the Planalto Region of Angola. As suggested by the USAID mission in Angola, Donovan also met with the Farmer to Farmer director for Angola and discussed potential linkages between the programs on extension messages and market information.

Mozambique

Discussions with TradeHub, Agrifuturo, and a private sector marketing firm (OLAM) have focused on two aspects. For TradeHub, the effort was to link South Africa traders and processors to producers and markets in northern Mozambique. With OLAM, the discussions focused on using OLAM buying points for storage and other technology dissemination. We will need to take advantage of those links in FY2012. PABREN and Pulse CRSP researchers wish to move the "Feijao"[2] Task Force forward jointly.

Honduras

The PI's met with: 1) the leaders and members of the farmer association to discuss the IMO certification process, the certification timetable, the costs of bean production, and the price that they required to supply WFM with 20 MT of beans, 2) a bean broker in Tegucigalpa to identify steps that had to followed to export the beans and the costs associated each step, 3) government official to understand the process for obtaining an export permit, and 4) bulk commodity purchasing staff at WFM to update them regarding the costs involved at each stage of the supply chain and to negotiate the price that WFM would be willing to pay for the beans.

Leveraged Funds

Angola

Name of PI receiving leveraged funds: Cynthia Donovan
Brief description of leveraged project and purpose: Funds for the markets research and price data collection.
Dollar Amount: It is difficult to calculate the value of contributions. At a minimum, we estimate $1,000 for Donovan travel to Angola.
Funding Source: World Vision

Mozambique

Name of PI receiving leveraged funds: Feliciano Mazuze
Brief description of leveraged project and purpose: PABREN funds for market research, farmer focus groups in the north
Dollar Amount: $5,000 (estimated)
Funding Source: PABREN

Honduras

Name of PI receiving leveraged funds: Juan Carlos Rosas
Brief description of leveraged project and purpose: Funds for supporting research related to agro-biodiversity, seed production, and organic bean production
Dollar Amount: $50,000/year; Funding Source: Norwegian Development Fund

[2] The word Feijão in Portuguese covers both beans and peas.

Scholarly Activities and Accomplishments

Angola

Artur Paulino, "Potencial comercial de feijão macunde em Angola" (Commercial potential for Cowpeas in Angola). 2011. Thesis for UJES.

Estevao Chaves. Interdependência dos Preços de Feijão-Vulgar entre Cinco dos Principais Mercados em Moçambique. (Interdependence of common bean prices among markets in Mozambique). MS Thesis for University of Vicosa, Brazil.

Mozambique

Publications pending.

Michigan State University/Honduras

In April 2011 PI Richard Bernsten received *The Ralph H. Smuckler Award for Advancing International Studies and Programs at MSU***,** The award recognizes and rewards a faculty member each year for his/her significant and lasting impact on the advancement of international scholarship, teaching, and public service.

Tables/Figures

Mozambique

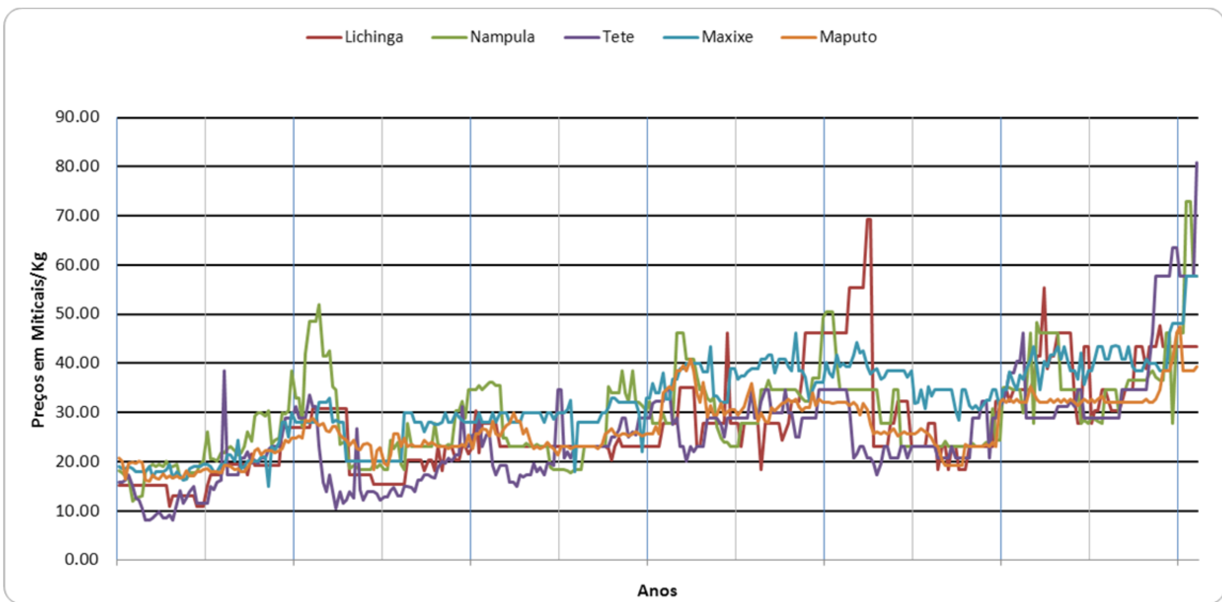

Figure 1: Common bean price tendencies in the markets of Lichinga, Maputo, Maxixe, Nampula e Tete, January 2005 – January 2011, in Meticais/Kg

Source: Chaves, Estevao. Interdependência dos Preços de Feijão-Vulgar entre Cinco dos Principais Mercados em Moçambique. (Interdependence of common bean prices among markets in Mozambique). MS Thesis for University of Vicosa, Brazil.

Literature Cited

No literature cited.

Contribution to Gender Equity Goals

In all countries, women participated in training activities and analysis of survey data included gender analysis.

Angola

The survey samples included women and the analysis of these data analyzed gender issues. Note: almost all cowpea traders are women.

Mozambique

The MS training of 1 female researcher was supported by the CRSP. In addition, 6 women participated in Short-Term training activities.

Honduras

Six women participated in Short-Term training. In addition, many of the participants in the on-farm trials were women and many women farmers are using organic fertilizer and pest control products.

Progress Report on Activities Funded Through Supplemental Funds

Mozambique

The computers, cameras and software (Camtasia) were purchased in FY 2011 and both Angola (UJES) and Mozambique (IIAM) are now using the equipment. Training on Camtasia was completed in early May 2011, and the team recorded an initial program on bean pricing in Mozambique, in collaboration with SIMA staff member Dolito Longanemio. The Angolan technical specialist Guilherme Eculica was in Mozambique May10-13, working with Sostino Mocumbi (IIAM), Dolito Longanemio (SIMA), David Cantor (SCIP project), and Donovan. With TradeHub, there is interest in the assisting with dissemination of storage information, so we will be linking him with the IIAM effort to create Portuguese voice overs for the University of Illinois animated videos showing solar drying and triple bagging. Our IIAM collaborator under the Capacity Building project has already created the voice over for the solar drying of cowpeas and we will be working further with IIAM and others to evaluate the usefulness of this communication technology with Pulse CRSP collaborator Barry Pittendrigh at University of Illinois.

Honduras

No supplemental funds received

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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

	Abbreviated name of institutions											
	#REF!			UNA			IIAM			EAP		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1: Angola												
1. Identify efficiency in marketing channels & leverage points to increase farmer profits & trader volumes												
Outreach on marketing report (Phase I) for smallholders and other stakeholders												
Database on bean production and marketing documented and established												
Focus groups with farmer associations held on marketing analysis				X		X						
Objective 2: Mozambique												
1. Identify efficiency in marketing channels & leverage points to increase farmer profits & trader volumes												
Database on bean production and marketing documented and established												
Outreach for Report on Bean Value Chain (output from Phase I)							X		X			
Farmer focus groups to discuss results and identify opportunities							X		X			
Meeting of National Bean Task Force							X	X				
Summary report on two windshield surveys and bean results												
Conduct additional field research with Windshield Survey 2011	X	X					X	X				
2. Develop cellphone-based information system for beans, to link farmers & traders to market prices & availability												
Launching of cell platform in at least one bean production zone												
Database on bean prices available through website	X		X									
Focus groups with farmers to ensure usefulness of cell phone system							X		X			
Objective 3: Honduras												
1. Conduct on-farm trials to validate organic bean-production practices, including organic fertilizer and pesticide from plant extracts												
On-farm trials using organic fertilizer and plant extracts										X	X	
Conduct commercial organic plots										X	X	
2.Provide technical assistance to farmer group interested in establishing commercial organic bean plots												
Collaborate with NGO on assisting CIAL										X	X	
Conduct training course											X	
3. Assist farmer groups to obtain fairtrade certification												
Prepare request with farmer organization												
Submit request for certification												
4. Export fairtrade beans to a US retailer												
Negotiate export contract												
Finalize export of beans	X		X									
5. Research papers summarizing constraints & opportunities for exporting fair trade beans	X		X									

Objective 4: Capacity Building												
Angola												
MS Thesis proposal	X	X		X	X							
MS thesis field research designed and conducted	X	X		X	X							
Students trained on use of market price data												
Mozambique												
MS thesis proposal for Univ. of Pretoria	X	X					X	X				
MS thesis field research designed and conducted	X	X					X	X				
CESE staff trained in Price data analysis												
CESE staff trained in Survey Research methods												
CESE staff member completes Intensive English course												
Honduras												
Training course for organic bean production												
Name of the PI reporting on benchmarks by institution	Bernsten-Donovan			Donovan-Kiala			Donovan-Mazuze			Rosas		
Name of the U.S. Lead PI submitting this Report to the MO	Richard H. Bernsten											

Richard H. Bernsten 10/4/2011

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, 2010 -- September 30, 2011)

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

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

Output Indicators	2011 Target (October 1, 2010-Sept 30, 2011)	2011 Actual (October 1, 2010-Sept 30, 2011)
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	24	2
Number of men	34	5
Technologies and Policies		
Number of technologies and management practices under research	6	6
Number of technologies and management practices under field testing	3	2
Number of technologies and management practices made available for transfer	2	2
Number of policy studies undertaken	2	2
Beneficiaries:		
Number of rural households benefiting directly	50	100
Number of agricultural firms/enterprises benefiting	3	1
Number of producer and/or community-based organizations receiving technical assistance	6	10
Number of women organizations receiving technical assistance	2	2
Number of HC partner organizations/institutions benefiting	5	2
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	100	200

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

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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.

Progress on Project Activities for the Report Period by Objectives

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

Activity 1.1 Breeding Mesoamerican bean lines with greater tolerance to drought and low P availability.

A set of 50 inbred-backcross (IBC) lines were selected from three populations (a total of 310 lines) under drought and low P conditions on greenhouse and field trials conducted in Honduras. Selection was based on agronomic adaptation traits (plant architecture, disease resistance, maturity, vegetative and reproductive growth), yield and seed color (1-9 red seed color scale), shape and size (100 seed wt) of these lines similar to those from the recurrent parent Amadeus 77. Part of this work was conducted as the research thesis for graduation by Mr. Fausto Román, a Zamorano student from Ecuador in 2009. These IBC populations were developed by crossing the small red cultivar Amadeus 77 (recurrent parent) with lines L88-13, L88-43 and L88-63 (donor parents) selected at PSU from the L88 (TLP 19 x B98311) population by having root traits associated to better adaptation to drought or low P stress conditions.

These 50 IBC lines were evaluated under greenhouse conditions and root traits were phenotyped by visual counts and observations of whorl number, basal roots number and angle; root density, surface area, volume and length were determined using the Winrhizo program. Part of this work was conducted as the research thesis for graduation by Mr. Antonio Morales, a Zamorano student from Panama in 2010. The same set of 50 IBC lines was sent for root phenotyping by at PSU facilities, and specific lines with contrasting root characteristics under low P greenhouse conditions, were identified for further studies.

A selected set of 20 IBC lines was screened during the primera raining season, under field conditions without fertilization in a low P soil at Zamorano. The IBC lines were evaluated for plant growth, root traits (whorl number, basal root number and angle) and nodulation at flowering, and seed yield and seed size at maturity. A small group of six IBC lines similar to the recurrent parent Amadeus 77 will be screened under farmer field conditions, to determine the performance of individual lines or line combinations under different soil fertility and moisture conditions.

A set of 18 lines including drought and low fertility tolerant lines (A774, VAX 3, PR0340-3-3-1, IBC 309-23, IBC 302-29, SX14825-7-1, TLP 19, RAB 651 and others) and two check cultivars (Amadeus 77 and the landrace Seda), were evaluated under field conditions at Zamorano, in a low P soil and without fertilization conditions. Plant dry weight, root whorl number, basal root number and angle, and nodulation were determined at flowering; and seed yield and seed size at maturity. Superior genotypes from this study will be used as donor parents for improving tolerance to drought and low fertility of small red and black commercial bean cultivars, using recurrent selection and other breeding methods. The same set of 20 lines is being characterized for root hair density under greenhouse conditions to determine the importance of this trait under limited moisture and low fertility soil conditions. In addition, the importance of root hair density on rhizobia nodulation is being characterized using the plastic pouches technique.

The same low P soil plot at Zamorano was used to test a set of 20 small red and black bean improved cultivars under no fertilization conditions. These cultivars are currently the most used by small farmers in Central America and Haiti, and are frequently grown under drought and low fertility soil conditions. The significant adoption of these improved cultivars in these regions is due to their superior disease resistance and greater adaptation to a variable array of production conditions, where drought and low fertility are some of the major production problems encountered by most small farmers. Selected cultivars having superior performance under low fertility and drought will be used to identify elite parental genotypes for developing superior small red and black bean cultivars in crosses with donor parents mentioned above.

Breeding lines developed under this project in previous years using the inbred backcross method, are currently in the stage of advanced testing on farmer fields. It is expected that at least one cultivar from this group of advanced lines will be released next year in Honduras and/or Nicaragua. This effort was conducted in collaboration with the UPR/Beaver DGPC Project.

IIAM/Mozambique and PSU

Activity 1.2. Evaluation and selection of bean genotypes with root traits adapted to drought and low P availability

Low phosphorus (P) availability and drought are major constraints to common bean production in many developing countries. Root traits influence P and water acquisition from the soil. Genotypes with shallow roots, many basal root whorls, adventitious roots and basal roots have advantages in acquiring P from low P soils, while genotypes with deeper basal roots and longer primary roots will acquire water from deeper soil horizons. More than 160 bean genotypes from CIAT were screened in 2010 and 2011. The objective of the present study was to identify sources of tolerance for drought and low P adaptability. The experiments were planted in a randomized complete block design with 4 replications in Mozambique and PSU. The number of basal root whorls and basal roots were evaluated in the laboratory 8 days after planting and in the field 45 days after planting. Field evaluations included adventitious and basal root number, basal root whorl number, length and branching of the adventitious, basal and primary roots, number of nodules and scores of the root rot infection. We found large variation in number of adventitious and basal roots, whorl number among genotypes. Variation in root density (branching), and root length of adventitious, basal and primary roots as well as number of nodules where detected (Figure 1). Sources of tolerance to drought and low P adaptability were identified and these genotypes could be used in breeding programs for development of bean genotypes adapted to specific stress. We identified 29 genotypes with a potential of having up to 13 basal roots per plant, and 31 genotypes with long and deeper roots for drought tolerance. Figure 2 illustrates examples of root traits of genotypes with root traits adapted to drought and low P conditions.

Root traits conferring adaptability to drought include deeper roots, while genotypes with shallower roots, numerous adventitious and basal roots, and long and dense root hair have advantage in acquiring P in the topsoil.

Activity 1.3. Identification of common genotypes adapted to drought

Drought is one of the major constraints to common bean production in Africa and Latin America. Most of the bean production areas in Mozambique and Southern Africa are located in regions susceptible to drought stress. The objective of the present study was to identify bean genotypes adapted to drought. Twenty-one bean genotypes introduced from CIAT and local germplasm including genotypes known to be drought tolerant were used in this study (Table 1). A field trial was conducted at the IIAM Agricultural Research Station of Chokwe, Mozambique in 2011. Genotypes with 2 and 3 basal root whorls were also included in the present study. The experiment was planted in a RCBD with 4 replications. Seeds of each genotype were sown in three rows of 5 m, and the planting space was 0.7 m between rows and 0.15 between plants in a row. Weed and pest management and irrigation were applied as needed. Collected data included phenological data such as days to flowering and maturity. Other collected data included number of pods per plant, weight of 100 seeds and yield. Currently we are drying the seed in order to collect yield data, and it was not possible to include the data this report. Preliminary results showed significant differences among genotypes in number of pods per plant at the 1% level of significance. The number pods per plant varied from 17 to 44.8. Tio Canela and BAT 477 had 44.8 and 44.6 pods per plant, respectively. G 19833 had an average of 31.7 pods per plant. Tio Canela and BAT 477 are drought tolerant genotypes and previous studies showed that these genotypes have deeper basal roots. The control local varieties Bonus had 28 and Khaki 26.2 pods per plant. Selected and promising genotypes will be used in advanced trials for yield performance and adaptability in both drought and low P conditions.

Activity 1.4. Development of P-efficient common bean genotypes and advance generations of selfing

The objective of this study was to develop P efficient lines adapted to Mozambique. Crosses using parents contrasting in root hair traits were made to incorporate good root hair traits into adapted bean varieties. Root hair traits of F3 and F4 lines were evaluated in the laboratory in 2010 at PSU. Our results showed genetic variation in root hair traits and basal root whorl number within populations (Figure 3). About 300 F5 lines derived from these crosses were increased in Chokwe in 2011. Selected lines will be tested in 2012 for adaptability and yield performance under drought and low P availability in different sites in Mozambique.

Activity 1.5. Phenotypic profiling of root traits of six genotypes tolerant to drought

Drought is one of the major constraints to common bean production in Africa and Latin America. Bean genotypes with deep and steeper roots have advantages in acquiring water from deeper soil horizons. The objective of the present study was to evaluate root traits of six bean genotypes. Six genotypes were planted in a RCBD with 4 replicates in Chokwe in 2011. Root architectural traits were evaluated 45 days after planting and soil cores were collected in 3 different horizons. Variation in adventitious, basal and primary root traits was found among genotypes. BAT 477, Tio Canela and SEQ 1003 had 67.5^{o}, 62^{o} and 57^{o} basal root growth angle (Table 2), respectively, corresponding to deep basal roots. These genotypes could acquire water from deeper soil strata under drought stress. The number of basal root whorls varied from 2 to 4, while the number of basal roots varied from 7 to 14 (Table 2). We also identified sources of tolerance to low P availability in local germplasm collected in Lichinga. Lines LIC-04-2-1 and LIC-04-3-1 had more whorls and basal roots, and shallower roots conferring adaptability to low P conditions (Table 2). We also collected other data to evaluate yield performance. We are currently drying the seed of these genotypes to measure yield performance and compare with root architecture. The roots from the soil core samples will be evaluated and compared with basal root growth angle.

Activity 1.6. Seed increase

Seeds of different genotypes were increased in Chokwe and Sussundenga in 2011. The objective is to multiply seed for future research and promising lines, and maintain common bean germplasm.

Activity 1.7. Utility of BRWN for breeding P efficient lines

We conducted a field study on the functional utility of basal root whorl number (BRWN) for phosphorus acquisition efficiency in common bean *(Phaseolus vulgaris L.).* Six contrasting RILs derived from G2333 x G19839 were used in the field experiment. The RILs used in this study were grouped in two root categories: genotypes with two whorls (G2333, GG 37 and GG 80), and genotypes with three whorls (G19839, GG 41 and GG 48). These genotypes were selected after screening the entire population of 87 recombinant inbred lines in cigar rolls method in the laboratory. A completely randomized design was used in the field experiments. Each treatment had 4 replications of each of 3 genotypes per BRWN category (2 vs. 3 whorls). Each plot contained three planting rows of two meters long and between-row spacing of 60 cm. Twenty-one seeds were planted in each row, with a spacing of 10 centimeters within the row (60 cm x 10 cm spacing).

The field study was carried out in Mozambique at the Sussundenga Research station in Manica Province (19^{o} 19’ 02.00” S and 33^{o} 14’ 25.24” E, 620 m.a.s.l.). The soil type at the research site is an Ustox with low pH (4.5 to 5.5), and low organic matter (less than 5%). Three months before planting, the soil was limed ($CaCO_3$) to bring the soil pH to 6.2. The annual average precipitation is 1100 mm. However on that particular year the region experienced some drought during the growing season, and the annual precipitation was about 758 mm, and unevenly distributed. However, this did not affect the experiment, since we irrigated the field as needed to keep soil moisture content close to field capacity, during plant growth. Temperatures ranged from 14 to 28 ^{o}C. The experiment was planted in February 2010. Seeds were inoculated with rhizobia inoculum (Bunda College Microbiology Lab, Malawi), on the day of planting. The experiment had phosphorus and low phosphorus treatments. All other nutrients were kept optimal through chemical fertilization. Simple superphosphate was used as the source of additional P for fertilized plots, and applied at the rate of 100 kg per ha. According to soil analysis taken after harvest, fertilized plots actually showed 19 ppm and low phosphorus plots showed 5.5 ppm phosphorus, indicating that we had moderate phosphorus and low phosphorus treatments. Weed control was performed manually. Pest control was performed through application of pesticides. Sprinkler irrigation was used for supplementary irrigation.

In order to evaluate root distribution with soil depth, we took cores in the field at 28 DAP. Root coring consisted in extracting soil samples by hammering 5-cm diameter metal cylinder vertically into the soil. Then soil sections were separated from 0-15 cm depth and 15-30 cm soil depth. Then root fragments were recovered from each of these soil sections then scanned. Scanned root images were analyzed using WinRhizo Pro (Régent Instruments, Québec, Canada), and then root length from the cores determined.

Collected data included shoot dry weight, total root length, total leaf surface area, basal root whorl number, basal root number, and total phosphorus content. Plant samples were collected in three harvests at 14, 21, and 28 days after planting. Shoot biomass was determined from samples dried at 60 ^{o}C for 5 days. Tissue phosphorus content was determined using Murphy and Riley method with a spectrophotometer (Murphy and Riley, 1962). During shoot sampling, leaf discs (6.6 cm^2) were collected from five fully expanded leaves. The ratio of dry weight to area of these disks was used to estimate total shoot leaf area from total leaf dry weight. At plant sampling, roots crowns were excavated and placed in a 20-liter container with soap for washing. Detergent was added to the water used to wash the roots helped to separate roots from soil particles, without significantly damaging the root system or losing a large number of fine roots. Then, root samples were washed and rinsed in clean tap water and placed in the vials with 25% ethanol solution for preservation. Roots were scanned on an EPSON Perfection V700 PHOTO scanner from ICE digital technologies). The images were analyzed for total root length, and root length in each of the root classification by root diameter, using WinRhizo Pro (Regent Instruments, Québec, Canada). Although genotypes were selected based on their basal root whorl number, plants harvested at 14 DAP were re-assessed for basal root whorl number to confirm the root phenotypes. The evaluation consisted of selecting and excavating three representative plants from each replication, determining BRWN and BRN by counting root whorls and basal roots, and calculating the average value for each replicate. Analysis of variance (ANOVA), Tukey test for comparisons between means, and regression analysis was performed using Minitab.

Variation in BRWN and BRN was evaluated and it was in accordance to whorl classes of the genotypes. Data analysis showed variation in shoot dry weight among genotypes with either medium or low phosphorus availability. However whorl class effect was greater in low phosphorus treatments than in high phosphorus. When genotypes were grouped by BRWN, statistically significant differences were detected between the two whorl classes under low phosphorus availability (Figure 4). Genotypes with three whorls showed statistically greater shoot dry weight compared to those with two whorls (Figure 4). Tukey test showed that genotypes GG48, GG41 and G19839, all with 3 whorls, had significantly greater shoot dry weight compared to genotypes GG37, G2333 and GG80, with 2 whorls.

Under low phosphorus availability, two out of three genotypes with 2 basal root whorls showed significantly less leaf area than genotypes with 3 basal root whorls. Statistical analysis showed significant differences in seed weights and interaction between whorl and weights, with F value =13.3 and 7.3, respectively.

Genotypes with 2 whorls had 33.2% reduction in tissue phosphorus content when grown under high phosphorus availability while under low phosphorus, the 2-whorled genotypes had 46.5% reduction in tissue phosphorus content compared to genotypes with three whorls (Figure 5).

Tukey test among genotypes growing with low phosphorus showed that genotype GG48, GG41 and G19839 all with 3 whorls had significantly greater phosphorus content compared to genotypes GG37, G2333 and GG80, with 2 whorls. Within 3 whorl-genotypes, genotype GG48 had statistically greater phosphorus content compared to the other two genotypes, which did not differ among themselves.

BRWN and BRN showed differences among genotypes in accordance with their respective whorl classes. Phosphorus treatment did not alter BRWN or BRN.

Genotypes were also evaluated for root hair length both under low and high phosphorus availability. All genotypes had greater root hair length under low phosphorus availability compared to high phosphorus availability but there were no statistically significant differences among genotypes within low or medium phosphorus treatments.

We collected soil cores at two depths in the field at 28 DAP to analyze root length distribution with depth. Root length in the cores collected at 0-15 cm depth showed statistically significant differences between whorl classes. Genotypes with 3 whorls showed more roots in the top 15 cm than genotypes with 2 whorls, while genotypes with 2 whorls had greater root length in the 15-30 cm segments. Total root length from soil cores (0-30 cm depth), was greater in genotypes with 3 whorls compared to genotypes with 2 whorls. This suggests that genotypes with increased number of basal root whorls have more extensive root system (in terms of total root length), compared to genotypes with less number of whorls. This was confirmed in scans of the entire root systems. Results of data analysis for relative root length among genotypes showed that genotypes with three whorls showed greater relative root length compared to genotypes with two whorls both under low phosphorus and medium phosphorus availability. Differences in number of adventitious roots ware observed among genotypes, but they were not influenced by phosphorus availability.

These results suggest that BRWN has the potential to improve plant performance under low phosphorus conditions. BRWN is beneficial not only by promoting an increase in BRN, but also by enabling a more dispersed root system that is capable of maximizing the soil volume being exploited by the plant. The positive effect of BRWN on total leaf area, shoot dry weight, and shoot phosphorus content suggests that this trait helped the plants to acquire phosphorus and other nutrients from the soil, which in turn enabled them to grow large and vigorous leaves for photosynthesis.

The variation in root hair length is less likely to be related to the basal root whorl number or total number of basal roots that a given genotype may have.
Adventitious rooting is important for topsoil foraging in common bean. Topsoil foraging by adventitious roots may have temporal as well as spatial benefits for plant phosphorus economy. Data analysis on adventitious roots among genotypes showed no correlation with variation in BRWN. However, there was an increase in the number of adventitious roots in the low phosphorus treatment in all genotypes regardless of BRWN. In fact, other studies found that phosphorus availability as well as number of environmental factors influences adventitious rooting in the field, notably soil moisture and aeration near the hypocotyl.

The differences observed in root length in the top 15 cm of the soil show that genotypes with 3 whorls had more shallow root distribution compared to genotypes with 2 whorls. This confirms our hypothesis that suggests that the more whorls a genotype may have, the more shallow root system it has. Therefore, the main benefit of having increased number of whorls is not obtained by the fact of having increased value of total root length, but it is mainly because of having more dispersed root system, with the roots coming from the upper whorls growing shallower. These plants then exploit a greater total volume of the soil and in particular, more of the top soil, facilitating a top-foraging process, reported to be very beneficial for plants growing under low phosphorus availability, since shallower basal roots allow more intense topsoil foraging, which may be advantageous in P-limited environments since phosphorus availability in most soils is greatest in surface horizons.

There are several lines of evidence suggesting that shallower basal root growth enhances topsoil foraging and thereby phosphorus acquisition efficiency. In addition, deeper roots formed from the lower whorls can be important for drought tolerance, since one of the root characteristics for drought tolerance is the existence of deep roots in beans. This suggests that the number of basal roots is important not only for nutrient acquisition but also for drought tolerance. Observations of wild and cultivated bean genotypes shows that cultivated varieties tend to have more basal root whorls compared to wild types.

The screening for basal root whorl number among Recombinant Inbred Lines (RILs) demonstrated the variability of this root trait among related genotypes. Our results show that genotypes with more root whorls have the ability to form more basal roots, and these basal roots are formed with a greater range of angles of insertion from the main primary root, which enhances the volume of soil exploited by the plant. The existence of variation in BRWN in common bean suggests that a breeding program can be devoted to development of genotypes with increased number of basal whorls that can perform well in the conditions of low phosphorus availability.

Activity 1.8. Utility of BRWN for drought tolerance in common bean

In this activity we tested the value of increasing BRWN for drought tolerance in two field studies; on**e** at the Russell E. Larson Agricultural Research farm in Rock Springs, PA, and one at the Ukulima Root Biology Center (URBC) in the Republic of South Africa (RSA), in two field seasons in 2010. As drought was developing at URBC the plots received substantial rainfall, negating drought effects. This summary will therefore focus on the Rock Springs study.

Rain-out shelters at the Russell E. Larson Experimental Farm of the Pennsylvania State University at Rock Springs, PA (40°43’N, 77°56’W) were used to impose a terminal drought treatment during the summer months of 2010. Sensing precipitation, shelters covered with clear greenhouse plastic film (0.184 mm) (Griffin Greenhouse & Nursery Supply, Morgantown, PA, USA), moved over the drought treatment plots, reversing direction to expose the plots at the end of the rainfall. Adjacent plots without shelters served as controls. The soil at this site was a Murrill silt loam (fine-loamy, mixed, semiactive, mesic Typic Hapludult), with a pH of 6.6. The plots were fertilized on 27 May 2010 with a custom blend at a rate of 35kg/ha N, 70kg/ha P and 20kg/ha K, deep chiseled, harrowed and scored in early June 2010. On 9 June 2010 all plots received herbicide, Medal II at 1.5pts per acre. Block 1 was planted on 29-30 June 2010 and Block 2 on 18-19 July 2010. The plots received herbicide, 2pts per acre Basagran, on 1 July

2010, and 2pts per acre Asana insecticide on 28 July 2010. Block 1 received 100.33 mm of precipitation/drip irrigation before imposing drought at 22 DAP, and Block 2 78.24 mm before starting drought at 21 DAP. The control plots continued to receive precipitation/drip irrigation through the final harvest at mid-pod, Block 1 receiving193.05mm and Block 2 134.12mm.

The trial design at Rock Springs was arranged as a split-plot for the water treatment. Each BRWN phenotype group (1, 2, 3) was represented by four genotypes of the ALB RIL population, with 5 extra genotypes for comparison. Each genotype was planted in a plot of 4 2m rows; 2 outside rows as borders and 2 inside rows for data collection. The genotype plots were distributed randomly throughout the control and drought plots. The in-row spacing was 0.10m and the between row spacing 0.60m to mimic the planting practice in Latin America.

All seed was provided by CIAT, in Cali, Colombia. Twenty genotypes from two RIL (recombinant inbred line) populations ALB and DOR364 x G19833 were used for these studies. (See Table 1 for the RIL numbers used and their BRWN.) The ALB RILs were planted in the trial at Rock Springs. Both population sets were planted at the trial at the Ukulima Root Biology Center (URBC). The ALB population (SER 16 x (SER 16 x G35346 – 3Q)) is an inter-specific cross of the drought tolerant, small red, Mesoamerican SER 16 a *Phaseolus vulgaris* with G35346 – 3Q a large seeded *Phaseolus coccineus*. SER 16 has a BRWN of 2 and G35346 – 3Q has a BRWN of 3.5. The progeny segregate for 1, 2 and 3 BRWN. DOR364 has a BRWN of 2 and G19833 has a BRWN of 3, are both *P. vulgaris*. The progeny segregate for 2 and 3 BRWN. DOR364 is a drought tolerant, small black, Mesoamerican. G19833 is a low phosphorus tolerant, large seeded Andean. The BRWN categorical grouping of the ALB and DOR364 x G19833 genotypes is based on phenotyping in sterile laboratory conditions 2-3 days after germination. The RILs were chosen based on CIAT's BRWN characterization, and confirmed before each trial.

At both sites a TDR100 system (Campbell Scientific Inc., Logan, UT, USA) was used to monitor soil volumetric water content over time. The data was collected using a CR1000 data logger (Campbell Scientific Inc., Logan, UT, USA). At the Ukulima Root Biology Center (URBC), because of cable length restrictions of the TDR100, data was collected continuously only in Block 2 with 7 reps in each treatment. The soil VWC was collected manually twice per week from the other 3 blocks with 5 reps in each treatment. Each rep had a three-pronged 20cm probe buried directly under a row at 20cm and 50cm.

At the trial in Rock Springs, soil VWC was collected continuously from Block 1 with 5 reps per treatment with three-pronged 20cm probes buried at 0.15m and 0.40m directly under a row.

Soil cores for soil water content were taken at both sites to compare with the TDR-100 measurements. The soil gravimetric water content from the cores was converted to volumetric water content using the bulk density of the soil, 1.28g/cm^3 at the URBC and 1.6g/cm^3 at Rock Springs site.

At the Rock Springs site, variation in secondary growth of basal roots was measured over time. Five samples from 4 genotypes were harvested for root crown evaluation beginning at 13 DAP and continuing every 7 days for 4 total harvests until R5 (42 DAP). Root crown evaluation included BRWN, BRN, the number of dominant basal roots, diameter of each basal root, diameter of a representative adventitious root, and the tap root diameter. Each diameter measurement was taken 1cm from the point of attachment. The basal area of each sample was preserved in ethanol for later sectioning.

At the Rock Springs site, root crowns were evaluated at R5 (Block 1 42 DAP, Block 2 43 DAP) and R7 (Block 1 69 DAP, Block 2 66 DAP). At both sites and harvest times the root crown evaluation included BRWN, BRN, the number of dominant basal roots, diameter of each basal root, the average basal whorl angle, and a compensation rating between the adventitious, basal, and tap root classes. The harvests at Rock Springs also included the diameter of a representative adventitious root and the tap root diameter. Each diameter measurement was taken 1cm from the point of attachment to the hypocotyl for the adventitious and basal roots, and 1 cm down from the boundary between the tap root and hypocotyl for the tap root measurement. At each harvest at the Rock Springs site each genotype plot had 5 subsamples of neighboring plants, 2 of which were preserved in ethanol for later sectioning.

Root distribution in the soil profile was measured from soil cores (Giddings Machine Co.,Windsor,CO, USA) taken at the Rock Springs site in Block 1 at both R5 (48 DAP) and R7 (72 DAP) stages, and at the Ukulima Root Biology Center (URBC) site taken in all blocks at both R5 (only control) (ALB at 42 DAP, DOR364 x G19833 at 48 DAP) and R7 (ALB and DOR364 x G19833 at 57 DAP) stages. Cores of 0.05mx0.50m were taken in-row between two neighboring plants. At the Rock Springs site, two genotypes from each BRWN category, and at the URBC 4 genotypes from both populations were chosen for sampling. Three subsample cores were taken per plot. The cores were divided into 5 0.10m sections, from which the roots were washed, scanned and analyzed for total root length and root length in diameter classes using WinRhizo software (WinRhizo Pro, Régent Instruments, Québec, Québec City Canada). Samples from the URBC were weighed immediately after washing for fresh weight then preserved in 75% ethanol, drained of ethanol, and transported to Penn State University for analysis with WinRhizo.

At the Rock Springs site several measurements were taken to determine the water status of the plants in control and the drought treatment plots. Before the R5 harvest (Block 1 48 DAP, Block 2 45 DAP) the pre-dawn water potential was measured using a Scholander leaf pressure chamber (“pressure bomb”) (Wescor, Inc). Four samples from 4 genotypes were measured from both control and treatment plots. The fourth or fifth trifoliate was used for this measurement.

Leaf relative water content (RWC) was measured before imposing drought (Block 1 22 DAP) and again after the harvest at R5 (Block 1 50 DAP, Block 2 52 DAP) and the harvest at R7 (Block 1 71 DAP). Two genotypes per phenotype were selected and sampled from both the well watered control and drought treatment areas. Discs (25.4mm) were cut from the first and second trifoliate using a hole puncher and immediately sealed in a plastic bag and the fresh weight (FW) determined. The discs were left floating in water overnight for fully turgid weight (TW) measured the next day, finally placed in a paper envelope and dried at 60C for 2 days (DW). Leaf RWC was determined by ((FW-DW)/(TW-DW))100 (Turner, 1981). Intermittent rainfall did not permit taking leaf RWC measurements at the URBC.

Leaf area and shoot branching were measured (Block 1 37 DAP, Block 2 39 DAP) before the harvest at R5 at Rock Springs to measure the effect of water deficit (Shao et al., 2009). At the

URBC, after the harvest at R7 (70 DAP), leaf area, branching and number of pods indicating flower abortion were measured.

At the Rock Springs site the shoot biomass was saved from root crown phenotyping and oven dried at 60C at both the R5 harvest (Block 1 42 DAP, Block 2 43 DAP) and R7 harvest (Block 1 69 DAP, Block 2 66 DAP). The same method was used at the URBC for the R7 harvest (55 DAP).

The statistical software RStudio Version 0.93.84 (RStudio, Inc.) was used for all data analyses. The pod partitioning index (PPI) was calculated by (pod dry weight/shoot dry weight) multiplied by 100. Standard ANOVA analysis was used for BRWN or other categorical grouping where group and water treatment are fixed variables. Regression and ANCOVA analysis were used for several root traits as noted in results, including allometric analyses. Significance level was set at 0.05 unless otherwise noted. The sample size of each analysis is noted throughout.

Greater BRWN was correlated with greater shoot growth of common bean under terminal drought. At R5, after 19 days of imposed drought, the plants under water stress had significantly less shoot dry weight than the well watered control. The well watered plots had no difference in shoot dry weight among the three BRWN phenotype groups, yet under terminal drought, genotypes with 3 whorls had 70% greater shoot dry weight than genotypes with 1 whorl (Figure 6). By R7 there were no differences in shoot growth among BRWN groups ($p = 0.7906$, $F = 0.24$). Genotypes with 2 whorls did have a greater pod partitioning index than genotypes with 1 whorl in drought ($p < 0.05$), and had pod weight in drought comparable to genotypes with 3 whorls under well watered control ($p < 0.05$).

Other Research Activities

1. Evaluation of 43 bean genotypes for performance under low phosphorus availability (Figure 1.1). Results of these evaluations have identified a number of genotypes with yields more than 1.5 MT/ha, which can preliminary considered phosphorus efficient genotypes. Further evaluations are planned for the upcoming season to validate the results obtained in the first evaluation and b) determine the root trait/traits associated to the observed phosphorus efficiency.

2. Evaluation of 32 BILFA genotypes for performance under low phosphorus availability (Figure 1. 2). Results of these evaluations have identified 3 genotypes (BILFA MR 13456-12-6, BILFA MR 13506-7 and BILFA MN 13389-6), with yields more than 1.5 MT/ha, which can preliminary considered phosphorus efficient genotypes. Further evaluations are planned for the upcoming season to a0 validate the results obtained in the first evaluation and b) determine the root trait/traits associated to the observed phosphorus efficiency.

3. Evaluation of 69 bean genotypes for performance under low phosphorus availability (Figure 1.3). Results of these evaluations have identified 39 genotypes with yields more than 1.5 MT/ha, which can preliminary considered phosphorus efficient genotypes. Further evaluations are planned for the upcoming season to a0 validate the results obtained in the first evaluation and b) determine the root trait/traits associated to the observed phosphorus efficiency.

4. Seed increase of promising materials for P efficiency has been conducted in Sussundenga and Rotanda fields.

5. Biofortified bean lines has been evaluated for P acquisition efficiency in the fields of Sussundenga Research Station.

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

Collaborators

Soares Xerinda, IIAM, Mozambique
Jonathan Lynch, PSU, USA

In 2011 we had some progress in creating conditions for continuing the work in 2012. The planned research for 2011 was not done as planned due to late allocation of funds beyond the planting time. There was cost rise of every item of the project. Therefore, we will consider reducing target areas to Gurue, Sussundenga and Chokwe, where is possible to conduct the research with minimum of travel cost. It is assumed that there will be timely allocation of funds for Implementation of the project. The bean planting time is January/February for Gurue and Sussundenga, and is March/April in Chokwe.

Planned activities	Conducted of activities
Establish, in Sussundega, Gurue and Lichinga, on farm demo plots of drought tolerant, and P efficient common bean genotypes with moisture conservation techniques. Draught tolerant genotypes that are outstanding in the drought screening trials conducted at Chokwe Research Station will be used in these sites.	This activity was not conducted due to not having funds during the cropping season (January to May). However, one on-farm trial was conducted from June to October in Chókwe with irrigation. The objective was to evaluate the effect of mulch on productivity of P-efficient Common bean genotypes. The trial was conducted during the dry season from June to October 2011. The data is still being processed.
Conduct, in Chókwe or Sussundenga, a multiple-season pot experiment to determine available P release, from rock P and lime effects, and incubation time effects on beans growth and yield. It is well known that the RP effects on crop growth and yield is not immediate. It is a result of P mining which gradually make the P more available for uptake by plants. Therefore, the research on use of RP involves multiple season trials.	Manual grinding of Rock Phosphate (RP) continued from June until now. We have 225 Kg of ground RP, transported 100 Kg to Sussundenda, 50 to Gurue, and 25 kg to Chókwe. This materials are planned to be incorporated before the planting season, which is January, February and April in Gurue, Sussundenga and Chokwe, respectively.
	We designed 2 Ha field experiments for long-term studies of P-efficiency and draught tolerance germplasm screening based on root traits; for agro-ecological intensification studies.
	A new study site is under development in Chokwe. The site has a very poor (<2 ppm of P, very low O.M. and is very low in N) sand soil and is located in semi-arid climatic zone. These characteristics make the site the best for screening of both low P, and low N studies. We have done soil profiling up to 2.0 m depth. we are now seeking funds for site development for fencing, and water supply.
Another related study	Effects on Rock Phosphate on growth and yield of climbing beans under sole-cropping and polyculture with maize. This trial is being conducted in Gurue in collaboration with the Climbing Common bean project funded by The Mcknight Foundation.

Objective 3: Socioeconomics

Collaborators

Jill L. Findeis, PSU, USA
Rachel Smith, PSU, USA
Maria da Luz Quinhentos, IIAM. Mozambique
Luis Sevilla, PSU, USA

Phase II

Phase II project activities builds on phase I survey research to understand constraints to adoption, income and nutrition potential for households, and intra-household impacts. Activities include 1) engagement of farm households in PVS at our research sites, 2) on-farm testing followed by a farm household survey to determine critical constraints hindering adoption or reducing the diffusion of improved seed, including access to seed systems, 3) inclusion of survey questions specifically focused on disposition of newly-adopted beans (sales in alternative markets across supply chains, household consumption) by households, and 4) inclusion of both male and female perspectives in the survey to estimate intra-household impacts. The economic network approach used in phase I will be used to estimate the village-wide impacts of stress tolerant germplasm. The use of this approach in phase II allows for a short run *ex ante/ex post* comparison, focusing on adoption constraints and impacts.

The farm household survey protocol for Phase II was developed and translated into Portuguese. The draft survey includes questions related to:

- constraints (agro-ecological, economic, social) to adoption and diffusion,
- impacts on household income and nutrition attributable to beans,
- intra-household impacts,
- questions related to markets for beans, and
- seed sharing.

In May, 2011 questions were pretested at two research sites near Sussendenga (i.e., Munhinga and Rotande). Both qualitative and quantitative survey approaches were used to assess villager understanding. The qualitative approach was used to understand (informal) seed sharing as well as constraints to adoption and diffusion. The work was undertaken collaboratively with IIAM personnel who were trained in using the survey instruments. The individual questions on the survey instrument are now being revised and will be submitted for final Penn State IRB approval. We also learned of a new IRB approval process within Mozambique, and are working toward approval of the survey instrument and protocol through the Mozambican board.

All mapping of the relevant networks is now complete, and include male (i.e., male to male) and female networks (separately) as well as household-to-household networks without differentiation on the basis of gender. Simulations are being developed / programmed to better understand the overall impact of the new technology on the bean-growing regions of Mozambique. Finally, latent class models were estimated from the *ex ante* data, showing that the populations most likely to adopt new phosphorous-efficient beans vary substantially from the adopter categories established by Rogers (2003). Latent class models were also estimated for adoption of malaria control, using data related to the food security-disease component of the *ex ante* survey. Both analyses underscore the need to establish user preferences for specific traits and the influence of networks for adoption and diffusion.

Collaboration with Michigan State in the past year included sharing of GPS data on the 8 study sites, and meeting between the socioeconomic PIs in Maputo. In May 2011, the socioeconomic team met with USAID personnel in Maputo to describe progress on our work and seek their input.

Participatory Variety Selection (PVS) activities were delayed because of delays in sending technicians from the Mozambique research sites to Zamorano for training in PVS and PPB. This activity will be undertaken in year 2 of Phase II.

Maria da Luz Quinhentos, IIAM socioeconomic unit, is now receiving training at Penn State as part of a leveraged project, and participates in this project. Scholar training will be undertaken in 2012 for a second IIAM socioeconomic unit trainee (Venancio Salugua).

Objective 4: Capacity building
Bean breeder Virginia Chesale from Malawi defended her MSc thesis and returned to Malawi. She has nor formally completed her program in December 2010 - still lacks my signature, since she has not completed minor thesis edits still outstanding. Samuel Camilo of IIAM passed the TOEFL and began his M.Sc. studies in May 2011.

Networking and Linkages with Stakeholders

Networking and linkages with stakeholders—Central America

During the present FY, several advanced breeding lines tolerant to drought and low fertility developed by the Project were distributed for testing in various countries of the Central American/Caribbean (CA/C) region thru the Bean Research Network. A similar group of lines were tested by farmer groups involved in the Participatory Plant Breeding Program for the Mesoamerican Region funded by the Norwegian Development Fund. From these groups of project lines, two cultivars has already been released in Honduras and are used by farmers; and at least one cultivar will be released during FY 12 in Honduras, El Salvador and Nicaragua. These locally released cultivars are being validated and disseminated thru the Bean Technology Dissemination Project from the DGPC/USAID in Honduras and Nicaragua. In addition, two promising abiotic tolerant lines has been included in the drought and heat tolerant bean lines trial distributed to national programs of CA/C for testing under the Bean Adaptation to Climatic Change in Central America and the Caribbean Project funded by the International Development Bank thru the Red SICTA/IICA. All these trials are organized and distributed by Zamorano. Several of these lines developed by the project were included in the set of 50 bean lines sent to IIAM in 2010.

Leveraged Funds

P.I.s: JC Rosas
Title: Participatory plant breeding
Amount: $250,000 over 5 years
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)

Agency: McKnight Foundation
Title: Increasing Bean Productivity and Household Food Security in Stressful Environments in Mozambique Through Use of Phosphorus-efficient Seeds by Farm Households.
P.I.: JP Lynch
Duration: 3/1/10 -2/29/14
Amount: $435,175

Agency: International Atomic Energy Agency
Title: Characterization of root traits contributing to enhanced phosphorus acquisition from low fertility soil
P.I.: P Lynch
Duration: 7/01/09 -10/30/12
Amount: $30,000

Agency: National Science Foundation Plant Genome Program
Title: Genetic control of root architecture
P.I.s: JP Lynch and others at other institutions
Duration: 7-1-08 to 6-30-12
Amount: $823,557 (PSU portion)

Agency: Generation Challenge Program
Title: Basal Root Architecture and Drought Tolerance in Common Bean
P.I.s: JP Lynch and colleagues at other institutions
Duration: 7-1-08 to 6-30-12
Amount: $900,000

Agency: Howard G Buffett Foundation
Title: Roots of the second green revolution
P.I.s: JP Lynch
Duration: 6-1-09 to 5-31-14
Amount: $1,426,000 plus ca. $500,000 in capital investments

Agency: USAID Pulse CRSP
Title: abiotic constraints to legume productivity in developing countries workshop
P.I.s: JP Lynch
Duration: 3-1-11 to 12-31-11
Amount: $100,000

List of Publications

Findeis, J.L., & Smith, R.A. (2011). Diffusion of technologies: Economic and social networks, and policy in rural Mozambique. Paper presented at the Max Planck Institute of Economics, Jena, Germany, February 18-19.

Smith, R.A., & Findeis, J.L. (forthcoming). Explaining audience segmentation: investigating adopter categories to diffuse an innovation to prevent famine in rural Mozambique. *Journal of Health Communication.*

Smith, R.A., Barclay, V.C., & Findeis, J.L. (2011). Investigating preferences for mosquito-control technologies in Mozambique with latent class analysis. Malaria *Journal*, 10:200, doi:10.1186/1475-2875-10-200.

Nord, E.A, K. Shea, J.P. Lynch. 2011. Optimizing reproductive phenology in a two-resource world: a dynamic allocation model of plant growth predicts later reproduction in phosphorus limited plants. Annals of Botany, doi: 10.1093/aob/mcr143

Lynch, J.P. Root phenes for enhanced soil exploration and phosphorus acquisition: tools for future crops. Plant Physiology, 156:1041-1049.

Nord, E.A., C.C. Zhang, J.P. Lynch. 2011. Root responses to neighboring plants in common bean are mediated by local nutrient depletion rather than self/non-self recognition. Functional Plant Biology, http://dx.doi.org/10.1071/FP11130

Simpson R.J., Oberson A., Culvenor R.A., Ryan M.H., Veneklaas E.J., Lambers H., Lynch J.P., Ryan P.R., Delhaize E., Smith F.A., Smith S.E., Harvey P.R., Richardson A.E. (2011) Strategies and agronomic interventions to improve the phosphorus-use efficiency of farming systems. Plant Soil (in press).

Blair M.W., A.C. Fernandez, F. Pedraza, M.C. Muñoz-Torres, N. Sella Kapu, K.M. Brown, J.P. Lynch (2011). Parallel sequencing of ESTs from two cDNA libraries for high and low phosphorus adaptation in common beans. The Plant Genome 4 (3): 1-14.

Richardson A.E., J.P. Lynch, P.R. Ryan, E. Delhaize, F.A. Smith, S.E. Smith, P.R. Harvey, M.H. Ryan, E.J. Veneklaas, H. Lambers, A. Oberson, R.A. Culvenor, R.J. Simpson. Plant and microbial strategies to improve the phosphorus efficiency of agriculture. Plant and Soil, in press.

Burton A.L., M Williams, J.P. Lynch, K.M. Brown. RootScan: Software for high-throughput analysis of root anatomical traits. Plant and Soil, in press.

Tables/Figures Cited in the Report

Table 1. List of the genotypes evaluated in Chokwe Research Station in 2011. CIAT – International Center for Tropical Agriculture. IIAM – Agriculture Research Institute of Mozambique.

Genotype	Source/Origin
SAB 516	CIAT
VTTT 924/2-4-2-1	CIAT/Malawi
LIC-04-2-3	IIAM
BONUS	Local/IIAM
VTTT 925/7-6	CIAT/Malawi
SAB 569	CIAT
G 19833	CIAT
LIC-04-1-3	IIAM
LIC-04-9-3	IIAM
KHAKI	IIAM
DOCTOR	IIAM
LIC-04-2-1	IIAM
TIO CANELA	CIAT
BAT 477	CIAT
LIC-O4-7-2	IIAM
SEQ 1003	CIAT
SUG 131	IIAM
SAB 518	CIAT
LIC-04-8-4	IIAM
SAB 572	CIAT
VTTT 924/15-2-1	CIAT/Malawi

Table 2. Root traits of six common bean genotypes evaluated in Chokwe 2011. The data are average of 4 replications measured 45 days after planting.

Genotype	Basal root growth angle	Basal root number	Basal root whorl number	Adventitious root number
BAT 477	67.5a*	7.2c	4a	5.5b
Tio Canela	62a	7c	3b	6.25b
SEQ 1003	57a	8.25bc	3b	4.25b
Bonus	37b	10.5b	2.5c	8ab
LIC-04-3-1	27b	14a	2c	12.5a
LIC-04-2-1	26b	11b	2c	7.5ab

* - means followed by the same letter are not statistically different.

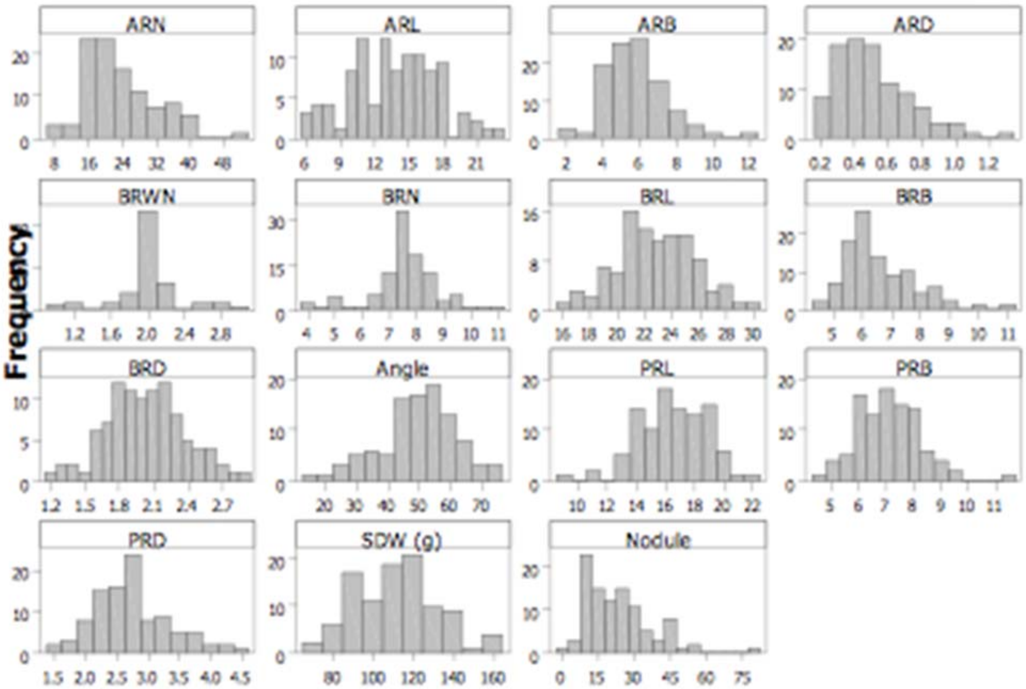

Figure 1. Phenotypic variation of root traits of part of the genotypes evaluated in the field in Rock Springs, 2010. Adventitious root number (ARN); Adventitious root length (ARL); Adventitious root branching (ARB); Adventitious root diameter (ARD); Basal root whorl number (BRWN); Basal root number (BRN); Basal root length (BRL); Basal root branching (BRB); Basal root diameter (BRD); Basal root growth angle (Angle); Primary root length (PRL); Primary root branching (PRB); Primary root diameter (PRD); number of nodules per plant, and shoot dry weight (SDW). Branching correspond to number of lateral roots in 2cm root segment. ARN, BRWN and BRN are counts per plant.

	
a) Genotype with 2 whorls and deeper basal roots	b) Genotypes with 3 whorls

Figure 2. Example of a genotype with few basal root whorls (a), and genotype with many basal roots (b) evaluated in the field.

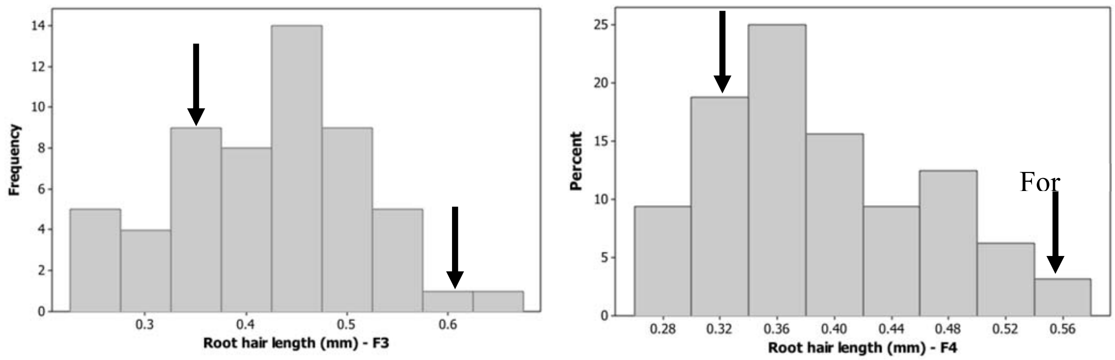

Figure 3. Frequency distribution of F3 and F4 lines derived from cross SEA 5 x SXB 418 (parents contrasting in root hair length and density). The root hair length was measured in 8 days old seedling in the laboratory. SXB 418 – parent with short root hairs. SEA 5 – parent with long and dense root hairs traits.

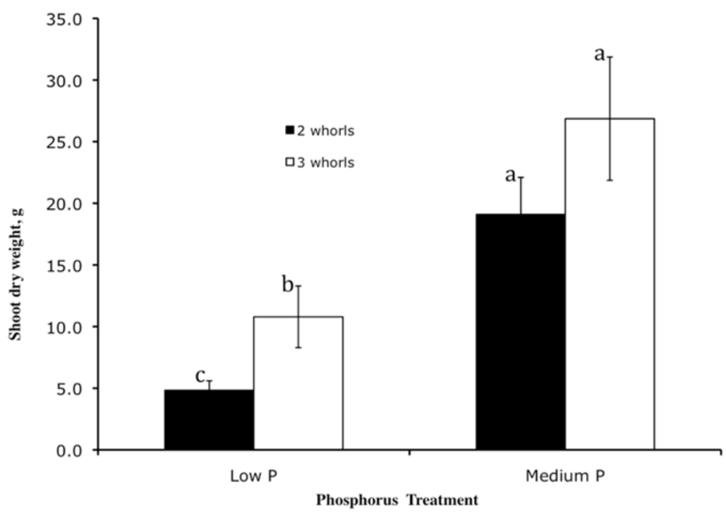

Figure 4. Shoot dry weight of genotypes with 2 and 3 basal root whorls (BRWN), grown under low P (5 ppm) and medium p (19 ppm) in the field. Plant samples were harvested at 28 DAP. Under low phosphorus, statistical significant differences were observed between the two root categories. Root categories did not differ in medium phosphorus treatments.

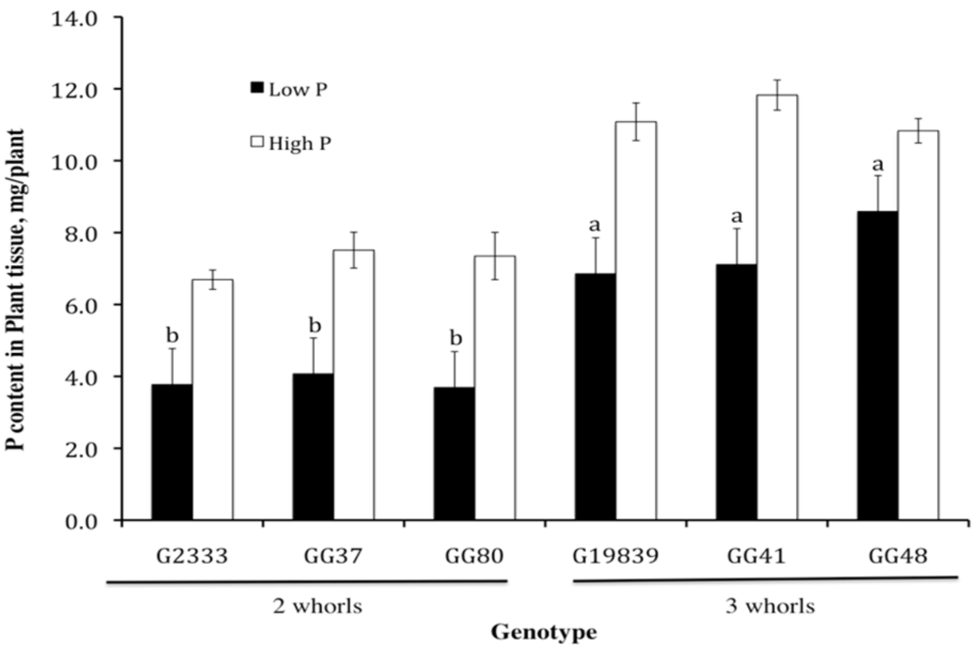

Figure 5. Phosphorus content among six genotypes contrasting for basal root whorl number (BRWN), grown under low phosphorus (5 ppm) and medium phosphorus (19 ppm) in the field. Statistically significant differences for phosphorus content were observed among genotypes grown under both medium and under low phosphorus availability. In low phosphorus treatments, statistical analysis showed that genotypes with 3 whorls showed significantly greater phosphorus content in plant tissue compared to genotypes with 2 whorls.

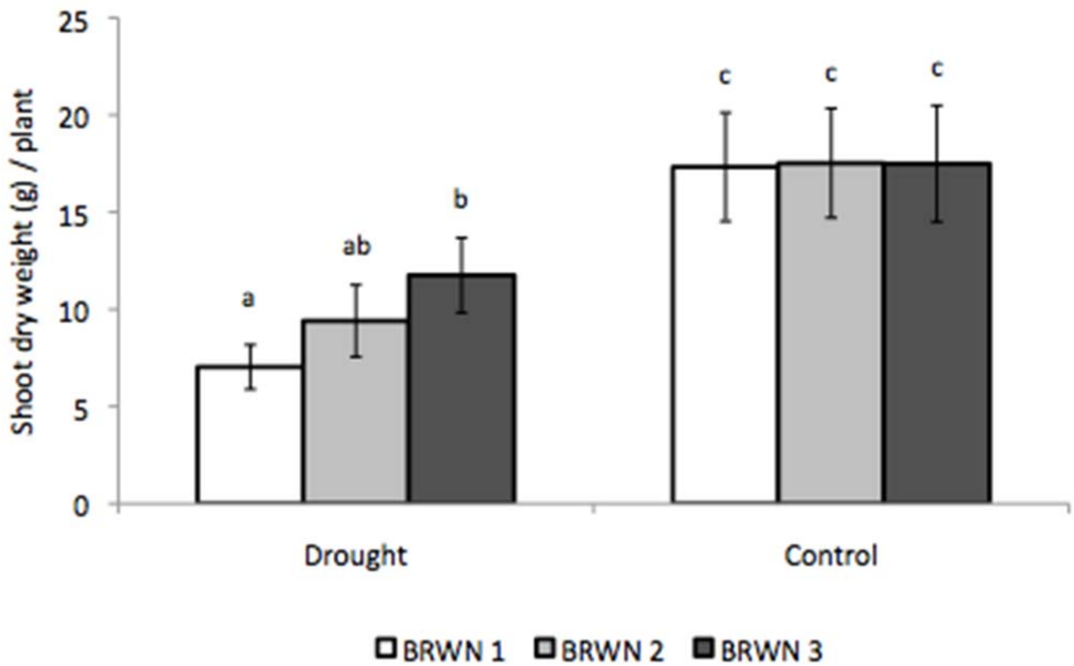

Figure 6. Genotypes with greater basal root whorl number (BRWN) had greater shoot dry weight at R5 under terminal drought conditions in the trial at Rock Springs, PA, in 2010. Genotypes with 1 whorl had significantly less shoot dry weight than genotypes with 3 whorls ($p < 0.001$). Genotypes with 2 whorls were not different from genotypes with 1 ($p = 0.0878$) or 3 whorls ($p = 0.0949$). (Tukey multiple comparison analysis, columns with different letters are significantly different.) Columns represent the mean of 4 replicates ±SE.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

Project Title: *Improving Bean Production in drought-prone, low fertility soils of Africa and Latin America - An integrated approach*

	Abbreviated name of institutions																	
	EAP			IIAM			PSU			0			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
testing small red IB lines	x	x		0	x		0			0			0			0		
BNF in small reds	x	x		0			0			0			0			0		
drought/low P advanced lines	x	x		0			0			0			0			0		
lines sent to IIA	x	x		0			0			0			0			0		
seed increase	0			x	x		0			0			0			0		
selection	0			x	x		0			0			0			0		
introgression	0			x			0			0			0			0		
Objective 2																		
prepare RP	0			0			0			0			0			0		
water conservation/genotype	0			x			0			0			0			0		
on farm demos	0			x			0			0			0			0		
RP pot study	0			x			0			0			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																		
train IIAM staff in PVS/survey	0			0		x	0	x		0			0			0		
develop PVS & HH surveys/transla	0			0	x		0	x		0			0			0		
Human Subjects clearance	0			0	x		0	x		0			0			0		
pretest HH survey in field	0			X			0	x		0			0			0		
interviewer training - HH survey	0			X			0	x		0			0			0		
conduct PVS/brief PVS survey	0			X			0			0			0			0		
Objective 4																		
MS training of IIAM plant biologis	0			0			X	x		0			0			0		
nondegree training of IIAM social	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			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Name of the PI reporting on benchmarks by institution	JC Rosas			M Miguel			K Brown											

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

Kathleen M. Brown
Signature

September 30, 2011
Date

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 20010 -- September 30, 2011)

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Improving Bean Production in Drought-Prone, Low Fertility Soils of Africa and Latin America – An Integrated Approach
Lead U.S. PI and University: JP Lynch, Penn State
Host Country(s): Mozambique, Honduras

Output Indicators	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women		
Number of men	1	1 (PSU)
Short-term Training: Number of individuals who received short-term training		
Number of women	2	3 (Moz), 1 (PSU)
Number of men	1	2 (Moz), 1 (EAP)
Technologies and Policies		
Number of technologies and management practices under research	10	8 (Moz), 5 (EAP)
Number of technologies and management practices under field testing	5	5 (Moz), 3 (EAP)
Number of technologies and management practices made available for transfer	2	3 (Moz), 2 (EAP)
Number of policy studies undertaken	2	2 (PSU)
Beneficiaries:		
Number of rural households benefiting directly	LA/C:200, Moz:500	Moz: 250; EAP: 200
Number of agricultural firms/enterprises benefiting	LA/C:1,Moz:5	Moz: 2; EAP: 1
Number of producer and/or community-based organizations receiving technical assistance	LA/C:10, Moz:50	Moz: 20; EAP 12
Number of women organizations receiving technical assistance	LA/C:1, Moz:5	Moz: 2; EAP: 2
Number of HC partner organizations/institutions benefiting	2 (EAP, IIAM)	3 (EAP, IIAM, INTA)
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	LA/C:1000, Moz:5	Moz: 3+2; EAP: 1200

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

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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, newly released 'blackeye' cowpea CB50 with larger brighter white seed and sold by several warehouses as a premium export class had production acreage increased in both 2010 and 2011. Elite novel dry grain 'all-white' cowpea line evaluations in four on-station trials for grain quality, yield, disease and insect resistance were positive again in 2011 and data collected to support its release. In Senegal, the line ISRA-2065 with thrips and aphid resistance was released in 2011 as 'Pakau'. 400 kg of Foundation Seed was produced in 2010 and an estimated 500 kg is expected in 2011. Following the advanced multi-location yield trials and on-farm tests conducted in the 4 seasons (2008 – 2011) up to 3 new lines will be proposed for release as varieties in Senegal based on grain quality, yield, disease and insect resistance. Progenies of 28-40 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 F5 stage in 2011. Under the seed production and delivery systems objective, the following was achieved: In Burkina Faso**,** Breeder Seed of 7 improved varieties was grown at Saria. Foundation Seed of 7 varieties was produced at Saria, Pobe-Mengao, and by individual farmers and farmers' organizations. More than 50 MT of Foundation Seed of 7 varieties will be sold to Certified Seed producers in 2012. Another group of 85 lead farmers were trained as Certified Seed producers. In Senegal, 3 ha each of Melakh and Yacine and 1 ha of Pakau Foundation Seed was produced at Bambey to supply EWA NGO seed producer network. 60 ha each of Melakh and Yacine Certified Seed was produced by farmers in 2010, much produced in the Touba Toul, Mekhe and Merina areas where women and men farmer groups were trained in seed production. Certified Seed production and training focused on farmer organizations. Some seed was also produced at Dahra by a private group (ARSM). A student from Angola completed the MS degree training in cowpea breeding and returned to Angola to aid in 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.

Increasing Cowpea Productivity

Low agricultural productivity is central to rural and urban poverty in Africa. On-farm cowpea yields in West Africa average 240 kg/ha even though potential yields (on-station and on-farm trials) are 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.

Increasing Marketing with Improved Varieties

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.

Increasing Seed Supply of Improved Varieties

Cowpea breeding by the CRSP, African NARS, and IITA (Senegal, Burkina Faso, Nigeria, and other countries) has led to improved cowpea varieties that are near release. However, only about 5% of the cowpea area in Africa is planted to improved varieties and their potential goes largely unrealized. 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.

Results, Achievements and Outputs of Research

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

Collaborators

Moctor Wade (weed scientist), CNRA, Bambey, ISRA, Senegal.
Tignegre Jean-Baptiste (breeder), INERA, Kamboinse, Burkina Faso.
Mme. Clementine Dabire (entomologist), INERA, Kamboinse, Burkina Faso.
Jose Pedro, CNRF/Faculdade de Ciências/ Universidade Agostinho Neto, Angola.
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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. Limited experiment station and/or on-farm tests are needed to complete the final evaluation of these lines.
In Burkina Faso and Senegal, on-farm evaluations and demonstrations of indicated lines (Table 1 in section VIII) will be conducted. The best performing INERA lines will be planned for release at the end of the FY12 workplan period following Breeder Seed production during FY12. In Senegal, the indicated ISRA lines, focused on large-seeded types, were planned for planting in 20 demonstration trials during FY11, with a second year of on-farm demonstration trials planned for FY12. This should complete the performance data required for the formal release. These lines were selected from the second-year on-farm replicated trials conducted during the FY10 main growing season. The lines are high yielding with resistance to the prevailing diseases (BB, CAbMV) and insects (aphids) and large seed size (at least 25 g /100 grains), with plots size sufficiently large (400 to 500 m^2) to allow mechanical planting. Yield, diseases and insects incidence will be recorded.

In Burkina Faso, the 6 varietal candidate lines developed at INERA were planned for on-farm trials by 5 farmer groups at 10 sites in Central (Saria, Nandiala, Donsin, Laongo, Manega) and Northern (Pobe, Pissila, Titao, Pathiri, Gourcy) zones. Sites were considered as replications and each plot was 100 m^2 (10 x10m). The six new varieties were compared to one local check variety KVx396-4-5-2D in each site.

In Angola, cowpea field evaluations were conducted at three locations targeting the main ecological zones (Alto Capaca-Benguela, Cela-Kwanza Sul, Mazozo-Luanda) with the aim of identifying candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal and/or Burkina Faso) and IITA varieties. The trials included 26 CRSP core entries, plus a similar number of local types. The set of 36 Angolan cowpea selections evaluated by Angolan student Antonio David in Puerto Rico with Drs Beaver and Porch were included in these field evaluations. Plantings in both 2011 and 2012 are needed to provide necessary field evaluation data, especially due to the problems of project phase 1 field evaluations thus far due to Ascochyta and soil alkalinity (pH 8.5). We anticipate one or more of these candidates will become the first varieties for each of the production zones to be formally produced under the project. A site visit and field trip to Angola by the UCR PIs is planned for November/December 2011 at the start of the FY12 workplan period, to aid in the coordination of these activities. The Angolan materials were SNP-genotyped to enable association mapping comparisons for major mapped cowpea traits.

In California. One advanced all-green pinkeye line, (07-11-350), and one all-white line (07-11-557) were tested in on-station trials in 2010 and advanced to large-scale strip trials in 2011. 12 new advanced dry green breeding lines and 5 all-white lines were planned for replicated trials at two locations in 2011. 26 new crosses involving these 12 lines were made in 2009 and F_4 selections from these lines were evaluated in nurseries in 2011.
Performance tests conducted in 2009 and earlier years indicated that only P-87 deserved to be taken forward for possible release. In 2010 trials with P-87 and blackeye cultivars were conducted, including a large-scale strip trial and including CB46, CB5, CB50 and P-87. Based on results, similar large-scale tests would be conducted in 2011, including tests in grower's fields.

In California, for continued development and testing of new elite blackeye lines, a breeding nursery with several hundred F_4 generation blackeye breeding lines was conducted. These breeding lines were derived from 26 new F_1's between selected promising breeding lines and CB46, breeding line 524B and cultivar CB27 made in 2009 and 2010.

In California, for development of lygus, nematode and aphid resistant varieties, lygus resistant breeding lines have been developed that are in different stages of testing. In FY11, a subset of these lines were selected based on their performance in lygus screening trials conducted in 2010, and evaluated for grain yield and grain damage under lygus protected and unprotected conditions at Kearney. We also initiated a new round of crosses in 2010 for breeding varieties with increased resistance to lygus and that have high quality grain, because while current lygus resistant lines including 07KN-42, 07KN-46 and 07KN-76 combine very high yield potential and resistance to lygus bug, improvement in grain quality is needed to meet market expectations. F4 lines developed from these crosses were screened in an unprotected nursery at Kearney under strong selection for resistance to lygus and for desirable grain quality. We are also breeding an improved version of CB46 with greater resistance to root-knot nematodes derived from IITA breeding line IT84S-2049. Line CB46-57Rk^2 is an advanced (BC6) backcross derived breeding line closely resembling CB46 with greater resistance to root-knot nematodes, but with smaller grain size than CB46. This line was crossed with CB46 in 2010 to create the BC7F1. In FY2011 inbred BC7F2 lines were developed, evaluated for resistance to nematodes in laboratory growth pouch assays and resistant lines increased in the greenhouse. For aphid resistance, breeding lines including 07KA-34, 07KA-173 were developed (from resistance source IT97K-556-6) that show strong resistance to this pest in aphid resistance screening trials. Following additional aphid resistance phenotyping in 2010, the most resistant lines were crossed with CB46 and CB50 as part of the process of transferring aphid resistance to adapted varieties. In FY11, the F1s of these crosses were grown in the greenhouse to obtain F2 seed, and the F2 generation scheduled for aphid screening nurseries at Kearney for selection.

Short-Term Breeding Strategy

A two-tiered breeding strategy is being followed to meet the immediate and longer term needs of farmers. The **Short-Term Strategy** uses 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 are being improved by breeding in resistance to diseases and pests plus other traits, using a rapid recurrent backcrossing approach.

In Senegal, from the new crosses made by Dr. Cisse at ISRA, progeny selection and advancement were made to develop varieties with medium to late maturity to cope with the changing cropping season length in the northern zones and with the growing interest in cowpea in the south and eastern areas. These materials included thrips resistance and good grain size and color qualities. For introgressing Striga resistance, Yacine was crossed with a more recent line (IT90K-76) for Striga resistance and Suvita 2 for Macrophomina. In FY11, these crosses were advanced to the BC2F2 and F4-F5 generations. Screenhouse and field techniques were used to evaluate the different populations and generation for Striga and Macrophomina resistance. These evaluations were combined with SSR markers for tracking Striga resistance. Thrips evaluation was field-based at the Nioro station hotspot.

In Burkina Faso, from the new crosses made by Dr. Drabo at INERA, progeny selection and advancement is being made to develop varieties with increased seed size of the improved varieties since large seed size is one of the most important characteristics of preference in the sub-region. The range of crosses established for backcrossing 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. 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.

During FY11 Senegal and Burkina Faso recurrent backcross populations were advanced and inbred to the BC2F3 stage, then greenhouse or field selected based on the target traits for each round of backcrossing. Leaf tissue sampling for DNA extraction, SNP genotyping and selection based on SNP marker complements was used to aid in the selection for multiple traits. Use of the KBioscience out-sourcing service for SNP-based genotyping was used, in which the leaf samples from Africa were sent to the genotyping service. Marker interpretations were team-based as a built-in training component.

The California advanced and inbred BC populations were either backcrossed or tested for yield performance during FY11 main growing season. The SNP-marker genotyping described above for Senegal and Burkina Faso backcross progenies was applied similarly to check for the resistance traits (to root-knot nematode, Fusarium wilt, and aphid).

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.

Stream One includes biparental crosses between highly drought tolerant lines SuVita 2, Mouride, IT93K-503-1 and IT97K-499-39. During the 2008-2010 project phase, the F1's were made at UCR, then advanced to the F2 generation and subjected to screening for drought tolerance. Drought-tolerant F2 individuals were identified and were advanced to the F3 for each population. The F3 lines were evaluated for drought tolerance and the best performing 100 selected and the family bulked for further evaluation. Selected families were planted in replicated field trials (2 rows x 3 reps) in Senegal and Burkina Faso in the main 2011 season for initial performance evaluation. These trials were located at Saria, Pobe and Kamboinse in Burkina Faso and at Bambey and Thilmakha in Senegal. Individuals from the most drought tolerant lines will be used for crossing to the improved lines developed under the backcrossing program described earlier.

Stream Two includes a set of popular local cowpea varieties chosen by breeders in Senegal and Burkina Faso during 2010 for targeted genetic improvement through MAS or MARS. These were hybridized to sources of known thrips resistance and heat/drought tolerance. The crosses were made between drought tolerant 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. In 2009, 352 F3 families were screened for performance under post-flowering drought conditions and the seed bulked. The 100 top performing bulks were re-evaluated in California in late 2010 and 4 single-plant selections made in the best 25 performing families. These 100 F5 selections were shipped to Burkina Faso and Senegal, where they were grown-out in field nursery plots and phenotyped for thrips tolerance and grain production under drought/heat conditions in 2011. Some additional crosses with Yacine and Melakh (e.g. Yacine x IT93K-503-1) made in Senegal were advanced by single seed selection to the F6 generation in 2011, with selection based on grain quality and SNP markers for drought, thrips and Macrophomina resistance.

In both Burkina Faso and Senegal, 20 elite lines from the GCP-Tropical Legumes II (TL-II) project were tested for grain yield and agronomic characteristics in 2010 in main season small replicated trials (2 rows x 3 reps) containing local check varieties. From these the best performing lines were evaluated in advanced trials (4 rows x 4 reps) in 2011, at Saria, Pobe and Kamboinse in Burkina Faso.

In California, Pigeonpea GA-1, a selection made in earlier years at UCR from materials supplied from Dr. Sharad Pathak at the University of Georgia, was tested in 2011 in a large replicated strip trial with three irrigation regimes at Shafter. A 4-fold replicated yield trial was conducted at Kearney in 2011 with 10 selections identified in 2010 evaluations.

Results, Achievements and Outputs of Research

Final Testing and Release of Varieties

In Burkina Faso (INERA): Results of two years of testing indicate that among the five tested white-grain lines, KVx 442-3- 25 is the most preferred line because of its high yield (average of 1250 kg/ha) and large seeds. We will produce breeder seeds of this line during the coming off-season. In 2010 a total of 7313 kg of Certified Seed of the new released varieties was produced for large production in 2011.Table 1 gives the quantity of Breeder Seed produced in Burkina Faso from 2005 to 2010. Note that a total of 879kg of seeds of KVx421-2J, IT98K-205-8 and Melakh were obtained. We have planned to produce at least 25 tons of Foundation Seed of these 3 varieties in 2011, although the final production weights are not yet known. We anticipate a larger Certified Seed production based on current plantings and a larger dissemination in 2012.

Table 1. Production of Breeder Seed at Saria and Kamboinsé from 2005 to 2010

Years Varieties	2005	2006	2007	2008	2009	2010
KVX 396-4-5-2-D	0,189	0,481	0,328	0,279	0,844	1,408
KVX 396-4-4			0,045	0,317	0,060	0,115
KVX 414-22-2	0,088	0,260	0,148	0,180	0,080	0,395
KVX 61-1	0,167	0,556	0,321	0,500	0,597	1,028
KVX 745-11P		0,335	0,078	0,443	0,516	1,142
KVX 421-2J			0,044	0,175	0,100	0,280
Gorom local	0,065	0,145	0,075	0,151	0,105	0,480
IT 98K-205-8			0,275	0,125	0,109	0,449
Melack			0,128	0,150	0,282	0,150
Telma				0,200	0,012	
Moussa Local		0,096				
KVX775-33-2				0,105	0,065	0,042
KVX771-10				0,040	0,029	0,033
KVX775-3-10				0,040	0,026	
TOTAL	**0,509**	**1,870**	**1,442**	2,763	2,858	**6,136**

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. 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 use 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 and again in the 2010 main season with larger plots (2500 m^2) on a total of 30 farms. These trials constituted the final activity for an official release and ISRA-2065 with thrips and aphid resistance was released in 2011 as 'Pakau'. The PADER project multiplied 3 ha of Pakau seeds in 2011for use in the coming season. 400 kg of Foundation Seed was produced in 2010 and an estimated 500 kg is expected in 2011. Following the advanced multi-location yield trials and on-farm tests conducted in the 4 seasons (2008 – 2011) up to 3 new lines will be proposed for release as varieties in Senegal based on grain quality, yield, disease and insect resistance.

In Angola, cowpea field evaluations were conducted at three locations targeting the main ecological zones (Alto Capaca-Benguela, Cela-Kwanza Sul, Mazozo-Luanda) 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 enabled a performance ranking. 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. All the tested Angola lines were SNP-genotyped using the Illumina GoldenGate Assay. These data were 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. This provided an assessment of the relatedness of the Angolan materials to other African cowpea stocks, which appear to derive from diverse genetic backgrounds. In FY12 we plan to test the highest ranked lines at six sites (Mazozo-Luanda, Alto Capaca-Benguela, Cela-Kwanza Sul, Humpata-Huila, Calussinga-Bié, and Chianga-Huambo areas).

In California. Replicated small plot tests of new dry-green blackeye, pinkeye and all-white varieties were conducted to determine varietal candidates. One advanced all-green pinkeye line, (07-11-350), and one all-white line (07-11-557) were tested in on-station trials in 2010. Yields of 07-11-350 were disappointing (Table 2), so a larger set of 20 new dry-green blackeye and pinkeye breeding lines were put into replicated tests at Kearney and Riverside in 2011(Table 3). Yields of all the dry green breeding lines were significantly less than elite blackeye variety CB46 in the Kearney trial. (Data is not yet available for the trial conducted at UCR). It is possible that there is a sufficient positive price differential for the dry green blackeye and pinkeye selections compared to blackeyes that growers and industry personnel will be interested in the best of these new advanced lines. We are continuing a line development program we hope will generate dry-green varieties with yields that are competitive with elite blackeyes. F_2 and F_3 progenies of 26

new crosses involving many of the all-green pinkeye and blackeye lines being tested were evaluated in breeding nurseries at Kearney and Riverside in 2010 and 2011 (Table 4).
On a very positive note, all-white breeding line 07-11-557 had grain yields even higher than elite blackeye cultivars in the 2010 tests, potentially indicating that transgressive segregation for yield has been achieved. Data for the 2011 trials is not yet available, but if 07-11-557 again outperforms the blackeye cultivars, we will initiate the release process. 07-11-557 and 3 additional all-white lines are being tested in trials conducted in 2011.

Table 2. Grain yield (cwt/ac) and individual grain weight of All-white line 07-11-557 and Dry-green breeding line 07-11-350 and nematode resistant near isogenic line CB46Rk^2 compared to blackeye check entries CB46, CB50 and advanced line P-87 at Kearney REC in 2010.

Entry	Grain Type	Yield (kg/ha)	Grain weight (g/100 seed)
07-11-557	All white	4584	20.4
P-87	Blackeye	4176	22.7
CB46-RK^2	Blackeye	4164	19.8
CB50	Blackeye	4152	27.3
CB46	Blackeye	4128	22.0
07-11-350	Dry green blackeye	3336	19.9
Mean		4092	22.0
LSD(0.05)		408	1.2
CV(%)		12	3.2

Table 3. Grain yield and size of standard blackeye cultivar CB46 and 21 promising new all dry green blackeye or pinkeye lines tested in replicated trials at Kearney and UC Riverside trials in 2011 and that were used in crosses to generate new lines (data for 2011 UC Riverside Trial not yet available).

	Line	Type	Grain yield-Kearney (kg/ha)	100 grain weight (gms)
1	CB46	Blackeye	2970	21.33
2	10-11-735	Dry-green blackeye	2424	16.57
3	10-11-673	Dry-green blackeye	2248	17.49
4	10-11-664	Dry-green blackeye	2234	17.32
5	10-11-701	Dry-green blackeye	2168	14.70
6	10-11-718	Dry-green pinkeye	2088	17.88
7	10-11-757	Dry-green blackeye	2083	16.24
8	10-11-721	Dry-green pinkeye	2061	10.87
9	10-11-706	Dry-green blackeye	2041	19.46
10	10-11-682	Dry-green blackeye	2006	17.92
11	10-11-725	Dry-green blackeye	1917	18.58
12	10-11-698	Dry-green blackeye	1897	16.97
13	10-11-779	Dry-green blackeye	1861	17.14
14	10-11-662	Dry-green blackeye	1840	15.60
15	10-11-727	Dry-green blackeye	1826	14.23
16	10-11-685	Dry-green blackeye	1786	14.01
17	10-11-719	Dry-green pinkeye	1738	17.94
18	10-11-751	Dry-green blackeye	1690	16.03
19	10-11-656	Dry-green pinkeye	1648	16.64
20	10-11-741	Dry-green pinkeye	1571	18.39
21	10-11-693	Dry-green blackeye	1553	16.97
	LSD(0.5)		423	1.38
	CV(%)		13	4.99

Table 4. Crosses made and advanced for selection of improved dry green varieties

	Cross Number	Pedigree	Type	2011
1	2009-013	08-11-70-1 x 08-11-154	Green x Green	F_4
2	2009-014	08-11-111 x 08-11-154	Green x Green	F_4
3	2009-015	08-11-153 x 08-11-110	Green x Green	F_4
4	2009-016	08-11-187-3 x 08-11-65	Green x Green	F_4
5	2009-017	CB46 x 07-11-350	Blackeye x Green	F_4
6	2009-018	CB46 x 08-11-70-1	Blackeye x Green	F_4
7	2009-019	CB46 x 08-11-91	Blackeye x Green	F_4
8	2009-020	CB46 x 08-11-187-2	Blackeye x Green	F_4
9	2009-021	07-11-350 x CB46	Blackeye x Green	F_4
10	2009-023	CB50 x 08-11-49	Blackeye x Green	F_4
11	2009-024	CB50 x 08-11-60-2	Blackeye x Green	F_4
12	2009-025	CB50 x 08-11-70-1	Blackeye x Green	F_4
13	2009-026	CB50 x 08-11-132	Blackeye x Green	F_4
14	2009-027	CB50 x 08-11-140	Blackeye x Green	F_4
15	2009-028	CB50 x 08-11-186	Blackeye x Green	F_4
16	2009-029	08-11-70-1 x CB50	Blackeye x Green	F_4
17	2009-030	08-11-78 x CB50	Blackeye x Green	F_4
18	2009-031	08-11-103 x CB50	Blackeye x Green	F_4
19	2009-032	08-11-106 x CB50	Blackeye x Green	F_4
20	2009-033	08-11-187-3 x CB50	Blackeye x Green	F_4
21	2009-034	CB46 x 02053F1	Blackeye x Green	BC_1F_4
22	2009-035	CB50 x 02053F1	Blackeye x Green	BC_1F_4
23	2009-036	02053F1 x 07-11-350	Blackeye x Green	BC_1F_4
24	2009-037	02053F1 x 02082F1	Blackeye x Green	BC_1F_4
25	2009-038	CB46 x G747-1	Blackeye x Green	F_4
26	2009-040	CB50 x G749-1	Blackeye x Green	F_4

In California, performance tests conducted in 2009 and earlier years indicated that only P-87 deserved to be taken forward for possible release. In 2010, we compared the performance of P-87 with standard blackeye cultivars (Table 2) in plot trials and in a large-scale strip trial. Unfortunately, unseasonably frequent rains prevented a commercial harvesting operation from conducting the harvest until December. Grain yields were considered highly suspect and grain quality so low the crop was sold as cattle feed. In the small plot trials, P-87 performed well, but not sufficiently superior to existing varieties to be considered for release.

In California, for continued development and testing of new elite blackeye lines, a breeding nursery with several hundred F_7 generation blackeye breeding lines was conducted in 2010 and seed of 15 new lines bulked for replicated tests that were conducted in 2011 (Table 5). New breeding lines, presently at the F3 generation, are also under development from 26 crosses made between elite breeding lines and between existing varieties and breeding lines (Table 6).

Table 5. List of new advanced blackeye and all-white breeding lines selected in 2010 and evaluated in replicated trials at Kearney and Riverside in 2011.

2010 Selection	2009 Origin	2008 Origin	2007 Origin	Type	Pedigree
2010-4	09Sh13-2	08Sh-39-3	07Sh-60-2	Blackeye	CB27/CB50
2010-10	09Sh13-4	08Sh-39-3	07Sh-60-2	Blackeye	CB27/CB50
2010-19	09Sh13-9	08Sh-39-3	07Sh-60-2	Blackeye	CB27/CB50
2010-23	09Sh13-11	08Sh-39-3	07Sh-60-2	Blackeye	CB27/CB50
2010-25	09Sh31-1	08Sh-73	07Sh-107-3	Blackeye	Sh 65/UCR53
2010-27	09Sh31-8	08Sh-73	07Sh-107-3	Blackeye	Sh 65/UCR53
2010-29	09Sh31-9	08Sh-73	07Sh-107-3	Blackeye	Sh 65/UCR53
2010-35	09Sh34-2	08SH-73-1	07Sh-107-3	Blackeye	Sh 65/UCR53
2010-77	Greenhouse	Greenhouse	Greenhouse	Blackeye	*CB27/CB5//CB5*^{2}*-7-2-3*
2010-83	Greenhouse	Greenhouse	Greenhouse	Blackeye	*CB27/CB5//CB5*^{2}*-9-1-1*
2010-115	Greenhouse	Greenhouse	Greenhouse	Blackeye	*CB27/CB5//CB5*^{2}*-70-1-1*
2010-121	Greenhouse	Greenhouse	Greenhouse	Blackeye	*CB27/CB5//CB5*^{2}*-7-2-4*
2010-138	09 K-2-1	08Sh-102	07-15-518-1	All-white	01-11-732/CB27//97-15-33/CB46
2010-141	09 K-2-1	08Sh-133	07-15-572	All-white	01-11-732/CB27//97-15-33/CB46
2010-142	09 K-2-1	08Sh-142	07-15-557-1-20	All-white	01-11-732/CB27//97-15-33/CB46

Table 6. Crosses for development of high yielding, pest resistant blackeye cowpea cultivars. Many of the advanced lines used as parents in these crosses were subsequently included in replicated yield tests in 2011 (see Table 5)

Cross No.	**Blackeye Crosses**	Current Generation	Generation in 2011
2010-066	CB46 x 09Sh-3-2	F_2	**F_3**
2010-067	CB46 x 09Sh-3-4- sps	F_2	**F_3**
2010-068	CB46 x 09Sh-3-6sps	F_2	**F_3**
2010-069	CB46 x 09Sh-13-6	F_2	**F_3**
2010-070	CB46 x 09Sh-36-2	F_2	**F_3**
2010-071	CB46 x 09Sh-93-3	F_2	**F_3**
2010-072	CB46 x 09Sh-105-2	F_2	**F_3**
2010-073	CB46 x 09Sh-112-6	F_2	**F_3**
2010-074	CB27 x 09Sh-13-6	F_2	**F_3**
2010-075	09Sh-93-3 x CB27	F_2	**F_3**
2010-076	09Sh-113-6 x CB27	F_2	**F_3**
2010-077	524B x 09Sh-13-1	F_2	**F_3**
2010-078	524B x 09Sh-13-6	F_2	**F_3**
2010-079	524B x 09Sh-31-1	F_2	**F_3**
2010-080	524B x 09Sh-36-8	F_2	**F_3**
2010-081	524B x 09Sh-113-10	F_2	**F_3**
2010-082	09Sh-95-8 x 09Sh-13-7	F_2	**F_3**
2010-083	09Sh-36-6 x 09Sh-109-2	F_2	**F_3**
2010-084	09Sh-95-8 x 09Sh-113-12	F_2	**F_3**
2010-085	09Sh-113-4 x 09Sh-95-8	F_2	**F_3**
2010-086	09Sh-113-4 x 09Sh-3-6 sps	F_2	**F_3**
2010-087	09Sh-113-5 x 09Sh-13-6	F_2	**F_3**
2010-088	09Sh-113-5 x 09Sh-31-10	F_2	**F_3**
2010-089	09Sh-113-5 x 09Sh-36-6	F_2	**F_3**
2010-090	09Sh-113-4 x 09Sh-93-1	F_2	**F_3**
2010-091	09Sh-113-1 x 09Sh-93-3	F_2	**F_3**

In California, for development of lygus, nematode and aphid resistant varieties, a range of lygus resistant breeding lines have been developed that appear very promising. Based on results of two trials conducted in 2010 (Tables 7 and 8), a subset of these lines was selected and evaluated for grain yield and grain damage under lygus protected and unprotected conditions at Kearney and under unprotected conditions at Riverside in 2011 (Table 9). We also initiated a new round of crosses in 2010 for breeding varieties with increased resistance to lygus and that have high quality grain, because while current lygus resistant lines combine very high yield potential and resistance to lygus bug, improvement in grain quality is needed to meet market expectations. The F_1s were advanced to the F_2 in 2011.

Table 7. Entry, grain yield, % grain loss due to lygus damage, and individual seed weight of CB46, CB27 and CB27 and 4 lygus resistant lines grown under unprotected (Unpro) and protected (Pro) conditions in a replicated trial at Kearney in 2009 and 2010. Unprotected yield rank data from 2008 are also included for comparison.

	Grain Yield							
	2008	**2009**			**2010**			
Entry	Unpro	Unpro	Pro	Loss	Unpro	Pro	Loss	Seed weight
	Yield Rank	cwt/ac		%	cwt/ac		%	gm
07KN-42	1	28.1	31.0	9	27.5	34.9	21	0.279
07KN-74	3	26.6	29.5	10	28.8	32.6	11	0.223
07KN-46	2	25.9	30.1	13	24.5	24.5	14	0.279
07KN-98	7	24.1	27.9	13	27.4	27.4	16	0.180
CB27	Not tested	27.7	34.2	16	23.3	27.8	16	0.217
CB46	12	23.9	31.9	24	27.9	33.9	18	0.214
Trial Mean		24.8	30.5	19	26.6	27.7	16	0.227
LSD(0.05)		7	6.9	19	4.8	4.5	NS	0.020
CV(%)		20	15.9	65	14	13	15	6

Planted May 25, 2010; hand-harvested August 28 (95 days).

The second trial ('unprotected' only) had ten new experimental lines from the 2009 lygus nursery screening program conducted at Kearney. These lines are the result of crossing previous lygus resistant materials back again to blackeyes in order to recover a blackeye variety with resistance to lygus. Two lines (09KLN-2-30 and 09KLN-1-38) had yields 5-6 cwt greater than CB46 (Table 8). These two lines and two or three others will be tested in 'protected – unprotected' trials in 2012 to confirm and expand on these results. These breeding lines are approaching 'blackeye' grain quality and agronomic characteristics needed by growers in commercial cultivars, but in case an additional backcross is needed, this will be done in late 2011.

Table 8. Grain yield of 9 new experimental lygus resistance lines, CB46 and CB27 when grown under insect unprotected conditions in 2010 and insect protected and unprotected yields in 2011 at Kearney REC.

	2010 Yield (kg/ha)	2011 Yield (kg/ha)		
Entry	Unprotected	Protected	Unprotected	Loss (%)
09KLN-1-38	2800 ab	2732	2097	23*
09KLN-1-35	2628 abc	3196	2014	37*
09KLN-2-164	2424 bcd	2066 c	1760 abc	15 a
07KN-74	3456	2763 ab	1736 abc	37 abc
09KLN-2-27	2532 abcd	3017 a	1651 bc	46 ab
09KLN-2-30	2860 ab	2301 c	1564 bc	31 bc
09KLN-1-9	2616 abc	2767 ab	1528 bc	45 ab
07KN-46	2940	2430 bc	1323 c	46 ab
CB46	2150 cd	2793 ab	1318 c	50 ab
CB27	2076 cd	2995a	1263 c	58 a
CV(%)		10.6	30	40

2010 trials planted on May 25 and hand-harvested on August 29 (96 days);
2011 trials planted on May 26 and hand-harvested on September 1 (99 days)
*Plots had only two good replicates.

We have developed a breeding line that is an improved version of CB46 with greater resistance to root-knot nematodes derived from IITA breeding line IT84S-2049 (Table 2). Line CB46-57Rk[2] is an advanced (BC_6) backcross derived breeding line closely resembling CB46 with equivalent yield potential that does have greater resistance to root-knot nematodes, but that has smaller grain size than CB46 (19.8 vs 22.0 g/100 seeds in 2010). This line was crossed with CB46 in 2010 to create the BC_7F_1. In FY2011 inbred BC_7F_2 lines were developed. These will be evaluated for resistance to nematodes in laboratory growth pouch assays and resistance lines increased in the greenhouse to obtain sufficient seed further tests in FY12.

For aphid resistance, breeding lines including 07KA-34, 07KA-173 were developed (from resistance source IT97K-556-6) that show strong resistance to this pest in aphid resistance screening trials. Following additional aphid resistance phenotyping in 2010 and confirmatory tests in 2011, the most resistant lines are now being crossed with CB46 and CB50 as part of the process of transferring aphid resistance to adapted varieties. The F_1s of these crosses will be grown in the greenhouse this winter to obtain F2 seed, and the F2 generation planted in aphid screening nurseries in 2012 at Kearney for selection.

Short-Term Breeding Strategy

We initiated a new two-tiered breeding strategy to meet the immediate and longer term needs of farmers. The **Short-Term Strategy** is using 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.

Advanced Yield Trials

The California blackeye lines being improved by recurrent backcrossing are summarized in Table 9, along with their current status as of October 2011. Depending on the stage of backcrossing and inbreeding, these materials were either backcrossed or tested for yield performance during FY12 main growing season. The SNP-marker genotyping described above for Senegal and Burkina Faso backcross progenies will be applied similarly to check for the resistance traits (to root-knot nematode, Fusarium wilt, and aphid). Markers for Lygus bug resistance are not yet identified, and these will be pursued using the segregating progenies for marker-phenotype associations.

Table 9. California blackeye lines being improved by introgression of specific traits using backcrossing at UCR.

Recurrent Parent Line	Trait donor parent	Trait being introgressed	Status at start of FY11 Workplan	FY10 and 11 activities
CB5	CB27	Fusarium wilt	BC2F7	Four advanced lines in replicated yield tests at UCR and Kearney in 2011
CB46	UCR 03-11-747	Green grain	BC4F10	Test results for 2010 given in Tables 2 and 3
CB46	IT84S-2049	Root-knot nematodes	BC6F9	Test results for 2010 given in Table 2, 2011 results pending harvest
CB46	Bambey 21(Senegal)	All-white grain	BC4F10	Test results for 2010 given in Table 2, 2011 results pending harvest
CB46	IT97K-556-6 & UCR 779	Aphid resistance	BC1F6	Lines phenotyped lines for aphid resistance in 2010 and 2011 and crosses to be made in late 2011.
CB46	IT93K-2046	Lygus resistance	BC3F6	BC4 lines tested in replicated yield trials (Table 8) and new crosses made between promising lygus resistant lines.

In Burkina Faso, one advanced yield trial composed of 192 lines and 8 checks was conducted at Saria in 2011 in order to select high yielding lines with large seeds. The best lines will be reevaluated next year at Saria, Pobé and Kamboinse.

From previous trials in 2009 and 2010, on-farm test using the best three varieties KVx 912-1P1, IT98K-1111-1 and KVx 442-3-25 was conducted in 10 sites in 2011. KVX442-3-25 with an average yield of 1125 kg/ha was superior to the two others. Farmers preferred that variety and it will be released in 2012. This trial will be conducted again in 2012.

In Senegal, two advanced yield trials were conducted at the Bambey, ISRA field station in 2010 and 2011. 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 were used for yield and agronomic characterization of each line, and harvest data were collected. 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. In 2011, 20 on farm trials were conducted in the Louga and Mekhe areas with 10 lines selected from the previous years.

<u>Crosses for Developing New Breeding Lines</u>

In Burkina Faso, progenies of new crosses made by Dr. Drabo were advanced to the F5 stage during 2010. The F6 bulk of these crosses was harvested in 201 for planting in 2012 in order to do a single plant selection for desired traits. 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. 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, 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 2009-2010 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. These new materials were advanced in 2011 for further grow-out and selection in 2012.

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. **Stream One** includes a set of breeding lines developed from crosses between drought tolerant 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. In 2008 the F1's were made at UCR, then advanced to the F2 generation and subjected to screening for drought tolerance at Coachella. Drought-tolerant F2 individuals were identified and were advanced to the F3 for each population. In 2009, 352 F3 families from these crosses were screened for performance under post-flowering drought conditions at Coachella. Seed of the top performing 19 F4 lines were re-evaluated in California in late 2010 in a replicated trial with 12 parental and check lines (Table 10). CRSP-44, CRSP-161, CRSP-10 and CRSP-145 had grain yields statistically greater than 11 of the 12 check entries and higher than the best elite IITA line IT97K-499-35 (although not statistically greater). These top-yielding lines will be shared with our African partners at the end of 2011 and intercrossed in an attempt to pyramid drought tolerance factors.

Table 10. Yield of 19 F4 drought-tolerant selected lines evaluated in Coachella, California in late 2010 in a replicated trial with 12 parental and check lines

Entry	Pedigree	Yield kg-ha	
CRSP-44	CB27/IT90K-284-2	1421	A
CRSP-161	IT93K-503-1-1/IT97K-556-6	1310	AB
CRSP-10	IT97K-IT97K-499-39/IT93K-503-1-33	1307	AB
CRSP-145	KVx61-1-1/Mouride	1204	ABC
IT97K-499-35		1159	ABCD
CRSP-239	IT93K-503-1-1/556-6	1154	ABCDE
CRSP-71	IT95K-1479/Mouride	1128	BCDE
IT84S-2246		1104	BCDEF
IT93K-503-1		1103	BCDEF
CRSP-68	IT95K-1479/Mouride	1102	BCDEF
CRSP-29	IT97K-IT97K-499-39/IT93K-503-1-33	1085	BCDEF
CRSP-14	IT97K-IT97K-499-39/IT93K-503-1-33	1083	BCDEF
SuVita 2		1079	BCDEF
IT90K-284-2		1079	BCDEF
CB46		1065	BCDEF
CRSP-32	IT97K-IT97K-499-39/IT93K-503-1-33	1060	BCDEFG
CRSP-46	CB27/IT90K-284-2	1039	BCDEFG
Mouride		1021	CDEFG
CRSP-33	IT97K-IT97K-499-39/IT93K-503-1-33	1011	CDEFG
KVx61-1		1002	CDEFGH
CRSP-57	CB27/IT90K-284-2	995	CDEFGH
CRSP-70	IT95K-1479/Mouride	949	CDEFGHI
CRSP-86	KVx61-1-1/Mouride	896	DEFGHI
CRSP-47	CB27/IT90K-284-2	875	EFGHI
IT99K-1263		873	EFGHI
CRSP-282	SuVita2/Mouride	843	FGHI
IT95K-1479		833	FGHI
IT97K-556-6		823	FGHI
CRSP-51	CB27/IT90K-284-2	784	GHI
CB27		724	HI
CRSP-53	CB27/IT90K-284-2	698	I
CRSP-147	KVx61-1-1/Mouride	684	I

In Burkina Faso, 95 families of the crosses using the set of parents IT84S-2246, IT93K-503-1 and Mouride have been evaluated in a replicated trial at Pobé during the main 2011 season. In Senegal the F3 lines from these families were evaluated for drought tolerance and the best performing 100 selected and the family bulked for further evaluation. Selected families were planted in replicated field trials (2 rows x 3 reps) during the off-season and in the main 2011 season for initial performance evaluation. These trials were located at Bambey and Thilmakha. Data will be analyzed soon. Individuals of the most drought tolerant lines which have large seeds will be used for crossing to the improved lines developed under the backcrossing program.

Stream Two includes two four-way cross populations developed from diverse yet elite African and California cultivars with a host of desirable traits (Table 11). Population 1 was made by first making biparental crosses between CB27 with IT82E-18 and IT84S-2049 with IT84S-288. Population 2 was made by crossing IT84S-2246 with IT93K-503-1 and IT00K-1263 with SuVita2. Then 300 four-way double crosses were made to generate 300 4-way individuals. These 300 individuals were selfed one generation in the greenhouse and are currently growing at the Coachella Valley station for within-family selection for high pod production in December, 2011. These materials represent a very broad-based assemblage of elite genetics. They will be shared with the new breeding program in Angola.

In Burkina Faso, 20 elite lines from the GCP-Tropical Legumes II (TL-II) project were tested for grain yield and agronomic characteristics in 2010 in main season small replicated trials (2 rows x 3 reps) containing local check varieties. From these the best performing lines were evaluated in advanced trials (4 rows x 4 reps) in 2011 at Saria, Pobe and Kamboinse.

Table 11. Constituent lines used in the development of the two 4-way cross populations for recurrent selection, and key tolerance and resistance traits present in these parental lines.

			Identified as high yielding under drought in:				
Genotype	**Source**	**4-way Popln#**	**Senegal**	**Burkina Faso**	**Mozambique**	**IITA**	**Key Tolerance/Resistance traits**
CB27	UCR	1	Yes		Yes		Heat tolerance
IT89KD-288	IITA	1			Yes	Yes	Striga (races 1,2,3,4,5)
IT82E-18	IITA	1			Yes		
IT84S-2049	IITA	1		Yes			Aphid, bacterial blight, CAbMV
IT84S-2246	IITA	2		Yes	Yes		*multiple resistance traits - see list at bottom
IT00K-1263	IITA	2		Yes		Yes	*Yield, grain quality*
IT93K-503-1	IITA	2	Yes				Drought, *Macorphomina*, *Striga* (races 1,3,4)
SuVita 2	INERA	2	Yes	Yes	Yes		*Striga* (races 1,2,4)

In Burkina Faso, two phenotyping trials were conducted at Saria and Pobé with the lines obtained with the cross between Suvita2 and IT98K-499-35 and 248 lines of the cross 2011-002. The data is being processed and the lines will be SNP-genotyped.

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). The Illumina platform was converted to a breeder-friendly KASPAR genotyping system run by KBioscience. Leaf samples from the NARS and California trials can be sent to KBioscience for DNA extraction and genotyping with custom sets of SNP markers. The focus is on MABC of backcross progenies with the goal of identifying individuals carrying a majority of molecular markers associated with the genetic background of the recurrent parent, with the addition of the trait markers from the donor parent. The trait-marker associations have been identified through QTL mapping efforts that combined AFLP and SNP marker data with extensive phenotyping data for drought tolerance (Muchero et al., 2008, 2009a.b), insect resistance (Muchero et al, 2009c) and continuing efforts for root-knot nematode, Macrophomina, Fusarium, and other disease resistance traits. Genotyping through the KBioscience SNP platform was conducted in 2010 and 2011to aid in progeny selection.

In California: Pigeonpea

GA-1, a selection made in earlier years at UCR from materials supplied from Dr. Sharad Pathak at the University of Georgia, is being tested in cooperation with Kern Country Farm Advisor Blake Sanden and the Cal Bean and Grain Cooperative in a large-scale (3.7acres) strip plot with three irrigation treatments at Shafter in 2011. This will be harvested in Nov. 2011 and yields determined. A small-plot 4-fold replicated trial is near harvest at Kearney with entries that include 10 selections from the 2010 pigeonpea nursery at Kearney and single-plant selections derived from a plot of GA-1 grown at Shafter in 2010. If significant yield differences are observed among selections, seed of the most promising lines will be bulked for larger-scale trials and a fast-track release path followed.

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

Collaborators

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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. This 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.

The approach is to 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. Working with the national extension services in Senegal (ANCAR), Burkina Faso, and Angola (SENSE) to reach the farmers' organizations in different communities will be coupled with strengthening 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, the primary effort is to produce Foundation Seed and Certified Seed of 6 newly released varieties (IT98K-205-8l, Melakh, KVx421-2J, KVX442-3-25, KVx771-10 an33-2d KVx735-33-2) and 10 existing varieties (Gorom local, KVx61-1, KVx396-4-4, KVx396-4-5-2D, KVx414-22-2, KVx745-11P, Telma, KN1, Moussa Local). Up to 60 tons of Certified Seed will be produced in seven provinces by trained farmers. 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. 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** tons of Foundation Seed. This will address the estimated 5% shortage of Foundation Seed, kick-starting an expansion of the self-sustaining seed production system. Training of farmers as Certified Seed producers will be done at Tougan (Sourou province), Saria (Bulkiemde province), Donsin (Oubritenga Province), Pobe (Soum province), and Pissila (Sanmatenga province). A target of 70 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 1 ha of Melakh, 1 ha of Yacine, and ½ 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 4 locations (Thilmakha region, Merina district, Mekhe, and Bambey). 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 continue to link with government and NGO institutions, including World Vision, Africare, CRS and ADRA-Angolana, to determine opportunities for advancing the cowpea seed system. This effort will be aided by a site visit, in which we will coordinate with the Pulse CRSP bean breeding project of Drs. Beaver and Porch. Opportunities for a coordinated bean and cowpea seed system based on the Breeder – Foundation – Certified Seed system chain will be pursued. We will provide guidelines and descriptions for Angolan nationals in multiplication of high quality seed of selected varieties for farmers. Our parallel efforts of cowpea field evaluations under Objective 1, to identify candidate varieties among local landraces, and Bean/Cowpea CRSP (in Ghana, Senegal and/or Burkina Faso) and IITA varieties, is anticipated to provide new release for increase and distribution.

Results, Achievements and Outputs of Research

In Burkina Faso: At the INERA station of Saria more than 70 tons of Foundation Seed was produced in 2010 using part of the Breeder Seed produced in 2009 as shown in Table 12 below. Table XX shows the quantity of seeds produced from 2005 to 2010. More than 6 tons of Breeder Seeds were produced in 2010. A part of these seeds have been used to produce Foundation Seed during the 2011 main season. We anticipate a production of at least 55 tons of Foundation Seed in 2011 since 19 tons of Foundation Seeds are in storage. Money obtained by selling the Foundation Seed in 2010 was used for supporting 2011 seed production activities in attempts to establish a self-sustaining plant seed production and delivery system.

Table 12. INERA Saria Station Breeder Seed production (tons) from 2005 to 2010.

Years Varieties	2005	2006	2007	2008	2009	2010
KVX 396-4-5-2-D	0,189	0,481	0,328	0,279	0,844	1,408
KVX 396-4-4			0,045	0,317	0,060	0,115
KVX 414-22-2	0,088	0,260	0,148	0,180	0,080	0,395
KVX 61-1	0,167	0,556	0,321	0,500	0,597	1,028
KVX 745-11P		0,335	0,078	0,443	0,516	1,142
KVX 421-2J			0,044	0,175	0,100	0,280
Gorom local	0,065	0,145	0,075	0,151	0,105	0,480
IT 98K-205-8			0,275	0,125	0,109	0,449
Melack			0,128	0,150	0,282	0,150
Telma				0,200	0,012	
KVx 442-3-25						0,758
Moussa Local		0,096				
KVX775-33-2				0,105	0,065	0,042
KVX771-10				0,040	0,029	0,033
KVX775-3-10				0,040	0,026	
TOTAL	**0,509**	**1,870**	**1,442**	2,763	2,858	**6,136**

In Senegal: 3 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 Network of farmers cooperatives (RESOPP) now set up by the NGO EWA. This network has several women seed producers as members. RESOPP has planted about 50 ha of Mélakh and Yacine Foundation and Certified seeds in 2011. 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. In 2011 these acreages were doubled to 2 ha for each variety and farmer. 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. These acreages were raised to 25 ha in 2011. 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. The same acreage was conducted in 2010 and 2011. With the closing of the EWA activities in the Louga area, we supplied 8 ha of Certified Seed production to the farmers' cooperative RESOPP. This area benefited from the 50 ha conducted by RESOPP in 2011. In addition, 20 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, 2010 and 2011 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.

Objective 3: Technology dissemination (seed of improved cowpea varieties in West Africa).

Collaborators

Jeff Ehlers (cowpea breeder), University of California, Riverside, USA
Samba Thiaw (agronomist), CNRA, Bambey, ISRA, Senegal.
Jean-Baptiste Tignegre, INERA, Kamboinse, Burkina Faso.
Dr. Amadou Moutari, INRAN, Niger
Dr. Mamadou Toure, IER, Mali

Approaches and Methods

INERA, Burkina Faso: In Burkina Faso during FY 11, Breeder Seed of seven improved cowpea varieties (IT98K-205-8, Melakh, KVX421-2J, KVX414-22-2, KVX442-3-25, KVX775-33-2, Gorom Local) will be produced at Saria and Pobe. This should yield 800 kg of Breeder Seed of each variety. Theory and practical training will be conducted at five locations (Tougan, Saria, Donsin, Pobe and Pissila), during the period April –May, 2011. This activity will train 120 farmers, of which at least 30 will be women. The 120 trained farmers also will be guided in producing Certified Seed of the INERA improved cowpea varieties. Each farmer will plant 1 ha (total of 840 kg of Breeder seeds) starting at the end of June 2011 in several villages of five provinces (Sourou, Oubritenga, Bulkiemde, Soum 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 will be made to each farmer's field during the June-September production season to provide updates on practical training and advice. Breeder (7 ha at SARIA, Koudougou) and Foundation (16 ha at Saria, Kamboinse and Pobe) Seed of the seven varieties will also be produced during the 2011 growing season (July-October). This is estimated to yield 350 kg of Breeder Seed of each variety and a total of 20 T of Foundation Seed.

ISRA Senegal: In Senegal, the availability of Foundation Seed is a bottleneck for adequate supply of seed to farmers. Additional Foundation Seed will be produced of three varieties (Melakh, Yacine, ISRA-2065) to supply new Certified Seed to growers. The plan was to produce 1 T of Foundation Seeds during the off-season (March – May 2011) under irrigation to complement the Foundation Seed obtained during the rainy season of 2010. During the 2011 rainy season 3 ha each of Melakh and Yacine foundation seeds and 1 ha of Pakau were produced. The project team will work with the National Extension Service (ANCAR) and 80 farmer organizations at 5 locations (Thilmakha, Merina, Mekhe, Bambey and Louga), where farmers (100 – 200) will be trained in seed production, harvest and post-harvest handling. ISRA will focus 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 is estimated that 50-60 T of Certified Seeds will be produced. Seed will be packaged in 4 Kg bags from a government processing unit in Diourbel near Bambey. At least 100 ha of Melakh and Yacine will be grown initially for Certified Seed, with the goal of scaling up in future years. During the 2010 growing season 2-3 T of Foundation Seed production was achieved at the ISRA Bambey Research Station. In 2011, 5-6 T of Foundation Seed is the goal. Support will also be provided to the Millennium and RESOPP organization set up by EWA to expand their cowpea seed production. One private seed company (ARSM) has been engaged for production of Certified Seed on 20 ha in 2011.

Results, Achievements and Outputs of Research

INERA, Burkina Faso: In Burkina Faso during FY 11, Breeder Seed of seven improved cowpea varieties (IT98K-205-8, Melakh, KVX421-2J, KVX414-22-2, KVX442-3-25, KVX775-33-2, Gorom Local) was produced at Saria on 7 ha. This yielded about 350 kg of Breeder Seed of each variety. Theory and practical training was conducted at five locations (Tougan, Saria, Donsin, Pobe and Pissila), during the period April –May, 2011. This activity trained 120 farmers, of which 35 were women. The 120 trained farmers were guided in producing Certified Seed of the INERA improved cowpea varieties. Each farmer planted 1 ha (total of 840 kg of Breeder Seed) starting in July 2011 in several villages of five provinces (Sourou, Oubritenga, Bulkiemde, Soum and Sanmatenga). This activity is estimated to have generated 40 T of Certified Seed produced on a total area of 60 ha. Two visits by the INERA national cowpea research team to each farmer's field were made during the July-October production season to provide updates on practical training and advice. Foundation Seed (16 ha at Saria, Kamboinse and Pobe) of the seven varieties was also produced during the 2011 growing season (July-October). Atotal of 20 T of Foundation Seed was produced across the three locations.

ISRA Senegal: To address the Foundation Seed bottleneck for adequate supply of seed to farmers, additional Foundation Seed was produced of three varieties (Melakh, Yacine, ISRA-2065) to supply new Certified Seed to growers. 1 T of Melakh and Yacine and 500 kg of ISRA-2065 (Pakau) Foundation Seeds were produced during the off-season (March – May 2011) under irrigation to complement the Foundation Seed obtained during the rainy season of 2010. The project team worked with the National Extension Service (ANCAR), a private organization (ARSM) 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 will be produced after completion of harvest. 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 attained and an additional of 50 ha was planted. During the 2011 growing season 5-6 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.

As part of the cowpea seed systems expansion effort, the meeting of cowpea scientists and breeders planned to be held in May 2011 in Mali (with Dr. Toure, IER) and in Niger (with Dr. Moutari, INRAN) was delayed until May 2012 to discuss the two year results from field evaluations, deliver planting seed of improved Senegal and Burkina Faso cowpea varieties and to discuss protocols for field testing. Further testing of the new improved varieties was conducted in Senegal and Burkina Faso to determine which to test in southern Niger and southwest Mali during the next growing season. An advanced yield trial with the 8 selected varieties was conducted in Burkina Faso at Saria and Pobé in the 2011 main season. The trial at Pobe failed because of late planting and severe drought in September. Data from the Saria planting is being processed. We will contact Dr Toure and Dr Baoua to discuss about the outcome of the trial and decide which varieties to promote in their 2012 field evaluations.

Objective 4: Capacity building for host country NARS
Develop a cowpea breeding program in Angola and strengthen existing breeding programs in Senegal and Burkina Faso through targeted training.

Collaborators
James Beaver and Timothy Porch, University of Puerto Rico, US.
David Kiala, Faculdade de CIências Agrárias (FCA)/Universidade José Eduado dos Santos, Huambo, Angola.
Antonio David, Instituto de Investigacao Agronomica, Luanda, Angola.
Students from Africa

Approaches and Methods
A significant portion of requested budget (U.S. for Host Country) to be spent on degree training in modern breeding for African students, and for training current NARS breeders in Angola, Burkina Faso and Senegal in application of the new high-throughput based molecular genotyping protocols for marker-assisted breeding to cowpea germplasm and breeding populations described under Objective 1. We anticipate the proposed breeding and seed dissemination research and training activities will build sustainable capacity through the development of new and improved cowpea varieties and elite breeding populations in the Host Countries, coupled with strengthening and expanding the cowpea seed production and dissemination systems (Breeder, Foundation, and Certified Seed production capability). Training in and adoption of the new SNP-based marker selection technology for the Host Country cowpea breeders will build capacity in the African cowpea breeding programs, and should result in significant breeding efficiencies. We anticipate continuing the leveraging of CRSP resources with other funding to propel the cowpea program forward.

Results, Achievements and Outputs of Research
Degree (MS and PhD level) training for two African scientists is being undertaken with the goal of developing the next generation of cowpea breeders. One trainee, Antonio David, from Angola, completed the MS course in plant breeding at the U. Puerto Rico, in collaboration with Dr. James Beaver. He started the UPR MS course in August 2009 and graduated in July, 2011. His training and return to Angola targets where a new cowpea breeder can complement the efforts to support a re-invigorated new cowpea breeding program. We worked with several trainee applicants for the PhD program at UC Riverside, and have now had one accepted in the Plant Pathology Graduate Program with a start date of Winter Quarter 2012 (January 2012). The student is Mr. Arsenio Daniel Ndeve, from Mozambique, who recently completed a MS degree in Denmark and is working with cowpea breeder Dr Rogerio Chiulele, at Universidade Eduardo Mondlane. He is an excellent candidate for training in cowpea breeding with emphasis in pathology, building on the vigorous cowpea breeding program being established by Dr. Chiulele with assistance from IAMM and their research stations at Umbelezi and especially Chokwe, where the station manager is Celestina Jochua, HC PI for Jonathon Lynch's Pulse CRSP project in

Mozambique. Another student, Madame Penda Sarr from Senegal, has enrolled at the University of Dakar (UCAD) for a PhD, focusing on *Macrophomina* disease of cowpea and cowpea genetics/breeding. She is working with HC PI Dr. Cisse and also with Dr Mbaye Ndiaye, Plant Pathologist stationed in Niamey, Niger. One other MS trainee from Senegal is now enrolled in the AGRA breeding program at the University of Ouagadougou, Burkina Faso, and working on cowpea.

Training current cowpea breeders in the development and application of DNA-based markers for MAS in the cowpea breeding programs has been embedded in the research effort under Objective 1. Cowpea breeders were 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. The focus has been on the Senegal and Burkina Faso programs and to some extent on Angola through the MS student Antonio David. This training utilizes the KBiosciences KASPAR SNP genotyping platform populated with 1057 informative markers derived from the Illumina SNP-genotyping platform we developed for cowpea. The approach has involved growing breeding progenies in Africa, leaf sampling, and shipping leaf samples to KBiosciences in 96-well customized plates for DNA extraction and SNP-based marker genotyping. The genotyping results are being co-analyzed by the US and HC team jointly via Skype and data sharing for data display on a monthly basis during the active breeding periods. Additional training was made through joint interpretation of data sets and progeny selections as a hands-on MAS and MARS experience at meetings in Madrid in May and India in September, linked with GCP-organized meetings. The genotyping allows all target traits described under Objective 1 to be advanced by indirect selection. Markers linked to traits including drought tolerance and *Macrophomina* and thrips resistance are being emphasized. This activity will require a continuing training effort extending through FY12 and beyond, in order to build by experience the necessary competence within the project team.

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 which provided 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: J Beaver, T. Porch, P. Roberts and J. Ehlers
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 2012
Type of CRSP Support (full, partial or indirect) partial/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: Mame Penda
Last Name TBD: Sarr
Citizenship Senegal
Gender: Female
Degree Program for training: PhD
Program Areas or Discipline: /Plant Pathology
Host Country Institution to Benefit from Training: Senegal
University to provide training: University of Dakar (UCAD)
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? N/A
Supervising CRSP PI: Ndiaga Cisse, Mbaye Ndiaye, PA Roberts
Start Date October 2010
Projected Completion Date October 2013
Type of CRSP Support (full, partial or indirect) Full
If providing Indirect Support, identify source(s)s of leveraged funds: GCP project funded to UC-R and ISRA
Amount Budgeted in Workplan, if providing full or partial support:
Direct cost: $ 10,000
Indirect cost:
U.S. or HC Institution to receive CRSP funding for training activity: ISRA

PhD Student 4
First and Other Given Names: Arsenio
Last Name: Ndeve
Citizenship: Mozambique
Gender: Male
Degree Program for training: PhD
Program Areas or Discipline: Plant Breeding/Plant Pathology
Host Country Institution to Benefit from Training: Mozambique
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, J. Ehlers and R Chiulele
Start Date January 2012
Projected Completion Date October 2016
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

MS Student 4
First and Other Given Names: Mouhamadou Moussa
Last Name: Diangar
Citizenship: Senegal
Gender: Male
Degree Program for training: MS
Program Areas or Discipline: Plant Breeding/Genetics
Host Country Institution to Benefit from Training: Senegal
University to provide training: University of Ouagadougou
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? N/A
Supervising CRSP PI: Ndiaga Cisse, HC PI
Start Date: October, 2010
Projected Completion Date August 2012
Type of CRSP Support (full, partial or indirect): Indirect
If providing Indirect Support, identify source(s) of leveraged funds: Kirkhouse Trust
Amount Budgeted in Workplan, if providing full or partial support: N/A

Explanation of 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. The site visit scheduled for December 2011 should help push this effort forward.

Under Objective 4 - 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 came to UC Riverside for intensive English language training in FY 2010. The outcome of TOEFL and GRE exams determined that one student (Penda Sarr) was enrolled in a PhD plant pathology program under our project guidance at the University of Dakar (UCAD), while Arsenio Ndeve has been admitted to the Plant Pathology Graduate Program at UC-Riverside and will start in January 2012.

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 Dry Pulse CRSP project PIs cowpea seed. We also worked with Drs. Jim Beaver and Tim Porch at the University of Puerto Rico on training a CRSP student from Angola and Dr. Mbaye Ndiaye at Aghrymet, Niger for the student from Senegal. 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 have been working with Association FERT, a French NGO whose aim is to improve cowpea production in the northern part of the country, and continued on-farm tests of improved varieties and we are helping them to produce Certified Seed. Linkages have also been maintained 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 continued with a Seed Producer Association named Venegre and one seed entrepreneur named Famille Kabre. Linkages have been made with 3 ministers (Former Prime Minister, the Minister of Agriculture and the Minister of Research and Technology) to produce Foundation and Certified seeds of variety IT98K-205-8.

In Senegal, collaboration was established with the extension service ANCAR in the Kaolack and Thiès regions and with RESOPP of EWA in the southern region of Sedhiou, for Certified Seed production of the variety Pakau. The Millennium Project, the private enterprise (ASRM) 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.

In Angola, multi-stakeholder partnerships are increasingly becoming a common feature of agricultural research for development in Angola. We have been working with Faculty of Agrarian Sciences, Institute for Agrarian Development, AFRICARE, an American NGO, and Small Farmers Association/Community Based Organizations (CBOs). The Would Vision, another American NGO, has ceased its activities in the agricultural sector in Angola.

Dr. David Kiala of the Faculty of Agrarian Sciences has carried out evaluation of germplasm across agro-ecological zones capturing farmers' preference and gender considerations for selecting cowpea varieties.

José Pedro of the National Center for Phytogenetic Resources has carried out cowpea landrace characterization.

Leveraging 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), focused 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 were also 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.

INERA leveraged funds: For our cowpea work we are getting: - $52,000 from GCP/TL1 project (Improving tropical legume productivity for marginal environments in sub-Saharan

Africa). 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).

ISRA leveraged funds: 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.

IIA leveraged funds: For our cowpea project we are working only with funds from the CRSP / UCR and from the IIA. However, we expect to receive funds from the Ministry of Health for multiplication and dissemination of the varieties of cowpea rich in minerals and proteins. Also, we will benefit from the financial support from the Rural Development Program and the Fight Against Poverty in seed cowpea multiplication.

Scholarly Activities & Accomplishments (Publications, Awards, Recognition, PVPs)

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Barrera-Figueroa, B**.,** Gao, L., Diop, N.-N.**,** Wu Z., Ehlers, J., Roberts, P.A., Close, T.J., Zhu, J.-K. and Liu, R. 2011. Identification and comparative analysis of drought-associated microRNAs in two cowpea genotypes. *BMC Plant Biology* 2011, 11:127 doi:10.1186/1471-2229-11-127.

Lucas, M.R., N.-N. Diop, S. Wanamaker, J.D. Ehlers, P.A. Roberts, and T.J. Close. 2011. Cowpea-soybean synteny clarified through an improved genetic map. The Plant Genome 4:1-11. doi:10.3835/plantgenome2011.06.0019.

Dr. Ndiaga Cisse was appointed as Director of the ISRA/CERAAS regional laboratory in 2011.

Dr. Philip Roberts was appointed Chair of the Department of Nematology, UC-R, in 2011.

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Muchero, W., J.D. Ehlers, and P.A. Roberts. 2009c. QTL analysis for resistance to foliar damage caused by *Thrips tabaci* and *Frankliniella schultzei* (Thysanoptera: Thripidae) feeding in cowpea (*Vigna unguiculata* L. Walp.). *Molecular Breeding* 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.

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

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Contribution to Gender Equity Goal

Among the target beneficiaries of the project work, the activities in Burkina Faso and Senegal resulted in producer/community based organizations being recipients of technical assistance during the report period, which are comprised of women and men. In addition, Host Country partner organizations/institutions in Burkina Faso and Senegal benefitted from the seed systems technology. More specifically, women organizations received technical assistance in Senegal and Burkina Faso. Also short-term training of women and 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 Technology Dissemination Seed Systems work under Objective 3.

Progress Report on Activities Funded Through Supplemental Funds

Capacity Building Supplement: ISRA, Senegal: 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 2010, 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. This training was completed during the project period.

Dry Grain Pulses CRSP

<u>Report on the Achievement of "Semi-Annual Indicators of Progress"</u>

(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by <u>October 1, 2011</u>

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	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Varietial test & release	x	x		x	x		x	x		0			0			0		
Germplasm seed increases	0			0			0			x	x		0			0		
Germplasm screening	x	x		x	x		0			x	x		0			0		
Variety candidate test - Angola	0			0			0			x	x		0			0		
Advance/test BC popns	x	x		x	x		x	x		0			0			0		
Advance/test elite popns	x	x		x	x		x	x		0			0			0		
SNP genotyping	x	x		x	x		x	x		x			0			0		
Objective 2																		
Breeder Seed production	0			x	x		x	x		0			0			0		
Foundation Seed production	0			x	x		x	x		0			0			0		
Certified Seed prodn. training	0			x	x		x	x		0			0			0		
Assess seed system - Angola	0			0			0			0			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																		
Breeder's Seed production	x	x		x	x		x	x		0			0			0		
Foundation Seed production	x	x		x	x		x	x		0			0			0		
Certified Seed production	x	x		x	x		x	x		0			0			0		
Certified Seed producer training	0			x	x		x	x		0			0			0		
Variety tests in Mali	0			x	x		x	x		0			0			0		
Variety tests in Niger	0			x	x		x	x		0			0			0		
Objective 4																		
MS Training Angola/UPR	x	x		0			0			x	x		0			0		
PhD Training UCR	x		x	0			0			0			0			0		
Training - MAS with SNPs	x	x		x	x		x	x		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		
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

#####

Date

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2010 – September 30, 2011)
Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the U.S.

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

Under Objective 2 Assess Seed System - Angola

This assessment is taking longer to complete than originally planned. In particular, the US PIs planned trip to Angola in December 2010 had to be cancelled because visas were not issued in a timely manner. We are currently planning to conduct this trip i8n December 2011.

Under Objective 4 Training: PhD Training (Breeding-HPR)

Delay was encountered in identifying an appropriate African student for this program, due to English language inadequacy. Two African student candidates came to UC Riverside for intensive English language training. After re- taking TOEFL and GRE exams, one of them has now been admitted into the UCR graduate program and will start in the winter quarter (Jan 2012) of this academic year.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 20010 -- September 30, 2011)

FY 2011 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	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
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	80	55
Number of men	140	135
Technologies and Policies		
Number of technologies and management practices under research	13	16
Number of technologies and management practices under field testing	10	10
Number of technologies and management practices made available for transfer	5	8
Number of policy studies undertaken		
Beneficiaries:		
Number of rural households benefiting directly	26,400	61,000
Number of agricultural firms/enterprises benefiting	19	29
Number of producer and/or community-based organizations receiving technical assistance	75	91
Number of women organizations receiving technical assistance	18	22
Number of HC partner organizations/institutions benefiting	23	29
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	36,200	76,000

Biological Foundations for Management of Field Insect Pests of Cowpea in Africa and Technology Dissemination Project

Principal Investigator
Barry Robert Pittendrigh, University of Illinois at Urbana–Champaign, USA

Collaborating Scientists
Clémentine Dabiré, INERA, Burkina Faso
Ibrahim Baoua, INRAN, Niger
Mohammad Ishiyaku, IAR, Nigeria
Mamadou N'diaye, IER, Mali
Manuele Tamò, IITA, Benin
J. Bello-Bravo, University of Illinois at Urbana–Champaign, USA
Malick Ba, INERA, Burkina Faso

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 FY11 to build a capacity to address all the three necessary steps to deliver IPM solutions to West African cowpea producers.

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). 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)(Scientific Animations Without Borders) and (2) an online peer review system for host county collaborators to share these educational materials (Sustainable Development Virtual Knowledge Interface), (3) in addition to developing working relationships with other organizations 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 the 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.

Progress on Project Activities for the Report Period by Objectives

Objectives 1 and 2 are given below together in relation to the insect species and detailed activities – it is presented in this manner to make it easier for the reader to follow activities associated with given species.

<u>Objectives 1 & 2:</u> Characterization of Pests of Cowpeas (*Maruca 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).

<u>Collaborators</u>

Dr. Sanon, University of Ouagadougou, Burkina Faso
Dr. Jeremy McNeil, University of Western Ontario, Canada
Dr. William Muir, Purdue University, Indiana, USA
Dr. Brad Coates, Iowa State University, Iowa
Dr. Venu Margam, Purdue University, Indiana, USA

<u>Approaches and Methods</u>

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; and (ii) in Burkina Faso the existing locations are Farako-ba, and Kamboinsé. 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 (SNPs).

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; Margam et al., 2011). 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 FY11

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., submitted; Huesing et al., accepted).

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 several publications (Ba at el. 2009; Margam et al., 2011) 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. **This represents an important outcome of our project that will directly benefit U.S. agriculture.** A manuscript using this approach has been published in a peer-reviewed journal (Margam et al., 2011).
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 this 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 was completed in FY10. The manuscript was submitted to the Journal of Economic Entomology in the summer of 2011 and is currently under review. Based on this work, Drs. Pittendrigh and Tamò were also co-authors on an expert panel paper that has been accepted in the journal "GM Crops" and is due to be published at the end of 2011 or early 2012.
7. All of the molecular tools we have developed, along with their applications for insect control, were applied, in 2011, 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 in 2012 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 and performed the first steps of 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 FY12) these molecular marker 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)

Agunbiade, T.A., B. S. Coates, D. Forgacs, V. M. Margam, L. L. Murdock, M. N. Ba, C. L. Binso-Dabire, I. Baoua, M. F. Ishiyaku, M. Tamò, B. R. Pittendrigh. The spatial genetic differentiation of the legume pod borer, *Maruca vitrata* F. (Lepidoptera: Pyralidae) populations in West Africa. Journal of Heredity. Submitted.

Bello-Bravo, J., F. Seufferheld, T. Agunbiade, L. Steele, D. Guillot, M. N. Ba, C. L. Binso-Dabire, I. Baoua, M. N'Diaye, M. Tamò and **B. Pittendrigh**. Scientific Animations Without Borders: cell-phone videos for cowpea farmers. In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

Agunbiade, T., L. Steele, B. Coates, A. Gassmann, V. Margam, M. Ba, C. Dabiré-Binso, I. Baoua, J. Bello-Bravo, F. Seufferheld, and **B. Pittendrigh**. IPM-omics: from genomics to extension for integrated pest management of cowpea. In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

Kyky. G.K., Tounou, A.K., Agboton, C., Dannon, E.A., Pittendrigh, B.R., and M. Tamò. Interactions between the aphid parasitoid *Lysiphlebus testaceipes* Cresson (Hymenoptera: Aphidiidae) and its hyperparasitoid *Syrphophagus africanus* Gahan (Hymenoptera: Encyrtidae). International Journal of Tropical Insect Science. Submitted.

Onstad D. W., Kang J., Ba N. M., Dabire C., Tamò M., Jackai, L. and B. R. Pittendrigh. Modeling Evolution of Resistance by *Maruca vitrata* to transgenic insecticidal cowpea in Africa. Journal of Economic Entomology. Submitted.

Huesing, J., Romeis, J., Ellstrand, N., Raybould, A., Hellmich, R., Wolt, J., Ehlers, J., Margam, V., Pasquet, R., Stein, J., Tamò, M., **B. R. Pittendrigh**, Fatokun, C., Hokanson, K., Ishiyaku, M., Matole, M., Mignouna, J., Moar, W., Nangayo, F., Ouedraogo, J., Schaal, B., and Murdock, L. Regulatory considerations surrounding the deployment of Bt-expressing cowpea in Africa: report of the deliberations of an expert panel. GM Crops. Accepted.

Baoua, I., N. M. Ba, T. A. Agunbiade, V. Margam, C. L. Binso-Dabiré, S. Antoine, and **B. R. Pittendrigh**. 2011. Potential use of *Sesbania pachyca* DC (Fabaceae: Papilionoideae) as a refugia for the legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae). International Journal of Tropical Insect Science. Accepted.

Bello-Bravo, J., F. Seufferheld, L. D. Steele, T. Agunbiade, D. Guillot, G. Cutz, & **B. R. Pittendrigh**. 2011. Scientific Animations without Borders: an international online approach for building applicable scientific educational materials for use on cell phones, portable devices, and the Internet in developing nations. The International Journal of Science in Society. Accepted.

Margam,V.M., B.S. Coates, D. O. Bayles, R.L. Hellmich, T. Agunbiade, M.J. Seufferheld, W. Sun, J.A. Kroemer, M.N. Ba, C.L. Binso-Dabire, I.B. Bokary, M.F. Ishiyaku, F.G. Covas, R. Srinivasan, J. Armstrong, L.L. Murdock, and **B. R. Pittendrigh**. 2011. Transcriptome sequencing, and rapid development and application of SNP markers for the legume pod borer *Maruca vitrata* (Lepidoptera: Crambidae). PLoS One. 6(7): e21388.

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. 2011. Geographic distribution of phylogenetically-distinct legume pod borer, *Maruca vitrata* (Lepidoptera: Pyraloidea: Crambidae). Molecular Biology Reports. 38(2): 893-903.

Margam, V., B. S. Coates, R. L. Hellmich, T. Agunbiade, M. J. Seufferheld, W. Sun, M. N. Ba, A. Sanon, C. L. Binso-Dabire, I. Baoua, M. F. Ishiyaku, F. G. Covas, R. Srinivasan, J. Armstrong, L. L. Murdock, and **B. R. Pittendrigh**. 2011. Mitochondrial genome sequence and expression profiling for the legume pod borer *Maruca vitrata* (Lepidoptera: Crambidae). PLoS One. 6(2): e16444.

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.

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. (Not directly funded by CRSP but a by-product of our current research efforts and this was funded by Dow Agro Sciences).

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. 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.

<u>Objectives 1 & 2:</u> Characterization of the Other Pests of Cowpeas (other than *Maruca vitrata*) and Molecular Markers

<u>Objective 2:</u> 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 *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. These are the pests we have studied in this objective.

<u>Collaborators</u>

Dr. Sanon, University of Ouagadougou, Burkina Faso
Dr. Jeremy McNeil, University of Western Ontario, Canada
Dr. William Muir, Purdue University, West Lafayette, IN, USA
Dr. Brad Coates, Iowa State University, Ames, Iowa
Dr. Venu Margam, Purdue University, West Lafayette, IN, USA

<u>Approaches and Methods</u>

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 FY11 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 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 is 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. We have collected the necessary samples of insects and begun the process of 454 sequencing of mixed samples (within each species) to discover polymorphisms that will be used for SNP analysis is FY12.
2. 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.

3. The good results obtained in FY10 with viral sprays against the pod borer *M. vitrata* (yield increases in the test plots (26-34%) were confirmed also in FY11. Detailed experiments in Benin indicated an average of 67% yield increase in the first cropping season, as compared to the untreated plot. ***Better, a combination of aqueous formulation of neem oil combined with the virus doubled the cowpea grain yield (108%).*** (Also – see Objective 5).
4. 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.

Implications for pest control strategy

1. We have defined which regions and 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 (combined with neem oil) 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.

Details of Efforts over FY11

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.

<u>Objective 1:</u> 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.

<u>Collaborators</u>

Dr. Jeremy McNeil, University of Western Ontario, Canada
Dr. Venu Margam, Purdue University, West Lafayette, IN
Dr. David Onstad, UIUC, Urbana, IL

<u>Approaches and Methods</u>

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 FY11

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 2.5-years. 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., 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.

Objective 6: 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, 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 The Beta version of the online information sharing system for extension materials was launched in February of 2011 [the Sustainable Development Virtual Knowledge Interface (SusDeViKI); http://susdeviki.illinois.edu; Bello-Bravo *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);
In response to feedback from host country collaborators on the outcomes of successful pest control strategies (based on cultural practices), we have developed 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. All three videos were released in 2011 and have been translated into multiple local languages (please see for an incomplete list of the total language videos for two of the videos http://sawbo.illinois.edu/OnlineMaterials/VIDEO/AGR/Cowpea01/EN/ and http://sawbo.illinois.edu/OnlineMaterials/VIDEO/AGR/NEEM01/EN/) and can be found on the SusDeViKI system (http://susdeviki.illinois.edu - over 100 entries into the system – with over several thousand downloads of). This cost-effective way to produce such material (with easy voice-overs in new languages) has resulted in the development of a UIUC-based group called "Scientific Animations Without Borders" (SAWBO) which will also be producing videos for other development and socially related projects and programs (with other funding sources). A video explaining the overall program can be found at http://www.youtube.com/watch?v=JjtOHFFJSpc. 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). A first contact has been made with staff of the Ministry of Communication in Benin to promote this technology within their current strategy of introducing ICT innovations to the rural areas. A meeting has been scheduled early November to discuss the details of this collaboration.

Also, a number of governmental agencies (INRAB, SPV) and NGOs have been contacted in Benin and the information about SusDeViKI and SAWBO passed on to them. The early feedback received so far is encouraging, and dissemination of the animated videos will be continued in FY12.

6 In FY12 we have perform studies to address the access of women in rural areas to cell phones in Burkina Faso; we expect the data to be summarized by the middle of FY12.

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
Ministry of Communication, 1 collaborator
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-Entomology

Approaches/Methods/Results

Farmer Field School

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 farmer 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-Bravo at UIUC 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-Bravo received funding from UIUC to travel to Benin to interact with IITA staff to initiate this project and she is currently working with IITA, and Tolulope Agunbiade at UIUC on a manuscript to summarize the critical knowns and unknowns of the gender differences. Dr. Bello-Bravo 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).

Technician 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 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.

Bello-Bravo, J., F. Seufferheld, L. D. Steele, T. Agunbiade, D. Guillot, G. Cutz, & **B. R. Pittendrigh**. 2011. Scientific Animations without Borders: an international online approach for building applicable scientific educational materials for use on cell phones, portable devices, and the Internet in developing nations. The International Journal of Science in Society. Accepted.

Objective 4: Dissemination project capacity building of host countries

Summary of Accomplishments for Objective 5A-5D

1. Low-cost/highly efficient system for mass rearing techniques for *M. vitrata* (and its parasitoids *A. taragamae* and *Nemorilla maculosa*) using cowpea sprouts adapted for HC conditions and currently in use in Benin, Burkina Faso and Niger.

a) Approximately 30X less expensive and much easier technology than the previous rearing technology.
b) Parasitoids and viruses can be produced on a much larger scale for a fraction of the costs.
c) The technology can easily be transferred to new programs and organizations.
d) 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* are currently being experimentally field-tested in Benin during FY11.

3. A detailed field experiment in Benin confirmed the good results obtained last year with the viral sprays. In the first cropping season, the application of aviMNPV led to an average grain yield increase of 67.2% as compared to the unsprayed plot. In the same experiments, a combination of aqueous formulation of neem oil and MaviMNPV resulted in 106.8% yield increase, statistically superior than the yield increase with the synthetic insecticide (66%). The second season experiments are currently in the field in Benin, Niger and Burkina Faso. In Benin the results showed at minimum of 34% increase in cowpea yield due to this novel control spray. The results will be available mid-November to early December 2011.

<u>Objective 4 5A:</u> Build capacity at host country institutions for the rearing and mass release of bio-control agents that are currently ready for release.

<u>Approaches and Methods</u>

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 2 (FY11)

1. The technique developed and tested in FY10, using germinating cowpea grains to rear *M. vitrata*, is currently been successfully applied for mass production of the parasitoid *A. taragamae* used for field releases in Benin. In addition, this methodology is, so far, the only one that works for rearing the newly introduced tachinid parasitoid *N. maculosa*. Earlier attempts to establish rearing colonies of this second parasitoid on *M. vitrata* using artificial diet failed after the second generation, indicating a possible nutritional deficiency, see below. 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 artificial 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 1a and 1b. The in-field mass rearing technique using *Sesbania cannabina* scheduled for year 2-3, and already developed during FY10, was further modified and adapted in FY11 to use naturally occurring patches of *Tephrosia platycarpa*, a weedy legume widely available in the Savannah area in Southern Benin, an important host plant for *M. vitrata*. This was done in the perspective of using this caging device in rural areas, without having to purchase galvanized pipes and planting crops of *S. cannabina*. The experimental inoculation was repeated three times, and cocoons of *A. taragamae* could be observed on the leaves of *T. platycarpa*, and also on leaves of the accompanying vegetation (such as *Andropogon* sp. as in Figure 2). From these first inoculations, it appears that the density of *A. taragamae* cocoons will be less on *T. platycarpa* than previously observed on *S. cannabina* (up to 40 cocoons/sqm). However, considering the reduced costs and labor, we can anticipate having more caging devices that it would be possible for *S. cannabina*.

Figure 2. A cocoon of *A. taragamae* found on the grass Adropogon sp. (touching a *M. vitrata* infested inflorescence of *T. platycarpa*) in the caging device.

In addition to the above, detailed experiments were set up in Benin to monitor the short range dispersal capacity of the parasitoid *A. taragamae*. For this purpose, sentinel *Sesbania cannabina* plots artificially infested with *M. vitrata* were planted at 5 and 25 m distance from a release point of A taragamae (an earlier planted *S. cannabina* plot artificially infested with *M. vitrata* and inoculated with *A. taragamae*), and monitored regularly for the formation of *A. taragamae* cocoons. The dispersal of *A. taragamae* from the release site was subjected to the prevailing wind direction, and could be measured in all sentinel plots at both 5 and 25 m distance. This information is particularly important for shaping future deploying systems using caged natural vegetation as already attempted with *T. platycarpa*.

2. Nursery plots of *T. candida* were established at INERA Farakoba and INRAN Maradi as planned. The plants started to flower in August 2011, and the first inoculation is in progress and will be completed in November 2011.

Objective 5B: *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. Thus, we have worked with and are working 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 (FY11), 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 (FY11)

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. Initial sequencing steps have occurred.

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. Initial sequencing steps have occurred.

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

<u>Approaches and Methods</u>

In partnership with HC collaborators, we will be developing rearing and delivery systems for the following priority natural enemies:

<u>Against *M. vitrata*</u>

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).

<u>Against *C. tomentosicollis*</u>

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).

<u>Results for Year 2 (FY11)</u>

1. The results from the late experiments carried out in 2011 (but in November, hence already in the period covered by this report, i.e. FY11) confirmed the caged experiments carried out at the station in FY10. An average egg mortality of 73.4% was recorded in cages using sentinel egg batches of *M. vitrata*. Under artificial infestation with *M. vitrata* adult females, however, no statistically significant differences in *M. vitrata* infestation could be observed. It must be noted that, in spite of the artificial infestation, *M. vitrata* larval population levels were quite low in both the untreated control (3.6 larvae/plant) and the *T. eldanae* inoculated cages (2.3 larvae/plant). This might be due, as observed in the field already, to the unseasonal high rainfall which persisted in the region where the experiment has been carried out, and which might have interfered with the oviposition behavior of *M. vitrata*. Nonetheless, the potential of *T. eldanae* to parasitize eggs of *M. vitrata* on cowpea has been clearly demonstrated and warrant the continuation of developing field deployment systems as described below.
2. We are currently testing an improved slow release system using different substrates (millet-based and cowpea-based) for rearing the rice moth *Corcyra cephalonica*, whose eggs are used as oviposition substrate for *T. eldanae*. Last year's experience with jute bags was not quite positive, so we had to look for different releasing systems. In fact, the jute bags developed and used in the McKnight project for releasing the parasitoid *Habrobracon hebetor* unfortunately induced very high mortalities in tiny hymenopteran such as the

trichogrammatid *T. eldanae* while trying to pass through the meshes. We tested larger mesh jute bags, but there were too many escapes of *C. cephalonica*, and also loss of millet grains. Hence, we focused our efforts on other materials, such as ordinary mosquito screen, or plastic bowls, both readily available on local markets in West Africa.

3. A similar release device has also been developed for the release of the egg parasitoid *Gryon fulviventre*, attacking eggs of the brown coreid bug *Clavigralla tomentosicollis*. Adults of *C. tomentosicollis* are reared inside a plastic bowl containing cowpea grains as food substrate (Fig. 3). The eggs produced are parasitized by females of *G. fulviventre* previously inoculated into the device with the pod bugs. The device is currently being field tested in Benin, first results will be available early December 2011.

Figure 3. Improved slow release system for bio-control agents using inexpensive local materials.

4. 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 was hand-carried by an AVRDC staff visiting Nigeria in December of 2010. A total of 50 pupae were received, however, some of the parasitoids had already emerged during transit and died before inspection (a normal mortality rate for when transporting such materials). Rearing of this new parasitoid on *M. vitrata* started with 23 surviving adults, 17 females and 6 males. A total of 212 larvae of *M. vitrata* were presented for parasitization on piece of artificial rearing diet, and 43 pupae of *N. maculosa* were obtained during the first generation. Unfortunately, for unknown reasons the second generation gave only 7 parasitoid pupae, and none of the emerging tachinids was able to further parasitize *M. vitrata* larvae. A new batch of *N. maculosa* was received in September 2011, and this time we used *M. vitrata* larvae reared with the new cowpea grain sprout method for exposing to the parasitoids. The resulting generations were all fit and we are now successfully rearing over 200 parasitoids from the

initial 37 which survived the trip from Taiwan. A series of pre-release studies, focusing on host range, will start in December 2011.

Additional result: Based on the encouraging results from the viral spray experiment carried out in Benin, Burkina, Niger and Nigeria last year (with yield grain increases averaging 31.3% for the MaviMNPV treatment over the control), a detailed experiment was carried out in Benin comparing conventional spray with aqueous formulation of both neem oil and oil of *Jatropha curcas* mixed with the virus, in order to control the other cowpea pests (e.g. thrips, aphids) present in the field together with *M. vitrata*. In the first season, the application of MaviMNPV alone was able to control *M. vitrata* thereby producing a cowpea grain yield increase of 67.2% over the unsprayed control, and statistically comparable to the chemical treatment. ***However, the association of the virus with the aqueous formulation of neem oil gave by far the best yield gain, 106.8% compared to the unsprayed plot, and statistically superior to the chemical treatment (65.9%).*** These results are very encouraging and confirm reports from the literature about the synergistic effect of mixing aqueous oil formulation with NPVs, whereby the addition of oil would assure some degree of UV protection to the virus, while at the same time controlling the companion insect pests on cowpea. A second season experiment has just started, and the results will be available early December 2011. Also, second field season of last year's field experiment comparing MaviMNPV with conventional insecticides is currently on-going in Burkina, Niger and Nigeria, results are expected by mid-November 2011.

<u>Objective 6:</u> Other institutional capacity building training activities in rearing and release of biological control agents

<u>Approaches and Methods</u>

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. Also, interactions with other groups such as Peace Corps, NGOs, and Farmer Field Forums also occurred.

<u>Results for year 1 (FY11)</u>

This cross-training activity has occurred both in FY10 and FY11 by exchanges of technicians between institutions and by intra- and inter-institutional one-day and multiple-day training sessions.

Training

<u>Non-degree 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 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.

Additionally, a research exchange occurred with Drs. Tamò, Dabire, Ba, and Baoua all visiting the Pittendrigh laboratory in 2011. This exchange was critical for the planning of the FY12 program as well as to summarize datasets from the previous years and to develop new voice overlays for extension materials useful in their respective countries.

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 and she has been spearheading the effort to sequence the other pest species. 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 (SAWBO), and working on the molecular biology aspects of the project.

Additionally, Dr. Pittendrigh 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 two M.S. students (one female and one male) through the University of Ouagadougou. They are now continuing their PhD program with Dr Dabire. These students are directly funded by the CRSP.

Degree Trainees

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: Traore
Last Name: Fousseni
Citizenship: Burkina Faso
Gender: Male
Degree Program for training: PhD 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, Ba, and Sanon
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: Sanou
Last Name: Appoline
Citizenship: Burkina Faso
Gender: Female
Degree Program for training: PhD 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, Ba and Sanon
Start Date of Degree Program: 2010
Program Completion Date: July 2014
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: Tamò
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: Female
Degree: PhD
Discipline: Entomology
Host Country Institution to Benefit from Training: Benin, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamò
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: Tamò
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 was October 2008 and October 2010. 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, 2011: on-going
When did the Short Term Training Activity occur? July – Oct 2011
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- 2
Female- 3
Total- 5

Type of Training: technician
Description of Training Activity: biocontrol of cowpea pests
Status of this Activity as of September 30, 2011: on-going
When did the Short Term Training Activity occur? FY11
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? FY11
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- >250
Female- >250
Total- >500

Type of Training: Online Video Materials on SusDeViKI, SAWBO site, e-mail distribution, in country distribution, media exposure, and YouTube views

Description of Training Activity: Individual and groups wishing to access video-based training materials on the Internet (some of these are just views on the web and some are actual use of cell-phone ready videos).
Status of this Activity as of September 30, 2011: February-ongoing
When did the Short Term Training Activity occur? FY11
Location of Short Term Training: Burkina Faso, Mali, Nigeria, and Niger, and other countries across West Africa (and countries beyond West Africa including Rwanda)
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Educators and Farmers
Number of Beneficiaries by Gender:
We are not able to keep track of gender, but we assume it to be relatively equal numbers

SusDeViKI views of CRSP videos across the world - >10,000
SusDeViKI downloads of cell phone ready SAWBO/CRSP videos – >1200
YouTube views of various Scientific Animations Without Borders Videos - >16,757
SAWBO views and download of videos (only up since the beginning of September) – >200 views and downloads
The SAWBO and SusDeViKI sites have been shared online (via e-mail introductions) with over 300 NGOs, governmental agencies, universities, and other potentially interested organizations.
Voice of America has released several articles on SAWBO including YouTube videos – the “hits” to date include 4,747 views in the English version and 1,159 views for the Vietnamese version.
An incomplete list of the all the media articles on SAWBO can be found at https://sib.illinois.edu/pittendrigh/sawbo/news
We maintain active Twitter, YouTube, Facebook, and LinkedIn sites and interactions with international development organizations to promote the use of these videos.
The SAWBO team did an interview with PBS in August of 2010 and we expect this to be aired nation-wide (in the USA) in January of 2011. This program is expected to go out to

1.5 million viewers (both within the USA and abroad) and will be hopefully followed up with an online version that can be viewed on YouTube. From this we hope to identify more organizations that can assist in deployment of these videos in developing nations. As a result of the previous media exposure we are now interacting with "Esoko", a company based in Ghana - focused on deployment of educational materials through cell phones – Dr. Pittendrigh plans to visit with this company in January to push forward with approaches to deploy these videos to a large number of farmers in West Africa. Dr. Bello has received internal UIUC funding to also travel to Ghana to interact with Esoko. Videos have also been distributed "on the ground" from cell phone to cell phone in our host countries to farmers, farmer organizations, companies, and NGOs. For example, In Benin, the neem video was 'seeded' by IITA to 4 NGOs, 2 national research organizations, and 2 farmer organizations.

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 5^{th} 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. Based on this meeting we have had continued interactions with CORAF.*** This is in keeping with suggestions by the TMAC. CORAF has also been informed of our extension programs and has been provided with access to all these materials.

Other Universities Involved

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
Our project is maintaining active collaborative links with MEAS and the ADM post-harvest loss institution – both groups are headquartered at UIUC

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-Bravo has received CIBER funding for her efforts dealing with the extension component of our project.
7. Dr. Tamò received $15,000 from GTZ/BMZ for work on the biocontrol of *M. vitrata*
8. Dr. Bello-Bravo's participation in the meeting in Ecuador was cost-shared by UIUC funds.

Scholarly Activities and Accomplishments

Adati, T., Tamò, M., Downham, M.C.A. Migration and mating status of the legume pod borer, *Maruca vitrata* in Northern Nigeria with reference to the efficacy of synthetic sex pheromone traps.In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

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. Plant protection deployment strategies for extension services and cowpea farmers. In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

Dabiré, C., Tamò, M. Ouédraogo, T.J., Tignegré, J. B., Ba, M., Hammond, W. Coulibaly, O. Efforts de gestion des contraintes biotiques au Burkina Faso et en Afrique de l'Ouest. In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

Dannon,E., 2011. Biology and ecology of *Apanteles taragamae*, a larval parasitoid of the cowpea pod borer *Maruca vitrata*. PhD thesis dissertation, University of Wageningen, The Netherlands, 188 pp.

Dannon, E., Tamò, M., Huis, A., Dicke, M. Effect of *Maruca vitrata* (Lepidoptera: Crambidae) host plants on life-history parameters of the parasitoid *Apanteles taragamae* (Hymenoptera: Braconidae). Insect Science (in press).

Dannon, E., Tamò, M., Huis, A., Dicke, M. Assessing non-target effects and host feeding of the exotic parasitoid *Apanteles taragamae*, a potential biological control agent of the cowpea pod borer *Maruca vitrata*. BioControl (in press).

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).

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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-Bravo. Expanding the Impact of Practical Scientific Concepts in Developing Nations through Cutting Edge Technologies. World Universities Forum, Davos, Switzerland, January 9-11, 2010.

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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.In: Tamò M., Fatokun, C., Boukar, O., Coulibaly, O. and Muranaka, S (eds.). Improving livelihoods in the cowpea value chain through advancements in science. Proceedings of the 5th World Cowpea Research Conference, 26 September – 1 October 2010 Saly, Senegal (under review).

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-Bravo 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 – due to be published at the end of 2011 or beginning of 2011). 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 Institutional Capacity Building 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

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.

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.

The "*Technology Dissemination*" project is described under Objectives 4 and 6. 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, 2011 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

Project Title: *(1) Biological Foundations for Management of Field Insect Pests of Cowpea in Africa and (2) Implementation of a Comprehensiv*

	Abbreviated name of institutions																	
	UIUC			IITA			INERA			INRAN			IER			IAR		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/1	Y	N*	9/30/1	Y	N*	9/30/1	Y	N*	9/30/1	Y	N*	9/30/1	Y	N*	9/30/1	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1 Characaterize life-hitsory partterns of pests of cowpeas																		
Pod sucking bugs				X	X		X	X		X	X							
Groundnut aphids				X	X		X	X		X	X							
Aphids				X	X		X	X		X	X							
Maruca				X	X		X	X		X	X							
Objective 2 Development of molecular margers to study populations of five pests of cowpeas																		
Finalize collection of insects				X	X		X	X		X	X							
Sequencing of insect populations	X	X																
Objective 3: Development and deployment of extension materials for IPM for pests of cowpea																		
Develop MP3 and videos	X	X		X	X		X	X		X	X		X	X		X	X	
Dr. Baoua visits UIUC	X	X								X	X							
Dr. Ba visits UIUC	X	X					X	X										
Purchase materials for extension	X	X					X	X		X	X							
Objective 4: Capacity at host country institutions for the rearing and mass release of bio-control agents																		
Maruca parasitoid				X	X		X	X		X	X							
Thrips parasitoid				X	X		X	X		X	X							
Maruca viral control				X	X		X	X		X	X							
Objective 5: Genomics of biological control agents																		
Initial sequence of biocontrol age	X	X																
New biocontrol agents in development				X	X		X	X		X	X							
Objective 6: Institutional capacity building																		
Tech, Peace Corps, and NGO trair	X	X		X	X		X	X		X	X							
Farmer field forums				X	X		X	X		X	X		X	X		X	X	
Audio/Videos deployed	X	X		X	X		X	X		X	X		X	X		X	X	
Non-degree training				X	X		X	X		X	X		X	X		X	X	
Degree training	X	X		X	X		X	X										
Name of the PI reporting on benchmarks by institution	Barry Pittendrigh			Manuele Tamo			Clementine Dabire			Ibrahim Baoua			Mamadou N'Diaye			Mohammed Ishiyaku		

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

Signature

Date: 10/1/2011

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 20010 -- September 30, 2011)

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: (1) Biological Foundations for Management of Field Insect Pests of Cowpea in Africa and (2) Implementation of a Comprehensive Bio-Control Program for the Management of Economically Important Insect Pests on Cowpea in West Africa – Technology Dissemination Project UIUC West Africa

Lead U.S. PI and University: Barry Pittendirgh, UIUC

Host Country(s): Niger, Nigeria, Mali, Burkina Faso, and Benin

Output Indicators	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
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	>100	≥250
Number of men	>100	≥250
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	5	5
Number of policy studies undertaken	N/A	N/A
Beneficiaries:		
Number of rural households benefiting directly	>1000	≥1000
Number of agricultural firms/enterprises benefiting	>5	7
Number of producer and/or community-based organizations receiving technical assistance	50	≥50
Number of women organizations receiving technical assistance	25	25
Number of HC partner organizations/institutions benefiting	5	5
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	>5000	≥5000

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

Principal Investigators
James Beaver, University of Puerto Rico, Puerto Rico
Consuelo Estevez, University of Puerto Rico, Puerto Rico
Timothy Porch, USDA-ARS, Puerto Rico

Collaborating Scientists
Juan Carlos Rosas, (EAP), Honduras
Emmanuel Prophete, National Seed Program, Ministry of Agriculture, Haiti
António Chicapa Dovala, IIA, Angola

Abstract of Research Achievements and Impacts

Significant progress was made toward research and training objectives. The small red BGYM and BCMV resistant cultivar 'CENTA Chaparrastique' was released in El Salvador. The small red bean cultivar 'Paisano PF', developed by PPB (participatory plant breeding) approaches in collaboration with farmers from the Yojoa Lake region, was released in Honduras. 'Beníquez', a BGYMV, BCMNV, BCMV and rust resistant white bean cultivar, was released in Puerto Rico in collaboration with the UPR, the USDA-ARS-TARS and the University of Nebraska. Web blight resistant breeding lines PR0401-259 and PR0650-31 were released in cooperation with the UPR, the USDA-ARS-TARS and Zamorano. 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 was used for selection of CBB and BCMV resistance and phenotypic selection for ALS resistance. Yellow bean breeding lines were developed that have resistance to BGYMV, BCMV and common bacterial blight. Bean breeding lines from Oregon State University had high levels of resistance to the common bean weevil.

Greenhouse trials conducted in Honduras identified lines with higher nodulation scores and greater root and shoot dry weights under low N conditions. The soil cylinder technique was used at Zamorano to measure the response of bean lines to specific strains of *Rhizobium*. Inbred-backcross populations were developed to study the expression of nodulation and N_2 fixation traits. The most promising F_4 lines derived from crosses between diverse parents having good nodulation will be recombined to form the second cycle of recurrent selection for enhanced biological nitrogen fixation. Significant *Rhizobium* strain x bean line interaction for seed yield was observed in a field trial planted at Isabela, Puerto Rico. Lines were identified that nodulated and yielded well when inoculated with either strain 899 or 1597.

USDA and UPR scientists collaborated in the identification of the dominant gene, *Xap-1*, that confers resistance to common bacterial blight. The response of common bean to *Macrophomina phaseolina* (ashy stem blight) was evaluated in the field and greenhouse using a detached-leaf inoculation technique. ENM-Few/RVe primers showed potential for indirect select selection for the *bc-3* gene. The web blight and root rot reactions of nine *Rhizoctonia solani* isolates from bean leaves and roots were studied in the greenhouse. There were significant bean line x isolate

interactions for both web blight and root rot reactions. PR0401-259 had the best overall resistance to web blight.

There were significant differences among Lima bean landrace varieties from Haiti, the Dominican Puerto Rico varieties for seed type, leaf and pod type, days to flowering, seed yield and concentration of HCN in the leaves and seed. The Caribbean collection of Lima bean landraces was sent to CIAT for preservation in the germplasm collection. The diversity of Angolan cowpea germplasm, in relation to a diverse worldwide collection, was evaluated through phenotypic characterization in two field trials planted at Isabela, Puerto Rico, and for seed elemental composition in the laboratory. The initial seed elemental composition results indicate some unique nutritional characteristics of Angolan germplasm, including high protein and iron content. Tepary (*Phaseolus acutifolius*) breeding lines were developed from crosses between elite germplasm resulting in lines with increased seed size, improved architecture characteristics, and bacterial blight resistance. These lines are being tested in Honduras, the U.S., Angola and Puerto Rico.

Two technicians from the Instituto de Investigação Agronómica completed M.S. degrees in Plant Breeding at the University of Puerto Rico, Mayagüez and returned to Angola to work in common bean and cowpea breeding. One student from Puerto Rico completed his M.S. degree at the University of Puerto Rico in plant breeding. Two students completed B.S. degree training at Zamorano. Short term training was provided for Pablo Vargas (Zamorano student) at the University of Puerto Rico and at the USDA-ARS-TARS.

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 also benefits 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 the region. This limited release of germplasm 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 Nicaragua, 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. Although this Dry Grain Pulse CRSP project emphasizes field-testing of black bean breeding lines in Central American and Caribbean countries, the project also develops and releases Andean (red mottled, yellow and light red kidney) bean lines that have resistance to BGYM, BCMNV and other diseases of economic importance.

The research project is in the position to make significant impact in Central America, and the Caribbean. 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 has leveraged additional funds that will extend the potential impact of the collaborative research in Haiti. The project also trains 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 Angola, given the similarity in agro-ecological 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 other Dry Grain Pulse CRSP projects and bean research networks in Africa (e.g., SABRN, ZARI, CIAT) in the evaluation of improved bean cultivars and breeding lines from the U.S., Central America and the Caribbean. Project personnel meet frequently to evaluate bean lines in nurseries and to exchange information at scientific meetings.

Progress on Project Activities for the Report Period by Objectives

<u>Objective 1</u>: Development, release and dissemination of improved bean cultivars for Central America, the Caribbean and Angola

<u>Approaches and Methods</u>

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 were 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 and red mottled 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 provided 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

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. Parents used in the crosses included promising breeding lines, improved cultivars and landraces, and sources of disease resistance and tolerance to abiotic factors from Zamorano, the UPR, the USDA-ARS, 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, and others for Angola. During the past year, F_1 populations were developed and F_2 plants were evaluated and selected for highly heritable traits. 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. Populations derived from crosses including local landrace cultivars were developed using participatory plant breeding (PPB) approaches in collaboration with farmer groups and researchers from El Salvador, Honduras and Nicaragua. Early generation populations were 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.

Breeding populations were derived from crosses between landrace x improved cultivars to improve the most common Honduran small red bean landraces ('Paraisito', 'Cincuenteño' y 'Marciano'). Selected lines from these populations are currently under validation in farmer fields in most bean production areas in Honduras. It is expected that at least one improved landrace cultivar will be released in Honduras during FY12. Some of these improved landrace cultivars and lines are useful for Nicaragua and El Salvador, where landraces with similar characteristics to those from Honduras are commonly grown by small-scale farmers.

During the current period of funding, the project has made a major effort to develop superior black bean cultivars for Guatemala and Haiti. This effort has led to the release of several black bean cultivars in both countries during past few years. In addition, promising black bean cultivars are currently being tested in field trials in Nicaragua, where black bean production for export has increased in recent years. Breeding populations derived from crosses, including the black bean cultivar 'Vaina Blanca Negro' from Costa Rica, were tested in 2009-10, and promising lines selected from these populations are being evaluated in farmer fields. At least one of these improved black bean lines is expected to be released as a cultivar in Costa Rica during FY12.

Inbred backcross populations for developing small red and black bean cultivars that combine BGYMV, BCMV and BCMNV resistance for Central America and the Caribbean were generated and advanced to early generations using the black bean cultivar XRAV40-4 and the small red breeding line PR9825-49-4 as BCMNV resistance sources. F_4-F_5 families have been selected for superior agronomic performance, desirable seed traits and SCAR markers for BGYMV and BCMV resistance. Selected F_{5-6} families will be screened for resistance to BCMNV at the University of Puerto Rico during FY12. The development and release of BCMNV resistant bean cultivars for Central American is vital to deal with the potential spread of this virus which has caused severe bean seed yield reductions in the Caribbean. The black bean lines under development should also be useful for bean production in Haiti and other Caribbean countries, where resistance to BGYMV and BCMNV, in combination with other disease resistance genes, and adaptation to production constraints such as limited rainfall and low soil fertility are necessary.

Germplasm collected in Angola representing predominant market classes (medium sized yellow, green, and white types; and large seeded cranberry and kidney types) grown in the major common bean growing regions of Bie, Huambo, Cuanza Sul, and Malange provinces were evaluated in Puerto Rico by Monica Martins as part of her M.S. thesis research at the UPR. All of the Angolan landraces were found to be susceptible to CBB and BCMV, and they were largely susceptible to ALS (Table 1), which are important diseases based on disease evaluations in Angola by Dr. Estevez. Several of the Angolan lines showed good BNF potential, while most were not well adapted in Puerto Rico to high temperatures (data not shown). Based on testing of improved varieties and breeding lines in Angola over the past 4 years, genotypes were selected that are adapted to Angola and that have resistance to BCMV, BCMNV, CBB, and ALS. Populations were developed in 2007, 2008 and 2009 at USDA-ARS based on crosses between the commercial seed types used in Angola with the sources of disease resistance (Table 2). Marker assisted selection and field and greenhouse evaluations were used to select breeding lines with CBB and BCMV resistance. During the upcoming year, the performance of F_3, $F_{4:5}$ and $F_{6:7}$ breeding lines will be evaluated in Angola. In total, over 400 F_3 lines, 130 $F_{4:5}$ lines, and 46 $F_{6:7}$ lines have been sent for evaluation by Monica Martins in Huambo, Angola in the fall of 2011. Drs. Beaver and Porch will participate in the evaluation of this germplasm during their visit to Angola in December 2011.

Table 1. Mean readings of common bean and lima bean landraces from Angola as a result from inoculation with *Phaeoisariopsis griseola* and the NL3 strain of Bean Common Mosaic Virus (BCMV) in February 2011.

Genotype	Angular leaf spot response[1]	Severity readings of powdery mildew[2]	Response to the NL3 strain of BCMV[3]
Ermelinda	6	+	2/2 Mosaic
Amarelo	5	++	3/3 Mosaic
Cebo	5	+	3/3 Mosaic
Manteiga	5	++	1/1 Mosaic
Catiolo	4	+	1/1 Mosaic
Fernando	4	+	3/3 Mosaic
Quilumba	4	+	2/2 Mosaic
Olho-de-Perdiz	4	++	3/3 Mosaic
Katarina	4	+	3/3 Mosaic
Manteiga	4	++	1/1 Mosaic
Chumbo	4	+	2/2 Mosaic
Carioca	4	+	2/2 Mosaic
Pedro I, *P. lunatus*	4	+	2/2 Mosaic
Canario	3	+	3/3 Mosaic
Ervilia	3	+	2/2 Mosaic
Calembe	3	+	2/2 Mosaic
Olho-de-Perdiz	3	+	3/3 Mosaic
Tabe	3	+	2/2 Mosaic
Calongupa	3	+	3/3 Mosaic
Amarela	2	+	2/2 Mosaic
Morales	2	-	ND
Ervilia	2	-	2/2 Mosaic
Verano	1	-	3/3 Top Necrosis
Mean	3.7		
LSD(0.05)	3.1		
CV (%)	52.0		

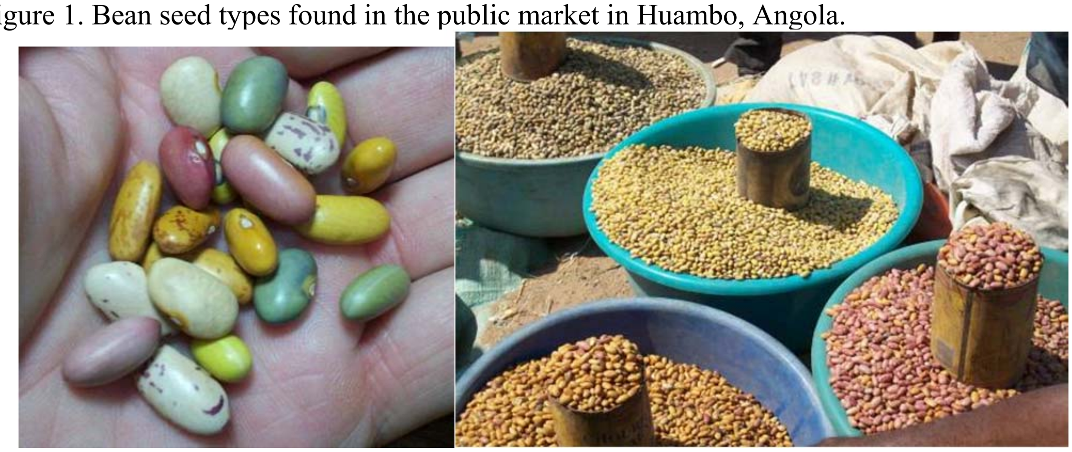
[1] Based on CIAT of 1-9 where 1 = absence of symptoms and 9 = severe symptoms.
[2] (+) presence of disease, (++) high severity of disease, (-) absence of symptoms
[3] 1/1 mosaic= 1 plant in pot, 2/2 mosaic = 2 plants in pot inoculated, and 3/3 mosaic = 3 plants in pot and all inoculated, ND= no data.

Table 2. Performance of F_4 and F_5 Andean lines derived from crosses with Angolan cultivars and screened for resistance to common bacterial blight (CBB) and BCMV.

Line	CBB score[1] *Xap* 3353	CBB score[1] *Xap* 484A	SAP 6 (CBB)	SW 13 (*I* gene)	Seed type
097155-2-M-1	3	3	(+)	(+)	Red kidney
097155-2-M-2	3	3	(+)	(+)	Red kidney
097155-5-M-2	4	3	(+)	(+)	Red kidney
097155-7-M-3	3	3	(+)	(+)	Red kidney
102880-14-2	3	3	(+)	(+)	Red mottled
102881-10-2	2	4	(+)	(+)	Red mottled
102881-11-1	3	2	(+)	(+)	Pink
102881-11-2	3	3	(+)	(+)	Pink

[1] Rated on a scale from 1-9 where 1 = no symptoms and 9 = very severe symptoms.

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 (Figure 1). 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 multiple disease resistance. Marker-assisted selection and greenhouse evaluations were conducted in Puerto Rico (UPR and USDA-ARS-TARS) to identify lines that have genes for BGYMV and BCMV resistance. Lines were also selected in the field for common bacterial blight resistance. A group of the most promising yellow bean breeding lines will be tested in Haiti and Angola during the upcoming year.

The common bean weevil (*Acanthoscelides obtectus* Say) is a major seed storage pest (Kornegay and Cardona, 1991). 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 the bean weevil (Mobogo et al., 2009). A portion of the resistance of the breeding lines was derived from the tepary bean G40199. Individual plants were selected for local adaptation from BC_3F_{3-4} lines in the population 'Rojo*3/SMARC 2///ICA Pijao*2/G40199' in a nursery planted at Isabela, Puerto Rico in October, 2010. A bioassay was developed by UPR graduate student, Abiezer González, to screen the BC_3F_{4-5} bean lines for resistance to the bean weevil. Plastic cups (150 ml) containing 20 seed were infested with 20 adults of the bean weevil. Date of first emergence was noted and damage to the seed was measured approximately 100 days after infestation. The BC_3F_{4-5} lines were evaluated in two trials conducted at Isabela, Puerto

Rico during 2011. Seed of both Andean and Middle American bean cultivars were severely damaged by the bean weevil (Table 3). Three light red kidney lines from the OSU populations had useful levels of resistance. 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 days after infestation. Seed of resistant lines had ≥ 65% seed without holes. The only other line with a similar level of resistance was RAZ 25 which was developed at CIAT to possess the seed storage protein arcelin (*Arc-1*).The bean weevil resistant line AO1012-29-3 was crossed with white and black cultivars that have commercial seed type and BGYMV and BCMNV resistance. F_2 populations and F_3 lines derived from these crosses were planted at Isabela, Puerto Rico in July 2011. Individual plants with local adaptation will be screened in the greenhouse for reaction to the NL3 strain of BCMNV. Resistant lines will be screened for the presence of the *bgm-1* gene using the SR-2 and for the *I* gene using the SW13 SCAR markers.

Table 3. Damage caused by bean weevil (*Acanthoselides obtectus*) in 20-seed samples of common bean lines of diverse origin.

Identification	Origin	Seed type	Total # of holes in the seed	Percent seed without holes	Percent seed weight lost
AO-1012-27-2	OSU	Red kidney	9.5	65.0	0.0
AO-1012-29-3	OSU	Red kidney	14.5	75.0	0.0
AO-1012-31-4	OSU	Red kidney	14.0	65.0	18.8
Badillo	UPR	Red kidney	129.0	0.0	45.0
INIAP Fanesquero	Ecuador	White kidney	122.0	0.0	25.0
RAZ 25 (*Arc-1*)	CIAT	Red mottled	13.5	62.5	16.7
INIAP Portillo	Ecuador	Red morttled	180.5	0.0	37.5
INIAP Yungilla	Ecuador	Red mottled	132.5	0.0	37.5
INIAP Concepción	Ecuador	Red mottled	150.0	0.0	37.5
PR9745-232	UPR	Red mottled	125.5	0.0	35.8
Catarina	Angola	Cranberry	132.0	0.0	37.5
Calembe	Angola	Green	143.0	0.0	25.0
Canaria	Angola	Yellow	129.5	0.0	25.0
Verano	UPR	White	150.0	0.0	25.0
Morales	UPR	White	112.5	0.0	25.0
RAZ 75	CIAT	Small red	23.5	35.0	16.7
INTA Precoz	Guatemala	Small red	120.5	0.0	37.5
DEHORO	Zamorano	Small red	128.0	0.0	33.3
Amadeus 77	Zamorano	Small red	122.5	0.0	33.3
Carrizalito	Zamorano	Small red	106.5	0.0	33.3
CENTA Pupil	Zamorano	Small red	110.0	0.0	25.0
RAZ 50	CIAT	Black	79.5	10.0	16.7
Aifi Wuriti	Zamorano	Black	140.5	0.0	33.3
DPC 40	Dom. Rep.	Black	103.5	0.0	40.0
ICA Pijao	Colombia	Black	109.0	0.0	25.0
Mean			93.8	9.0	30.7
LSD(0.05)			18.0	8.9	12.6
CV(%)			9.7	50.1	20.7

During periods of wet weather, germination of seed in pods of bean plants near harvest maturity can be a serious problem in Central American and the Caribbean. National Seed Service scientists in Haiti have observed differences among bean lines in their ability to resist germination during wet weather. Lines that are resistant to germination in the pod tend to have thicker pod walls. NSS researchers plan to continue to study this important trait.

Regional performance trials

Advanced bean breeding lines were derived from crosses between disease resistant and abiotic stress (low fertility, drought and/or heat) tolerant parental lines from Zamorano, the UPR, USDA-ARS-TARS, CIAT and NBP. These advanced lines have resistance to the major diseases and enhanced levels of tolerance to at least one abiotic factor, good agronomic adaptation and commercially acceptable seed type. The most promising lines were included as entries in the VIDAC Nursery and ECAR Trials which are distributed annually to NBP members of the Central America/Caribbean Bean Research Network (BRN). This network is coordinated by Zamorano in collaboration with CIAT and the UPR.

More than 50 small red and black bean breeding line VIDAC nurseries and ECAR trials were distributed to collaborators from the National Bean Programs (NBP) from Central America and the Caribbean. Results describing the performance of the entries in these trials in comparison with improved and local check cultivars are presented in Tables 4 to 7. In addition, more than 60 elite lines were evaluated in COVAMIN (high iron/zinc bio-fortified lines), PASEBAF¨(low fertility, drought tolerant lines) and ERMUS (web blight tolerant lines) trials. More than 200 on-farm cultivar validation trials, including improved cultivars (ICTAZAM, Aifi Wuriti, XRAV40-4, ICTA Sayaxché, ICTA Petén), promising lines from the high minerals and drought and low fertility trials, and lines from populations developed to improve landrace cultivars, were conducted in collaboration with researchers from NBP, NGO and farmer groups in Central America and the Caribbean. Results from these trials identified several promising breeding lines for additional testing. During the upcoming year, at least three bean cultivars are expected to be released in Guatemala, Honduras, Nicaragua and/or El Salvador. Results from the 2009 and 2010 regional VIDAC nurseries and ECAR trials were presented at the 2011 meeting of the PCCMCA which was held in El Salvador.

More than 40 regional trials, including drought and heat tolerant small red (ERSAT Rojo Trial) and black bean (ERSAT Negro Trial) cultivars and breeding lines from the CA/C region, were prepared and distributed to NBPs of Costa Rica, Honduras, Panamá, Nicaragua, El Salvador y Guatemala, as part of the collaboration with the Red SICTA Project for climatic change adaptation. In Honduras, these ERSAT trials were distributed to collaborators including DICTA regional offices, the CARE/CIAT project in the southern region (known as the “dry corridor”), and the NGOs FIPAH and PRR collaborating with Zamorano in PPB activities. In addition, the project is participating in the regional evaluation of a Bean Adaptation Trial from CIAT to study climatic change adaptation in common beans using the DSSAT model.

Table 4. Performance of elite small red bean breeding lines from the VIDAC 2010 nursery conducted in Central America.

Line	Seed yield (kg/ha)	AA	CV	BGYMV	CBB
RRH 336-91	4,403	5	3	1	3
ESL 803-14	3,576	5	5	5	3
FPY 724-28	3,055	6	5	1	3
FPH 21-26	3,055	3	5	5	3
RRH 336-28	3,029	5	4	2	3
ALS 0532-6	2,971	6	5	2	3
RRH 336-24	2,952	5	5	1	3
Improved check	2,531	5	4	1	4
Landrace check	2,070	7	2	7	7
Mean (n=98)	2,407		3.4		

AA= Agronomic adaptation (scale 1-9; 1=excellent, 9= poor)), CV= Commercial value (scale 1-9; 1= excellent, 9= poor), BGYMV and CBB (1-9; 1-3= resistant, 7-9= susceptible).

Table 5. Performance of black bean breeding lines from the VIDAC 2010 Nursery conducted in Central America.

Line	Seed yield (kg/ha)	AA	BGMY	ALS	CBB
SEN 96	3,954	5	5	6	5
SJC 729-11	3,289	7	4	4	3
SJC 730-70	2,515	6	1	3	7
SJC 730-74	2,302	5	2	3	6
SJC 728-5	2,213	6	4	3	3
Local check	2,446	5	3	3	5
Mean (n=48)	2,038	5.4			

BGMY, ALS (angular leaf spot) and CBB (common bacterial blight) scale 1-9 (1-3= resistant; 7-9= susceptible)

Table 6. Performance of promising small red bean breeding lines from the ECAR 2010 trials conducted in Central America.

Line	Seed yield (kg/ha)	AA	CV
SRS 2-37-50	3,462	3	2
MHR 311-52	3,436	4	3
MHC 2-11-33	3,401	3	3
SRS 2-34-38	3,363	5	2
IBC 306-95	3,284	4	3
IBC 301-182	3,247	3	3
SRS 2-38-14	3,194	4	3
Local check	3,057	6	2
Improved (Dorado)	2,959	3	7
Mean (n=16)	3,190		

AA= Agronomic adaptation (scale 1-9; 1=excellent, 9= poor)), CV= Commercial value (scale 1-9; 1= excellent, 9= poor),

Table 7. Performance of promising black bean breeding lines from the ECAR 2010 trials conducted in Central America.

Line	Seed yield (kg/ha)	AA	BGYMV	CBB
MHN 322-9-63	1,784	5	1	6
XRAV40-4	1,750	3	5	3
MHN 322-49	1,694	4	1	3
MEN 2207-44	1,640	5	1	6
SEQ 342-89	1,480	4	3	5
XRAV 117-2	1,350	5	4	5
MHN 322-20	1,126	4	1	3
Local check	1,237	7	5	9
DOR 390 (check)	1,462	4	5	4
Mean (n=16)	1,337			

AA= Agronomic adaptation (scale 1-9; 1=excellent, 9= poor)), CV= Commercial value (scale 1-9; 1= excellent, 9= poor), BGYMV and CBB (1-9; 1-3= resistant, 7-9= susceptible).

Six ERMUS trials (Table 8) including web blight resistant lines from the first and second cycle of recurrent selection were distributed to NBPs in CA/C. Most of web blight resistant lines in the ERMUS trial were similar to VAX 6, the resistant check, and superior to the moderately resistant (Talamanca and ICTAZAM) and susceptible check Tio Canela 75. The lines are also resistant to BGYMV and BCMV, and have good agronomic adaptation and desirable commercial red seed type. The ERMUS 2011 trials included 20 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 ICTAZAM).

Table 8. Mean performance of the most promising WB resistant lines from ERMUS trials conducted at four sites in Central America in 2010-11.

Line	Seed yield (kg/ha)	Web blight incidence (%)	Agronomic adaptation (1-9)	BGYMV (1-9)	Seed type (1-9)
MHC2-16-26	3,450	30	3	3	6
MHR 312-75	3,276	40	3	2	5
MHC2-10-1	3,050	55	4	3	4
MH2-2	3,003	40	4	2	5
MHC2-8-50	2,880	43	4	3	5
Talamanca	2,469	55	5	7	Black
VAX 6	3,123	33	4	5	7
ICTAZAM	2,402	50	6	3	Black
Tio Canela 75	2,373	60	6	2	5
Range (n= 24)	1,881-3,450	30-90	3-7	2-7	2-7

The UPR 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. The red mottled lines were also evaluated in trials planted in Haiti, the Dominican Republic and Puerto Rico (Table 9a). PR0637-134 and PR0737-1 were among the highest yielding lines in the trials. These red mottled lines, which have the *bgm* gene for BGYMV and the *bc3* gene for BCMV and BCMNV resistance, also showed resistance to common bacterial blight and powdery mildew in Puerto Rico in 2011. Five kg of seed of PR0737-1 was brought to Haiti in May 2011 for seed increase.

Table 9a. Performance of red mottled lines planted in Haiti, the Dominican Republic and Puerto Rico in 2010 and 2011.

Line	Traits	2011 PR powdery mildew score[1]	2011 PR CBB score[1]	Mean seed yield from five trials (kg/ha)
PR0633-8	bgm, SW12, I, bc3, SAP6	3.0	3.2	1011
PR0637-134	bgm, I, bc3	2.8	3.0	1168
PR0737-1	bgm, bc3	2.2	3.0	1190
PR0737-6	bgm, bc3	4.0	3.2	1040
PR9745-232	bgm, I	4.0	3.4	1178
JB-178	I	4.2	4.0	979
PC-50	I, rust	4.2	5.2	1054
Mean		3.7	3.6	1070
LSD (0.05)		1.1	1.0	
CV(%)		22.8	23.1	

[1] Rated on a scale from 1 to 9 where 1 = no symptoms and 9 = very severe symptoms.

Lines developed for Central America and the Caribbean were evaluated in Angola during the main production seasons from 2008-2010. Results from these trials helped to identify economically important diseases in different bean production regions in Angola. A poster was presented by Monica Mbui at the 2011 meeting of the American Phytopathological Society, Caribbean Division, described these bean diseases. Field trials were planted in Angola in October, 2008, and in both August and October in the planting seasons from 2009-2011. Results from these trials identified bean breeding lines with different seed types (Matternorn, Beníquez, IBC301-204, BelDakMi RMR 22) that were well-adapted, had good yield potential and were resistant to disease. The red mottled line PR9745-232 was the top yielding red mottled line in trials planted in Angola (2,237 kg/ha), as well as in Puerto Rico (2,406 kg/ha), and Haiti (1,039 kg/ha).

Three white lines with resistance to BCMV, BCMNV and BGYMV yielded well in trials planted in Puerto Rico and Haiti in 2008 and 2009 (Table 9b). These lines were sent to Dr. James Steadman at the University of Nebraska to screen for rust resistance.

Table 9b. Seed yield (kg/ha) of elite white lines in Puerto Rico and Haiti.

Line	Pedigree	Puerto Rico			Haiti	Dom. Rep.
		2008	*2009*	*2010*	*2009*	*2010*
PR0806-70	*PR0301-295 /BelMiDak RMR 11*	3,790	2,619	1,826	1,656	1,879
PR0806-72	“	3,724	2,656	1,999	1,786	1,767
PR0806-82	*PR0301-304 /BelMiDak RMR 11*	3,018	2,521	2,082	1,430	1,931
Verano		3,764	2,591	2,011	1,460	1,873

On-farm validation of promising breeding lines

On-farm validation trials were conducted in Central America 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 which were developed with support from the Dry Grain Pulse CRSP, Red SICTA. The Agrosalud (COVAMIN) trials, which included small red lines with greater mineral content (iron and zinc) developed in collaboration with CIAT and INTA/Nicaragua, were conducted in Central America. During FY11, Agrosalud lines were released as cultivars in Nicaragua and El Salvador. During 2012, it is expected that at least one of these bio-fortified lines will be released as a cultivar in Honduras. The PASEBAF trial, a Red SICTA activity, was funded by IICA/COSUDE from 2007 to 2010. Lines developed by the IICA/COSUDE project were distributed for testing in Central America during the past year with support from the Dry Grain Pulses CRSP project. The cultivar ‘INTA Fuerte Sequía’ released in Nicaragua in 2010 was an entry in this PASEBAF trial. At least two cultivars from the PASEBAF trial will be released during the postrera of 2011 in Honduras by CIALs participating in PPB activities.

In the lowlands of Guatemala there is increased interest in the production of small red beans for export to El Salvador and the U.S. Cultivars with higher yield potential and greater disease resistance are needed for this purpose. Ten of the most promising small red bean cultivars and breeding lines from Central America were sent in 2009 to our HC collaborator in Guatemala (J.C. Villatoro), for testing in the most important lowland bean production regions, such as Petén and Jutiapa. During the past year, packages of seed of five of the most popular improved small red cultivars from El Salvador and other Central American countries, were provided to the FAO Seed Project, through J.C. Villatoro, for on-farm validation in Guatemala.

Zamorano is collaborated with technical personnel from Catholic Relief Services (CRS) in the evaluation of small red bean cultivars and promising bean breeding lines for adaptation to the western region of Honduras. Two types of trials were provided for on-farm testing to CRS. The COVAZA trial included seven improved cultivars and a local check variety adapted to highland conditions (> 1200-1400 m) of Honduras. The COVABI trials included seven small red cultivars and advanced lines adapted to lowland to intermediate conditions (< 1200 m) and a local check. Three small red cultivars were selected from the COVAZA trial by participating farmers, and are currently in the phase of on-farm validation using larger plots. Participatory approaches are being used in these activities.

Bean landraces with unique seed traits are still considered a valuable germplasm for bean export, due to preferences associated with seed color and taste. However, most landraces are susceptible to the major bean diseases and have lower yield potential than improved cultivars. Advanced bean breeding lines derived from crosses between landraces x improved cultivars, are being validated in Honduras as part of the development of cultivars which combine the seed traits and earliness of the landraces with disease resistant and yield potential of the improved cultivars. Validation trials including 2-3 advanced lines and the landrace check cultivar derived from the Honduran landraces ‘Paraisito’, ‘Cincuenteño’, ‘Marciano’ and ‘Rojo de Seda’, are being conducted in farmer fields at different locations in Honduras in collaboration with DICTA, CARE/CIAT, FIPAH and PRR.

Release of cultivars and seed multiplication

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. During the past year, the bean grower association in the San Juan de la Maguana Valley served as an important source of basic seed of ‘DPC-40’ for both Haiti and the Dominican Republic. During the summer of 2011, the National Seed Service in Haiti produced 10 MT of DPC-40 at Savane Zombi. This basic seed will be sold to the private sector in Haiti for multiplication and sale to farmers.

The pink bean line PR0401-259 and the black line PR0650-31 were released as improved germplasm. Both lines have the *I* gene 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. A paper describing the release of PR0401-259 and PR0650-31 has been accepted for publication in the *J. of Plant Registrations*.

The white bean breeding line PR0634-13 was released by the UPR in collaboration with the University of Nebraska, IDIAF, and the USDA-ARS 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. 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.

The small red cultivar 'Paisano PF' was released in 2011 in Honduras in collaboration with technical personnel from the Rural Reconstruction Program and farmers from CIALs of the Yojoa Lake region. This cultivar was developed using participatory varietal selection (PVS) approaches started from a VIROS trial distributed in 2006. This cultivar was originally identified as the breeding line MEN 2212-28, derived from the cross Milenio/Amadeus 77. After its selection from the VIROS trial, the line was tested under diverse farmer conditions and during several seasons, and then released as a cultivar.

The small red cultivar 'CENTA Chaparrastique' was released in El Salvador during 2011, as a BGYM and BCMV resistant, high yield potential cultivar with commercially desirable seed type. In Guatemala, the black bean cultivars 'ICTA Petén' developed by CIAT and ICTA and ICTA Sayaxché developed by the project were released in FY10 and disseminated during FY11.

TARS-MST1 and TARS-MST2 were developed by the USDA-ARS, the University of Nebraska, and the University of Puerto Rico. These black bean lines were selected for multiple stress tolerance including tolerance to high ambient temperature and drought stress. Specifically, the lines showed significantly higher yield under heat stress as compared to the local check, and comparable yield to both heat and drought tolerant controls under the respective stress conditions. TARS-MST1 also possesses resistance to bacterial blight and both to root rot disease. Both lines were found to carry the I gene, while TARS-MST1 has two CBB SCAR markers, SU91 and SAP6. A paper describing the release of TARS-MST1 and TARS-MST2 was published in the *J. of Plant Registrations.*

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

Approaches and Methods

Inadequate soil nitrogen is a frequent seed 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. The project has used recurrent selection to develop Mesoamerican 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 were 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. The root rot resistant black bean line PR0443-151 from

Puerto Rico and the CIAT bean breeding line VAX 3 have performed well in 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 were 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 has evaluated breeding lines for root rot resistance in a field maintained specifically for root rot screening and selection. 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 lines with poor BNF ability. A preliminary trial including 180 bean accessions from the working collection of the Zamorano breeding program was inoculated with a mixture of two *Rhizobium* strains, CR 477 (*R. etli*) and 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 among bean lines for nodulation using a 1 to 9 scale (1= none or very few, small nodules; 9= maximum number of large nodules), root, shoot and total dry weight (DW), and root/shoot ratio were observed. The cultivars and lines with higher nodulation scores also had greater root, shoot and total DW.

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 among bean lines 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 lines with higher nodulation had almost twice nodule DW and 50% greater plant DW, than those with less 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 the common bean is also nodulated by strains of *R. leguminosarum*, additional experiments are being conducted including the strain UPR 2010 of *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 common bean plants in the field more effectively. The same set of bean lines 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.

During the present year, F_4 families from 25 bean populations derived from crosses between diverse parents with good nodulation ability were screening in Honduras under greenhouse conditions using a soil:sand (1:1) substrate low in total N (0.08 %) and organic matter (1.7%). The F_4 lines were inoculated with a mixture of three *Rhizobium* strains (*R. tropici* CIAT899, *R. etli* CIAT 632 and *R. leguminosarum* UPR 2010) at 4 and 8 DAP using 1 ml of liquid inoculum per plant (1 x 10^7 cel/ml). Plant samples were taken at 40 DAP (flowering stage) and nodulation and shoot dry wt. were determined. Nodulation (number and size) was scored visually using a 1-9 scale (1= none or few, small nodules; 9= many, large nodules). The 20 best F_4 families from different populations will be recombined using a partial diallel crossing design to develop the populations for the second cycle of recurrent selection for nodulation.

The nodulation patterns of 20 bean lines selected from previous studies for adaptation to low N conducted in Honduras and Puerto Rico, and from a group which included the majority of small red and black bean cultivars released by the project in the CA/C region, were characterized in a low N soil using inoculation with the mixture of the three aforementioned *Rhizobium* strains. Differences in nodulation (visual score), root traits, plant growth and yield were observed among the cultivars and lines included in these trials. Results from these trials will be used to identify the most useful cultivars and lines for further hybridization and selection for greater nodulation and better adaptation to low N soils.

Field experiments conducted over a two year period in Puerto Rico identified breeding lines with greater N use efficiency in low N soils (Table 10). 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 9th in the – N plots (Table 11). Populations were developed using PR0443-151 as a parent to develop breeding lines that combine adaptation to low N soils with resistance to BCMV and BGYMV. Four black bean lines were identified that combine the disease resistance with superior performance in low N soils. Seed of these breeding lines were sent to Haiti and Honduras for further evaluation.

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 in a low fertility/root rot nursery at the USDA/ARS research farm in 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.

Phaseolus vulgaris is naturally nodulated by different Rhizobium strains. The most important species are *R. tropici* and *R. etli*. Promiscuity of the host and unfavorable environmental conditions can limit inoculation response. The successful introduction of inoculants depends on an efficient interaction between the *Rhizobium* strain and *Phaseolus* genotype. Bean cultivars and USDA-TARS and UPR bean breeding lines were evaluated for their efficiency to nodulate with *R. tropici* and *R. etli*. In 2011, two field experiments consisting of 15 lines and strains *R. tropici* CIAT 899 and *R. etli* UMR 1597 were conducted at the Isabela and Fortuna Substations using a split plot arrangement of a RCB design with four replications. At the Fortuna Substation, there were significant differences among lines and strains in the nodule position at twenty days after planting. Soil rhizobia plant infection counts were considered high at 10^4 rhizobia per gram of soil. Among the genotypes evaluated, PR9745-232 (Andean) nodulated with CIAT 899 in the upper 1 cm of the tap root and had greater number of nodules when compared to strain UMR 1597. In contrast, lines PR0401-259 and 10IS-2421 (both Middle American) had greater nodule number in the upper 1 cm of the tap root with UMR 1597. Cultivars 'Verano' and 'DPC-40' nodulated between 1-2 cm of the upper part of the tap root and had between 10-20 nodules which compared to the best performing cultivars. Root and shoot dry weights were not different between strains and lines. DPC-40 had greater shoot dry weight when inoculated with strain CIAT 899. Pinto line 10IS-2417 produced greater shoot dry weight with UMN 1597 (Table 11). PR0401-259, PR0137-1, PR0137-2, 10IS-2435, Verano and DPC-40 had the best plant vigor scores in the trial (data not shown). Strain x line effects were not significant. However, there were significant differences among lines for seed yield. The highest yielding lines were Beniquez, DPC-40, Verano and PR0401-259. The site at the Isabela Substation was previously planted with common beans and the soil rhizobia population was 10^2 viable cells per gram of soil. Nodulation was evaluated at 21 days after planting using the CIAT scale 1-9. The pinto line 10IS-2417 formed nodules in the crown with both strains CIAT 899 and UMR 1597. The most number of nodules were produced in lines PR0401-259 and 10IS-2423. Considering that no fertilizer was applied to the trial, seed yields were excellent. The small red line 10IS-2423 produced a mean yield > 2,000 kg/ha. Verano, Morales and Beniquez also performed well. The red mottled line PR0737-1 had the best overall performance for an Andean bean line. With the exception of DPC-40 and Badillo (opposite response), most of the lines produced similar seed yields when inoculated with strains CIAT 899 and UMR 1597. The pink bean line PR0401-259 nodulated well with CIAT 899 and UMR 1597. Competition with the established rhizobial population is a factor that can limit the success of an inoculant. At the Fortuna Substation, the rhizobial counts were considered high. The Isabela Substation had a lower native rhizobium population and better response to inoculation. Strain competitiveness probably was also important in Isabela. In subsequent experiments we will determine strain competitive ability when a mixture of both strains is applied in the inoculants.

Table 11. Performance of bean lines inoculated with Rhizobium strains CIAT 899 and UMR 1597 in trials planted at the Fortuna and Isabela Substation in February 2011.

Line	Seed type	Isabela seed yields (kg/ha)		Fortuna seed yields (kg/ha)
		Strain 899	Strain 1597	
PR9745-232	Red mottled	868	881	954
PR0401-259	Pink	1277	1293	1750
PR0737-1	Red mottled	1539	1427	1537
PR0737-2	Red mottled	1225	1208	1161
PR0661-77	Red mottled	810	719	1119
Beníquez	White	1704	2078	1948
Badillo	Red kidney	991	1200	1090
Verano	White	1718	1754	1582
DPC-40	Black	1953	1164	1800
Morales	White	1768	2008	1117
10IS-2423	Small red	2503	2218	1364
10IS-2423	Black	1851	1741	1615
10IS-2421	Cream	1847	1808	1305
10IS-2425	Navy	910	989	1009
10IS-2417	Pinto	1583	1795	918
Mean		1503	1485	1351
LSD(0.05) to compare line means		461		455
CV(%)		22.0		29.8

Rhizobial strains suitable for use as inoculants should be highly competitive, fast in the speed of nodulation, tolerant to environmental stresses and capable of forming nodules that fix nitrogen. In a field experiment planted at the Fortuna Substation during 2011, five strains were compared to a reference strain CIAT 899, an uninoculated control, and a commercial inoculant (Nodulator). Three additional treatments included fertilization with Nitrogen (N); Nitrogen Phosphorus and Potassium (NPK); and Potassium (K) according to the requirements of the crop based on the soil analysis. The trial was arranged in a randomized complete block design with four replications. The white bean cultivar ‘Verano’ was planted on 8 March 2011. An evaluation for early nodulation was conducted 10 days after planting. Individual plants were collected at physiological maturity for evaluation of nodulation and to measure plant and root dry weights.

The native soil rhizobia population was 10^4. The nodulation scores and dry weights were not significantly different among the strains and treatments, although the control treatment had the lowest number of nodules. Although there were no significant differences among treatments for seed yield, the treatments that produced the highest yields were inoculated with Rhizobium strains UMR 1512, CIAT 899 and UMR 1597. The field trial will be repeated during the upcoming year. It is expected that the results from the combined ANOVA will provide sufficient precision to detect significant differences among treatment means.

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).

Common bacterial blight is a broadly occurring and significant disease of common beans worldwide. QTL for this trait have been identified, but single genes have not. In order to facilitate breeding and selection for this trait, USDA and UPR scientists collaborated in the evaluation of the genetics of this trait using bi-parental populations and molecular marker analysis in order to identify tightly linked markers to a newly identified single dominant gene. By surveying available SCAR markers for CBB resistance, it may be possible to identify one linked to the dominant gene.

Bean common mosaic virus (BCMV) and the necrosis virus (BCMNV) are significant diseases for common bean production. The *bc3* gene is an important recessive resistance gene, but molecular markers are not yet available for this locus. In a recent study (Naderpour et al., 2010), a eukaryotic translation initiation factor (eIF4e) marker was found to co-segregate with BCMV resistance. Thus, PveIF4E appears to be associated with *bc-3* resistance and thus has potential for testing as a molecular marker. The ENM-FWe/RVe primers will be tested for association with the *bc3* gene in known genotypes of common bean through a CAPs assay, using a restriction enzyme, RsaI, after PCR amplification. If the CAPs marker is associated with *bc3*, then it will be used in segregating populations for verification of this new marker.

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. These lines were planted over a three-year period (2008-2009) 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 among RILs in the population and some lines were identified in which seed yield and detached leaf score corresponded (Table 12). The experiment is being replicated in order to attempt QTL analysis for detached leaf response in common bean. A new RIL population is also being generated for the evaluation of Macrophomina using superior lines from the BAT 477 x DOR 364 RIL population as resistant parents. The generation of a population from highly differential parents will facilitate phenotypic and genotypic screening.

Table 12. 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	
	Mean detached leaf score (1-9)	Rank	Mean seed yield (kg/ha)	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

USDA and UPR scientists collaborated in the identification of the dominant gene, *Xap-1*, which confers resistance to common bacterial blight of beans. This represents the first report of a gene for resistance to this disease. The SCAR marker SAP 6 co-segregates with this resistance gene. Results from this research were published in *Euphytica* (Zapata et al., 2011). Populations were developed during the past year to study the inheritance of a source of resistance to CBB associated with the SCAR marker SU-91.

The ENM-FWe/RVe primers, linked to the *bc3* gene, were optimized for amplification at the USDA-ARS. The primers were found to be associated with the *bc3* gene in known genotypes of common bean through a CAPs assay. Preliminary results suggest that this marker has potential for use in marker-assisted selection.

Rhizoctonia solani (Rs) is a widespread soilborne pathogen of common bean. This pathogen is a species complex classified in 14 anastomosis groups (AG). Some AGs can cause web blight (WB), one of the most important diseases of bean plants planted in the Caribbean, while others are responsible for root rots (RR). Knowledge of these subgroups and their interactions with plant hosts contributes to a better understanding of virulence patterns of the pathogen and may lead to more effective strategies to breed beans with resistance to WB and RR. Nine Rs isolates from bean plants expressing WB or RR symptoms were compared by measuring differential reactions among bean lines using a detached-leaf inoculation method. The same Rs isolates were also used to inoculate the roots of the differential bean lines using a mycelia solution. The experiments were planted in the greenhouse at the University of Puerto Rico, Mayaguez Campus. The Rs isolates obtained from the bean roots at the USDA-ARS Research Farm near Isabela, Puerto Rico were AG 4. Rs isolated from bean plants expressing WB symptoms were able to induce RR symptoms and vice versa. Significant line x isolate interactions were observed for the detached-leaf inoculation and root rot inoculations for the three planting dates suggested a differential response of the host to the pathogen. In general, WB 2 (AG 4) isolate had the most severe and the RR1 (AG 4) isolate had the least severe WB readings. The pink bean breeding line PR0401-259 had the best overall resistance to web blight. Averaged over the three experiments, the web blight scores of PR0401-259 at 72 h after inoculation were ≤ 4.0 on the differential lines. RR readings were generally more severe than the WB readings. The RR isolate RR1 (AG 4) produced the most severe RR scores. A few of the differential lines had mean RR scores ≤ 4.4 for some of the WB isolates. However, all of the bean lines had mean RR scores ≥ 5.0 when inoculated with the RR 1-3 (AG 4) isolates.

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 and in certain regions of Africa. 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 have 2 accessions from Haiti, ≤ 3 accessions from Puerto Rico and no accessions from the Dominican Republic. We collected and characterized the agronomic traits of 50 Lima bean landrace varieties from Puerto Rico and Haiti. Passport data was 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 serves as a facilitator in obtaining cowpea breeding lines for testing in Haiti. The project also attempts to identify research programs in Central America that are interested in evaluating cowpea breeding lines. Zamorano has conducted preliminary evaluations of cowpea lines and has provided 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. Masters degree student, Antonio David from Angola, completed his thesis work evaluating Angolan cowpea diversity in comparison to a collection of cowpea germplasm from major international production regions.

Tepary (*Phaseolus acutifolius*), a desert native species, has high levels of heat and drought tolerance, and common bacterial blight resistance. However, small seed size, prostrate growth habit, and poor palatability have reduced its acceptance in areas outside of its center of origin. As a result of global warming, there is increased need for and interest in abiotic stress-tolerant legumes. In order to increase possible adoptability of this species, USDA-ARS-TARS in collaboration with the UPR, initiated breeding of tepary for increased seed size and improved architecture.

Results, Achievements and Outputs of Research

Morphological, phenological and agronomic traits of 55 Lima bean landrace varieties from Haiti, the Dominican Republic and Puerto Rico were evaluated at Isabela, Puerto Rico Collaborators at the University of Puerto Rico studied the genetic diversity of the landrace varieties using molecular markers. Another collaborator from the University of Delaware evaluated the Lima bean varieties for HCN concentration in leaves and seed. Photoperiod insensitive Lima bean germplasm having low HCN concentration in the seed were identified. Results from the evaluations will be presented at the 2011 meeting of the Bean Improvement Cooperative. Seed samples of the Lima beans were sent to Dr. Daniel Debouk for long-term storage at CIAT. Seed of the complete collection of Lima bean varieties was also shared with collaborators in Haiti and the Dominican Republic.

Seventeen lima bean (*P. lunatus*) accessions from UPR collection were screened for adaptation in Honduras. 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 Central America and the Caribbean throughout the year. The 12 most promising accessions continue to be evaluated and a preliminary trial (ERLIMA). These accessions have been distributed to interested collaborators from Honduras and Nicaragua. This set is maintained because it represents a diverse array of adaptation, yield and seed types, which could be interesting for diversifying the farm production system and increasing grain legume consumption.

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 trials planted at Isabela, Puerto Rico in March and December 2010. Lines were evaluated for general adaptation, phenology, growth habit, yield components, seed characteristics, and elemental composition of the seed. The experiment included 16 cowpea lines of Angolan origin, 28 lines representing the worldwide cowpea collection, and two local checks. Angolan bean landrace varieties were identified that produced >1,000 kg/ha during both growing seasons. Cowpeas in Angola currently produce an average yield from 200 to 300 kg/ha. Cowpea leaves, which are commonly consumed in Angola had greater % protein than cowpea seeds. Angolan germplasm lines with higher levels of Fe and Zn in the seed were also identified. Preliminary results were presented at the World Cowpea Conference in Senegal from Sept 27-Oct 1, 2010. Genotypic characterization, complementing the phenotypic analysis, was conducted in collaboration with the University of California, Riverside, using about 1,500 SNPs from the Illumina Cowpea platform.

Nineteen cowpea lines from the UC-Riverside were screened for adaptation in Honduras and seven relatively short season lines were selected for further evaluation in Central America. The results of this preliminary screening were presented at the LVI PCCMCA Meeting held in El Salvador in April 2011. Seed of the most promising accessions was increased during the primera planting season at Zamorano, and a yield and adaptation trial (ERCAUPÍ) was distributed for testing during the postrera season of 2011, to several organizations from Honduras (CARE, FAO, CRS, FIPAH, PRR) and to INTA in Nicaragua. Seven red seeded cowpea accessions from the USDA PI collection were received from UPR for testing in Honduras, to determine if these red seeded type cowpea lines have better consumer preference in the Central American region where people are mostly small red bean consumers.

The nineteen cowpea lines from UC-Riverside were planted in Haiti in December 2009; one month before the earthquake. The nursery did not receive irrigation or weed or insect control after that event. Under these extreme conditions IT98K-128-2 and IT98K-205-8 were resistant to powdery mildew, had good agronomic traits and produced seed yields of approximately 300 kg/ha. Seed of the most promising cowpea lines from Antonio David's thesis research were brought to Haiti in May 2011 for testing.

Superior lines of tepary beans were selected from trials in PR and Nebraska in 2007 and 2008, and adapted, large seeded lines were selected for population development. Lines were developed from crosses between this elite germplasm and previously identified line with superior agronomic characteristics. Lines from the resulting populations were selected with increased seed size and seed quality, improved architecture characteristics, and bacterial blight resistance. These lines are being tested in Honduras, the U.S., Angola and Puerto Rico for possible release and for future incorporation of BCMV and BGYMV resistance.

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
- Completion Date: July 2011
- Type of CRSP Support (full, partial or indirect): Full
  If providing Indirect Support, identify source(s) of leveraged funds
- Amount Budgeted in Work plan, 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

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: July 2012
- Type of CRSP Support (full, partial or indirect): Full
  If providing Indirect Support, identify source(s) of leveraged funds
- Amount Budgeted in Work plan, 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

Trainee #3
- First and Other Given Names: Jorge Ronny
- Last Name: Díaz
- Citizenship: Peruvian
- Gender: Male
- Degree Program for training: B.S.
- Program Areas or Discipline: Crop Science
- Host Country Institution to Benefit from Training: Honduras
- University to provide training: EAP
- Supervising CRSP PI: J.C. Rosas
- Start Date: Jan 2011
- Projected Completion Date: Dec 2011
- Type of CRSP Support (full, partial or indirect): Partial
  If providing Indirect Support, identify source(s)s of leveraged funds:
- Amount Budgeted in Work plan, if providing full or partial support:
  Direct cost: $0
  Indirect cost: $
- U.S. or HC Institution to receive CRSP funding for training activity: EAP

Trainee #4
- First and Other Given Names: Luís Patricio
- Last Name: Moncaño
- Citizenship: Ecuador
- Gender: Male
- Degree Program for training: B.S.
- Program Areas or Discipline: Crop Science
- Host Country Institution to Benefit from Training: Honduras
- University to provide training: EAP
- Supervising CRSP PI: J.C. Rosas

- Start Date: Jan 2011
- Projected Completion Date: Dec 2011
- Type of CRSP Support (full, partial or indirect): Partial If providing Indirect Support, identify source(s)s of leveraged funds:
- Amount Budgeted in Work plan, if providing full or partial support:
  - Direct cost: 0
  - Indirect cost:
- U.S. or HC Institution to receive CRSP funding for training activity: EAP

Short-term Training

Training activity # 1

- Type of training: Workshop
- Description of training activity: Participatory Plant Breeding- Common beans.
- Location: Zamorano
- Duration: 3 days
- Scheduling of training activity:
- Participants/Beneficiaries of Training Activity: 15
- Anticipated numbers of Beneficiaries (male and female): 9M and 6F
- Amount Budgeted in Work plan:
  - Direct cost: $ 2,000
  - Indirect cost: $0
- If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: Norwegian Development Fund $2,000.
- Comments: Participants are young farmers involved in PPB activities in Central America.

Explanation for Changes

During the past year, project personnel invested a lot of time into planning meetings and trips related to the new Bean Technology Dissemination project. This affected the ability of project personnel to conduct some other DGP CRSP activities. For example, the BNF workshop at Zamorano for Central American and Caribbean bean researchers was delayed until November 2011 due to problems scheduling the event. The BNF workshop in Mozambique was also postponed until 2012.

Delay in the development of SCAR markers for ashy stem blight resistance genes

Because the putative RAPD markers reported in the literature proved 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. These lines were planted over a three-year period (2008-2009) 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 among RILs in the population and some lines were identified in which seed yield and detached leaf score corresponded. The experiment is being replicated in order to attempt QTL analysis for detached leaf response in common bean.

<u>Delay in field testing of cowpeas in Haiti</u>
The National Seed Service in Haiti did not receive the seed of the cowpea lines until May 2011. Results from the first year of field testing in Haiti will not be reported until 2012. The delay in the deliveruy of the seed, did permit seed of the most promising lines from the thesis research of Antonio David to be sent to Haiti.

<u>Delay of workshops in Honduras and Angola concerning the production, storage and distribution of *Rhizobium* inoculum</u>
During the past year, project personnel invested a lot of time into planning meetings and trips related to the new Bean Technology Dissemination project. This affected the ability of project personnel to conduct other DGP CRSP activities. The BNF workshop at Zamorano for Central American and Caribbean bean researchers was delayed until November 2011 due to problems scheduling the event. The BNF workshop in Mozambique was also postponed until 2012.

Networking and Linkages with Stakeholders
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. Four 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). Seed of these lines was increased in Puerto Rico and sent to Dr. James R. Steadman at the University of Nebraska for evaluation in the W-2150 Regional Hatch Project White Mold Nursery.

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 provides an opportunity to continue to test in the Dominican Republic the most promising lines from the DGP CRSP breeding programs. This collaboration is expected to result in the release of additional 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. We screened these bean breeding lines for resistance to BCMV and BGYMV using molecular markers and greenhouse inoculations.

BGYMV and BCMV are important production constraints 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 have resistance to these viral diseases. The lines were evaluated in Costa Rica during 2010 and 2011 using participatory plant breeding techniques and selected by farmers for additional testing.

Leveraged Funds
- <u>Name of PI receiving leveraged funds</u>: Management office of the Dry Grain Pulse CRSP and PII-UPR-1 project personnel.
  - <u>Description of leveraged project</u>: 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 to MSU with sub-contracts to Zamorano, INTA/Nicaragua, ICTA/Guatemala, DICTA/Honduras, UPR and the NSS in Haiti
- 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 through 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: $ 19,000 (3 years)
  - Funding source: IDB/Republic of Korea

List of Publications and Scientific Presentations

Beaver, J.S., M. Zapata, M. Alameda, T.G. Porch and J.C. Rosas. 2011. Registration of PR0401-259 and PR0650-31 dry bean germplasm lines. J. Plant Reg. (*In print*).

Beaver, J.S. and D.P. Maxwell. 2011. A legacy of bean-breeding against whitefly transmitted viruses in the Caribbean. Invited presentation at a session entitled “Whitefly-transmitted geminiviruses: a Caribbean legacy in honor and appreciation of Dr. Julio Bird. 2011Annual Meeting of the American Phytopathological Society, Caribbean Division held in San Juan, Puerto Rico. 19-22 March 2011.

Beaver, J.S. 2010. Contributions of genetic diversity to the improvement of dry edible beans. Invited presentation made at the C-08 Symposium ‘Using genetic resources: Does it have a role in increasing yield?’ 2010. ASA-CSSA-SSSA Annual Meeting. Long Beach, CA. 2 Nov. 2010.

Estévez de Jensen, C., T.G. Porch, J.S. Beaver, A. Chicapa Dovala., L. Baptista. 2011. Disease incidence in *Phaseolus vulgaris* in the regions of Chianga, Cuanza.

Sul and Malange, Angola. Presentation made at the 2011Annual Meeting of the American Phytopathological Society, Caribbean Division held in San Juan, Puerto Rico. 19-22 March 2011.

Hocdé H., J.C. Rosas y R. Araya. 2010. Co-desarrollo de variedades entre agricultores, científicos y profesionales, biodiversidad y otras cosas. ISDA 2010, Montpellier, France, 13 p.

Mbui Martins, M. 2011. Desarrollo de líneas de frijol (*Phaseolus vulgaris* L.) con mayores niveles de resistencia a las enfermedades. M.S. Thesis. University of Puerto Rico, Mayaguez Campus.

Mbui Martins, M., C. Estévez de Jensen, T.G. Porch, J.S. Beaver. 2011. Response of *Phaseolus vulgaris* lines to angular leaf spot. Presentation made at the 2011Annual Meeting of the American Phytopathological Society, Caribbean Division held in San Juan, Puerto Rico. 19-22 March 2011.

Mejía, P.Z., M.Pavon and J.C. Rosas. 2011. Avances en la producción orgánica de frijol en la región del Lago Yojoa, Honduras. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Ndengoloka David, A. 2011. Estudio de la diversidad genética de germoplasma de caupí [*Vigna unguiculata* (L.) Walp.] de Angola y un grupo de germoplasma que representa otras regiones del mundo. M.S. Thesis. University of Puerto Rico, Mayaguez Campus.

Porch, T.G., C.C. Urrea, J. S. Beaver, S. Valentin, P. A. Peña, and J. R. Smith. 2011. Registration of TARS-MST1 and SB-DT1 multiple-stress-tolerant black bean germplasm. J. Plant Reg. doi: 10.3198/jpr2010.08.0501crg; Published online 8 August 2011.

Rodriguez O., J.C. Rosas. 2010. Selección de genotipos de frijol común por su resistencia al tizón bacteriano. Agronomía Mesoamericana 21(2):1-6.

Rosas, J.C., A.G. Vargas, R. Ramos, S. Beebe, A. Llano, A. Clara, D. Escoto and J.C. Hernandez. 201. Resultados del SISTEVER 2010 de Frijol de Grano Rojo. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Rosas, J.C., A.G. Vargas, R. Ramos, J.S. Beaver, S. Beebe, A. Llano, D. Escoto, E. Prophete, J.C. Hernandez and J.C. Villatoro. 2011. Resultados del SISTEVER 2010 de Frijol de Grano Negro. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Rosas, J.C. and A.G. Vargas. 2011. Variaciones fenotípicas de la respuesta de genotipos de frijol a la inoculación con cepas de *Rhizobium*. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Rosas, J.S. and A.G. Vargas. 2011. Caracteres fenotípicos asociados con la tolerancia a la sequía y baja fertilidad de líneas endogámicas recombinantes de frijol. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Rosas, J.C., J.S. Beaver, A.G. Vargas and R. Ramos. 2011. Evaluación agronomica de germoplasma de caupí. Presentation made at the LVI PCCMCA Annual Meeting, April 25-29, Sonsonate, El Salvador.

Ruíz Quiles, L.A. 2011. Desarrollo de líneas de habichuela (*Phaseolus vulgaris* L.) con resistencia a BCMV, BGYMV y mejor adaptación en suelos bajos en nitrógeno. M.S. Thesis. University of Puerto Rico, Mayaguez Campus.

Zapata, M., J.S. Beaver and T.G. Porch. 2011. Dominant gene for common bean resistance to common bacterial blight caused by *Xanthomonas axonopodis* pv. *Phaseoli*. Euphytica 179:373-382.

Professional Recognition, Awards and Accomplishments

- Monica Mbui Martins received recognition for her poster presented at the 2011Annual Meeting of the American Phytopathological Society, Caribbean Division held in San Juan, Puerto Rico. 19-22 March 2011.
- James Beaver was selected as a 2011 Fellow of the Crop Science Society of America.

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.

Contribution of the Project to Target Performance Indicators

All of the host countries participating in this Dry Grain Pulse CRSP project 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 has used informal training to strengthen the capacity of the bean research programs in Central America, the Caribbean and Angola.

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

Equipment and materials have been purchased to improve the plant pathology laboratory and repair greenhouses at the IIA Research Station in Huambo, Angola. Tim Porch and Jim Beaver plan to visit Angola in December 2011 and will review progress in the establishment of the plant pathology facilities. Monica Mbui Martins has completed M.S. degree training at the UPR and has returned to Huambo, Angola. She plans to use both the plant pathology and greenhouse facilities for research related to the Dry Grain Pulse CRSP project.

Quotations have been obtained to purchase threshers for Haiti and Angola. The threshers need to be purchased during the upcoming year to facilitate the harvest of larger quantities of bean and cowpea seed on a timely basis.

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 were 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. A request to purchase a 4WD vehicle for the National Seed Service was approved.

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2011 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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

Provide abbreviated name of institutions in columns below

	UPR			USDA			EAP			IIA			Haiti		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmark Indicators by Objectives	**10/1/11**	**Y**	**N ***	**10/1/11**	**Y**	**N ***	**10/1/11**	**Y**	**N ***	**10/1/11**	**Y**	**N ***	**10/1/11**	**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				X	X		X	X							
Breeding populations tested	X	X		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 the most promising sources of BNF germplasm	X	X					X	X							
Complete crosses for the first cycle of recurrent selection for enhanced BNF							X	X							
Harvest seed from the first cycle of recurrent selection							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										
RAPD products cloned sequenced				X		X									
SCAR markers designed and initially tested				X		X									

Objective 4: Evaluation of other pulse crops for Central America and the Caribbean															
Complete the collection of P. lunatus	x	x													
Complete first year of field testing of cowpeas in PR, Haiti, and Central America	x	x					x	x					x		x
Characterize the phenological, morphological, and agronomic traits of P. lunatus (Haiti, PR)	x	x											x	x	
Objective 5: Increase the capacity, effectiveness and sustainability of agricultural research institutions that serve the bean and cowpea sectors in Central America, Haiti and Angola.															
M.S. degree training of Monica Martins	x	x													
M.S. degree training of Antonio David	x	x													
Informal training in Angola in bean research techniques				x	x										
Workshop in Honduras concerning the production, storage and distribution of *Rhizobium* inoculum							x		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							**Date**							

Dry Grain Pulses CRSP
PERFORMANCE INDICATORS/TARGETS for FY 11
(October 1, 2010 – September 30, 2011)

Project title: Development, testing and disseminationof genetically improved bean cultivars for Central America, the Caribbean and Angola

Lead U.S. PI: James S. Beaver, Univ. of Puerto Rico

Host Countries: Central America, Haiti and Angola

Output Indicators	2011 Target	2011 Actual
	(Oct 1 2010-Sept 30, 2011)	
Degree Training: Number of individuals who have received degree training		
Number of women	**0**	1
Number of men	**1**	1
Short-term Training: Number of individuals who have received short-term training		
Number of women	**10**	6
Number of men	**15**	9
Technologies and Policies		
Number of technologies and management practices under research	**3**	6
Number of technologies and management practices under field testing	**3**	5
Number of technologies and management practices made available for transfer	**1**	3
Number of policy studies undertaken	**0**	0
Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions	**75**	1000
Number of agriculture-related firms benefitting from CRSP supported interventions	**1**	5
Number of producer and/or community-based organizations receiving technical assistance	**4**	10
Number of women organizations receiving CRSP technical assistance	**1**	3
Number of HC partner organizations/institutions benefiting	**3**	8
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	**1,000**	5000

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

Principal Investigator
Mark E. Westgate, Iowa State University, USA

Collaborating Scientists
John Steven Tenywa, Makerere University, Uganda
Lynne Carpenter-Boggs, Washington State University, USA
Karen Cichy, USDA-ARS, USA
James D. Kelly, Michigan State University, USA
Phillip Miklas, USDA-ARS, USA
Henry Kizito Musoke, Volunteer Efforts for Developmental Concerns, Uganda
Susan Mchimbi-Msolla, Sokoine University of Agriculture, Tanzania
Augustine Musoni, ISAR, Rwanda
Daniel Krohn, Becker Underwood Inc., USA
Hamisi Tindwa, Sokoine University of Agriculture, Tanzania
Michael Ugen, National Crops Research Institute, Uganda
Peg Armstrong-Gustafson, Amson Technology l.c., USA

Abstract of Research 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.

Results, Achievements and Outputs of Research

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 BMF 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.

1. Improve farmer awareness of inoculation technologies
2. Conduct on-farm demonstrations comparing inoculant strategies
3. 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.

Objective 4: 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.

Degree Training

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

<u>Short Term Training</u>

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 Wangengen 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
	$V_1R_0P_0$	$V_1R_NP_+$	$V_1R_0P_0$	$V_1R_NP_0$	$V_1R_UP_0$	$V_1R_MP_+$	$V_1R_MP_0$	$V_1R_UP_+$
1	$V_1R_0P_+$	$V_1R_UP_0$	$V_1R_NP_0$	$V_1R_NP_0$	$V_1R_NP_+$	$V_1R_MP_+$	$V_1R_0P_0$	$V_1R_UP_+$
	$V_1R_0P_+$	$V_1R_UP_0$	$V_1R_UP_+$	$V_1R_MP_+$	$V_1R_MP_0$	$V_1R_NP_+$	$V_1R_MP_0$	$V_1R_0P_+$
	$V_2R_UP_0$	$V_2R_NP_0$	$V_2R_0P_0$	$V_2R_NP_0$	$V_2R_0P_+$	$V_2R_MP_+$	$V_2R_MP_0$	$V_2R_MP_0$
2	$V_2R_0P_+$	$V_2R_NP_+$	$V_2R_NP_+$	$V_2R_MP_+$	$V_2R_NP_0$	$V_2R_UP_+$	$V_2R_NP_+$	$V_2R_0P_+$
	$V_2R_UP_0$	$V_2R_MP_0$	$V_2R_MP_+$	$V_2R_UP_0$	$V_2R_0P_+$	$V_2R_UP_+$	$V_2R_0P_0$	$V_2R_UP_+$
	$V_3R_MP_0$	$V_3R_0P_0$	$V_3R_NP_+$	$V_3R_UP_0$	$V_3R_MP_0$	$V_3R_UP_+$	$V_3R_MP_+$	$V_3R_UP_0$
3	$V_3R_UP_+$	$V_3R_MP_+$	$V_3R_UP_+$	$V_3R_NP_+$	$V_3R_MP_+$	$V_3R_0P_0$	$V_3R_0P_0$	$V_3R_NP_+$
	$V_3R_NP_0$	$V_3R_0P_+$	$V_3R_0P_+$	$V_3R_NP_0$	$V_3R_0P_+$	$V_3R_NP_0$	$V_3R_UP_0$	$V_3R_MP_0$

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		
Research, Training and Outreach Workplans		
(October 1, 20010 -- September 30, 2011)		
FY 2011 PERFORMANCE INDICATORS-SUA		
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	**2011 Target**	**2011 Actual**
	(October 1, 2010-Sept 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	4	4
Number of men	3	4
Short-term Training: Number of individuals who received short-term training		
Number of women	50	4
Number of men	50	4
Technologies and Policies		
Number of technologies and management practices under research	1	1
Number of technologies and management practices under field testing	1	1
Number of technologies and management practices made available for transfer	1	1
Number of policy studies undertaken		
Beneficiaries:		
Number of rural households benefiting directly	1000	0
Number of agricultural firms/enterprises benefiting	6	3
Number of producer and/or community-based organizations receiving technical assistance	50	0
Number of women organizations receiving technical assistance	3	0
Number of HC partner organizations/institutions benefiting	6	3
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	1000	20

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

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			NaCCRI			SUA			Makerere			ISAR		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	########	Y	N*	########	Y	N*	########	Y	N*	########	Y	N*	########	Y	N*	########	Y	N*	########	Y	N*	########	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																							
Objective 1																								
Field Trial 1 established at HC sites													x	Y		x	Y					x	Y	
Quantified yield advantage of inoculation in US and HC field trials				x	Y		x	Y					x	Y		x	Y					x	Y	
Established project website for data storage/sharing	x		N																					
Secured non-nodulating lines for field studies							x	Y					x	Y										
Analysis of soil/weather data completed	x												x	Y		x	Y		x	Y		x	Y	
Common varieties to test at all HC sites identified													x	Y		x	Y					x	Y	
Finalized protocols for field sampling and controlled environment work	x	Y					x	Y																
Phenotypic responses to inoculant x genotype x environment identified	x	Y		x	Y		x	Y					x	Y		x	Y		x	Y		x	Y	
Soil from field sites tested for indigenous rhizobia strains	x		N	x		N	x		N				x	Y		x		N	x		N	x		N
Established indigenous rhizobia levels associated with environment							x		N															
Initial characterization of soil rhizobia populations conducted							x		N															
Trial inoculants evaluated for rhizobia titre	x		N				x		N															
Objective 2																								
Identified/collected bean lines for BNF diversity panel				x	Y		x	Y																
Collected/increased seed of non-nodulating adapted lines	x	Y		x	Y		x	Y																
Screened selected lines for BNF in low soil N +/- inoculants in HC field trials				x	Y		x	Y																
Greenhouse screening trials initiated on selected lines for BNF response				x	Y		x	Y																
Identify potential RIL parental lines for BNF response	x	Y		x	Y		x	Y																
Phenotyping of selected lines for BNF response at US site initiated				x	Y		x	Y																
Plant samples for SNP analysis collected from CAP and SA Core collection				x	Y		x	Y																
Mechanisms to correlate field and GH responses established	x		N	x		N	x		N				x		N	x		N	x		N	x		N
Initiated search for BNF responsive genes in silico				x	Y		x	Y																
Selected RILs advanced to F2				x	Y		x		N															
Objective 3																								
Created awareness among Extensionists at HC institutions in benefits of BNF										x	Y		x	Y		x		N				x		N
Evaluated farmer Knowledge, Practices, Attitudes on inoculation										x		N				x		N				x		N
Prepared for on-farm trials by identifying potential farmer cooperators										x		N	x		N	x	Y					x	Y	
Prepared for on-farm trials by training cooperators on field methods										x		N	x		N	x	Y					x	Y	
Initiated training materials on BNF and seed inoculation for extensionists	x	Y								x	Y								x		N			
Initiated production of training materials to disseminate through PELUM	x		N							x		N							x		N			
Objective 4																								
Graduate students identified																x	Y							
Graduate research programs initiated																x	Y							
Undergraduate student interns identified																								
Undergraduate student projects initiated																								
Team members trained in methods of SNP analysis							x		N															
Conducted short-term training of graduate students on BNF protocols	x	Y					x		N															
Name of the PI reporting on benchmarks by institution	Westgate			Clohy			Mklas			Muecke			Ugen			Mohimbi			Tenywa			Musoni		

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

[signature] ######

Signature Date

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

Principal Investigator
Maurice R. Bennink, Michigan State University, USA

Collaborating 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

Much of the activities planned for FY11 were not completed because of difficulties related to ordering and receiving cell counting reagents and the vitamin/mineral premix required for the study. These difficulties were partly due to SUA's antiquated process for ordering supplies. SUA needs to remove this constraint if it has aspirations of becoming a prominent research institution in Africa. The other difficulties were related to the attempt by customs officials to levy a VAT on materials used for research. Research related materials are supposed to be granted VAT exemption, but it took 4 – 11 months to get clearance from the customs office. Once the reagents and premix were received, then the study began. Activities that were scheduled for FY11 but not completed due to the above difficulties will be completed in FY12.

Project Problem Statement and Justification

The overall goal of the research is to determine if eating beans will improve the immune status of 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. 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. 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. Since the human immunodeficiency virus destroys CD4 cells (immune cells), opportunistic infections are common place among those living with HIV. 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. We previously showed that providing HIV+ children with a bean-maize supplement containing minerals and vitamins could reverse malnutrition if present <u>and</u> 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. Consuming a bean-based supplement could improve the lives of millions of HIV infected people which would at the same time benefit the entire bean value-added chain from farmers to consumers.

Progress on Project Activities for the Report Period by Objectives

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. Enroll 205 additional subjects (anticipated total number of subjects for the 30-month project is 540).
2. Purchase ingredients, cook and package food supplements, transport and distribute food supplements to 540 subjects.
3. Collect and analyze blood samples for CD4, CD8, CD3 and total lymphocyte counts.
4. Train six M.S. students to assist in research.
5. Provide field practical training in community nutrition and health for 16 undergraduates.

Results, Achievements and Outputs of Research

Seventy three children were enrolled and began the feeding intervention late in FY11. An additional 465 HIV-infected, HAARV - naïve children have been identified and will begin the study in FY12. Two hundred and sixty six children live in five rural villages in the northern region of Rombo. Two hundred and seventy two children live in eight rural villages within a 150 km radius of SUA. Additional subjects will be identified in the Morogoro Rural District during FY12 so that we will have adequate statistical power to determine if a particular nutritional supplement will elicit a difference in immune recovery (an increase in CD4 counts). Our goal is to have 540 subjects complete the study in the absence of HAARV. However, the availability of HAARV drugs is increasing and we anticipate some of the 538 subjects will start HAARV treatment during the study period. Therefore, we will enroll more than the planned 540 subjects that are HAARV-naïve to allow for the subjects that will begin ART treatment.

Food processing and packaging began in earnest in September, 2011. Four full-time technicians are required for this task. Approximately 17,000 individual packages of supplement will need to be produced each month once we have all subjects receiving nutritional intervention.

No CD4, CD8, or CD3 cell count data were prior to the end of FY11.

Field practical training in community nutrition and health was provided for 16 undergraduates. Two M.Sc. students will utilize data collected for this study for their thesis. They received support for their research activities related to objective one.

Objective 2: Determine the relative costs of three dietary treatments compared to HAARV drug treatment (Note: this will complete the data gathering begun in FY10).

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, Achievements and Outputs of Research

No activities related to Objective 2 were completed in FY11.

Objective 3: Determine if eating the bean-based supplement improves the integrity of the mucosal barrier in the gut and leads to reduced gut permeability and release of pro-inflammatory cytokines.

Approaches and Methods

1. Analyze dried blood samples shipped from Tanzania for HIV load, selected pro-inflammatory cytokines, and R16s.
2. Conduct studies with rats to ascertain extent of bacterial translocation across the gut and release of pro-inflammatory cytokines. This will be a continuation of the work begun in FY10 and the exact experiments will depend upon the results obtained from those studies.

Results, Achievements and Outputs of Research

No activities related to Objective 3 were completed in FY11.

Objective 4: Capacity building

- Pudensiana Kiwale, a doctoral student in Agricultural Marketing at SUA, will receive partial support and will conduct the cost analysis study.
- Sharon Hooper, a doctoral student in Food Science at MSU, will receive partial support and she will assist in assays related the rodent studies to be conducted at MSU.
- Two M.S. students in Nutrition and one M.S. Food Science student will be enrolled in the respective graduate programs at SUA. They will participate in the clinical trial which will become part of their dissertations.
- Two students in Nutrition and one in Food Science at SUA will complete their M.S. degrees and the work conducted as part of this overall project will be the basis for their dissertations.

<u>Degree Training</u>

<u>Trainee # 1</u>
First and Other Given Names: *Sharon*
Last Name: *Hooper*
Citizenship: *Jamaican*
Gender: *Female*
Training Institution: *MSU*
Supervising CRSP PI: *M. Bennink*
Degree Program for training: *Doctorate*
Program Areas or Discipline: *Food Science*
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID? *No*
Host Country Institution to Benefit from Training: *University of West Indies, Jamaica*
Thesis Title/Research Area: *Characterization of Bean Starch*
Start Date: *August 15, 2009*
Projected Completion Date: *August, 2012*
Training status (Active, completed, pending, discontinued or delayed): *Active*
Type of CRSP Support (full, partial or indirect) for training activity: *Partial*

Activities for Trainee # 1
Sharon continued her thesis research (characterization of bean starch) during the summer semester and will likely graduate in Dec., 2012.

<u>Trainee # 2</u>
First and Other Given Names: *Pudensiana*
Last Name: *Kiwale*
Citizenship: *Tanzania*
Gender*: Female*
Training Institution: *SUA*
Supervising CRSP collaborator: *Reuben Kadigi*
Degree Program for training: *Doctorate*
Program Areas or Discipline: *Agricultural Marketing*
If enrolled at a US university, will Trainee be a “Participant Trainee” as defined by USAID?
Host Country Institution to Benefit from Training: *Tanzania*
Thesis Title/Research Area: *Agricultural Marketing*
Start Date: *August, 2009*
Projected Completion Date: *August, 2012*
Training status (Active, completed, pending, discontinued or delayed): *Delayed*
Type of CRSP Support (full, partial or indirect) for training activity: *Indirect*

Activities for Trainee # 2
Pudensiana took a year of maternal leave. Her absence did not affect the progress of this project and she did not receive any support during FY11. Her activities will begin again in FY12.

<u>Trainee # 3</u>
First and Other Given Names: *Nyangi*
Last Name: *Amos*
Citizenship: *Tanzania*
Gender: *Female*
Training Institution: *SUA*
Supervising CRSP PI: *Theobald Mosha*
Degree Program for training: *MS*
Program Areas or Discipline: *Nutrition*
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?
Host Country Institution to Benefit from Training: *Tanzania*
Thesis Title/Research Area: *Nutrition*
Start Date: *2009*
Projected Completion Date*: August, 2011*
Training status (Active, completed, pending, discontinued or delayed): *Active*
Type of CRSP Support (full, partial or indirect) for training activity: *Partial*

Activities for Trainee # 3
Nyangi collected demographic data pertaining to subjects in the Rombo district. She will likely graduate in Feb. of 2012.

<u>Trainee # 4</u>
First and Other Given Names: *Sacred*
Last Name: *Jacob*
Citizenship: *Tanzania*
*G*ender: *Female*
Training Institution: *SUA*
Supervising CRSP PI: *Theobald Mosha*
Degree Program for training: MS
Program Areas or Discipline: *Nutrition*
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?
Host Country Institution to Benefit from Training: *Tanzania*
Thesis Title/Research Area: *Nutrition*
Start Date: *2011*
Projected Completion Date*: Feb, 2012*
Training status (Active, completed, pending, discontinued or delayed) *Active*
Type of CRSP Support (full, partial or indirect) for training activity: *Partial*

Activities for Trainee # 4
Sacred began assisting in supplement production and related activities in September, 2011.

Explanation for Changes
This project has been delayed at least 14 months due to our inability to purchase and move reagents and supplements through customs. The first major problem was the purchase of flow cell counting reagents that was to be through the normal SUA system. We had established an arrangement with Bectin-Dickinson to purchase their cell counting reagents in exchange for their

provision of a flow cell counting machine at no cost (a $40,000 machine if purchased). However, to purchase the flow cell reagents using funds at SUA required a month long process involving letters to various officials culminating with the vice chancellor of SUA. This was required because the reagents had to ordered from Belgium and SUA basically doesn't allow reagents to be ordered from foreign entities. Once the exception was granted and shipped, the reagents were held by customs officials because they claimed the reagents were medical supplies and therefore subject to VAT. It took four months with numerous phone calls, personal visits and letters before the appropriate official declared the reagents were exempt from VAT! For Bennink to purchase and send these reagents would result in a 52% increase in cost and these reagents are a major portion of the budget. A 52% increase in cost would necessitate a reduction in the length of the study. Even if Bennink was to purchase the reagents, we would probably still have to deal with customs because the reagents would be shipped directly by BD in Belgium and would again be held up in customs. Currently, the plan is to purchase the reagents through the local clinics since they routinely order the flow cell reagents. This arrangement will most likely increase the cost of the reagents a little, but we should be able to receive the reagents as needed.

The second major problem was related to the vitamin/mineral premix required to prepare the large quantity of supplements for this study. There is no supplier of the required minerals and vitamins in Tanzania. In the past, a 20 kg box of premix would be sent to SUA by air by Bennink with no difficulty, but air freight was expensive. Since this is a very large study with a requirement of approximately 2 tons of premix, we decided to purchase the premix as before (in the US) and send it by boat. This shipment was also held by customs for payment of VAT. It took 11 months with an unbelievable number of phone calls, personal visits and letters before the appropriate official declared the premix was exempt from VAT. Meanwhile, the pallet of premix was stored in a private warehouse and they demanded a storage payment of $2,500. After a prolonged negotiation, the shipment was released, but we had to pay $2,000 in storage fees!

A ton of the premix is currently at MSU and several approaches will be tried to determine what is the most cost efficient and expedient mechanism to ship these supplies to SUA.

Without the flow cell reagents and the vitamin/mineral premix, we could not collect blood samples, analyze blood or dried blood spots, or implement the feeding intervention. We believe we are now on track to complete the study. The remaining difficulty is related to the great deal of transportation necessary to collect the blood samples and to transport supplement to the villages that are 50 to 600 km from SUA. SUA has raised the mileage charges for using SUA vehicles from 350 to 1,000 Tanzanian Schillings per km during the past year. In addition it has become increasing difficult to schedule a vehicle for project activities. Perhaps the hesitancy is related to frequency of use, weight of material to be transported, and poor condition of roads to the remote villages. The research team will continue to explore ways to deal with this difficulty.

We envisioned two years ago when the activities for FY11 were written, that much of the day to day work would be handled by MS students at SUA. However, most current MS students at SUA are employed in the private sector and have research sponsorship provided by their employers and need to conduct research in areas that are not aligned with this project. Therefore, the pool of available MS students to become part of this project has greatly diminished. Moreover, we now realize due to the size of the study, MS students are not the best suited employees for completing much of the daily work activities. Thus, fewer MS will be trained than originally envisioned.

The clinical study has the highest priority and decisions regarding initiation of rodent studies and analysis of dried blood spots to determine mechanism of action for improved immune response will be delayed until after 6 mo of data has been collected. If the results of the clinical study warrant conducting activities related to determining mechanism of action and if it appears there will be funding left for these activities, then those areas of research will be implemented.

Funds committed to the activities that were not completed in FY11 remain available to complete these activities in FY12.

Networking and Linkages with Stakeholders

M. Bennink participated in a four day meeting of partners involved in Feed-The-Future activities funded by the USAID mission in Tanzania. The meeting took place in Udzungwa Falls Lodge near Kilosa, Tanzania in May 23 – 27, 2011. This was an excellent opportunity to inform NGOs of our work activities in Tanzania and to learn of their program activities. In addition, valuable contacts with USAID mission people were established. He also maintains informal contact with the US Dry Bean Council and several regional Dry Bean Commissions. He participated in two workshops involving scientific experts conducting research in the area of chronic disease reduction thru ingestion of dry beans.

T. Mosha and M. Bennink met with nutritionists at the World Food Program office in Dar es Salaam to discuss our research and potential interaction with the broad initiative of WFP to initiate a National food fortification program in Tanzania. Both Mosha and Laswai have subsequently participated food fortification activities. Dr. Laswai has chaired several of these meetings and he was involved in similar activities involving neighboring countries.

Drs. Mosha and Laswai often meet with a variety of local groups and individuals as they learn of the activities related to nutritional support of HIV-infected individuals. These discussions inform leaders local communities of the project's efforts. One noteworthy outcome was the establishment of a linkage with Tunajali (a NGO) that will share some of the costs associated with obtaining CD4 cell counts for our study.

Leveraged Funds

No leveraged funds directly related to this project were received during FY11.

List of Publications

One manuscript and one book chapter were submitted and are accepted for publication, but were not actually published during FY11. One other manuscript has been submitted, but a decision regarding acceptance has not been made.

Professional Recognition, Awards and Accomplishments

None

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

Project Title: *PIII-MSU-3 Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Intervention*

	Abbreviated name of institutions																	
	SUA			0			0			0			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*	9/30/11	Y	N*
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Enroll additional subjects	105		√	0			0			0			0			0		
Provide student training	16	√		0			0			0			0			0		
Analyze blood samples	250		√	0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 2																		
Investigate costs of	0			0			0			0			0			0		
supplement production	1			0			0			0			0			0		
Investigate costs of	0			0			0			0			0			0		
HAARV treatment	1			0			0			0			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																		
Analyze blood samples	0			250		√	0			0			0			0		
Conduct animal studies	0			1		√	0			0			0			0		
0	0			0			0			0			0			0		
0	0			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		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			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	M. Bennink

Maurice R. Bennink　　　　10/3/2011

Signature　　　　**Date**

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 20010 -- September 30, 2011)

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: PIII-MSU-3 Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Intervention
Lead U.S. PI and University: M. Bennink, MSU
Host Country(s): Tanzania

Output Indicators	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	7	1
Number of men	0	0
Short-term Training: Number of individuals who received short-term training		
Number of women	0	0
Number of men	0	0
Technologies and Policies		
Number of technologies and management practices under research	0	0
Number of technologies and management practices under field testing	0	0
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	300	73
Number of agricultural firms/enterprises benefiting	4	1
Number of producer and/or community-based organizations receiving technical assistance	4	1
Number of women organizations receiving technical assistance	3	1
Number of HC partner organizations/institutions benefiting	1	1
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	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.

Principal Investigator
Mywish K. Maredia, Michigan State University. USA

Collaborating Scientists
Richard Bernsten, Michigan State University, USA
Eric Crawford, Michigan State University, USA
Jim Beaver, UPR, Haiti
Juan Carlos Rosas, EAP, Haiti
Eduardo Peralta, INIAP, Haiti
Emmanuel Prophete, Haiti
Mathew Blair, CIAT
Ndiaga Cisse, ISRA, Senegal
Issa Drabo, INERA, Burkina Faso
Phil Roberts, University of California, USA
Jeff Ehlers, University of California, USA

Abstract of Research Achievements and Impacts

The project team completed the compilation of two databases: a) Database of improved varieties of beans and cowpeas in countries where the Bean/Cowpea CRSP has been historically involved in crop improvement research, and b) the database of socio-economic studies and impact assessments conducted by the DGP (and its predecessor) CRSP to date. Both these databases have been developed in MS Access with reports generated and available in MS Word and Excel. The database on improved varieties and the impact studies will be further scrutinized as part of the meta-analysis planned in FY 12

The impact pathway analysis for each of the Phase 2 and 3 projects was completed in FY 11 and results presented to the MO. Based on this analysis, the 10 CRSP Phase 2 and 3 projects can be grouped into three types—1) projects for which the prognosis for achieving development impacts is positive contingent upon successfully scaling up the application of outputs; 2) projects for which the potential for long-term impacts is low based on their current scope and scale; and 3) projects for which the potential for long-term impacts is uncertain because the realization of the vision of success depends on many factors outside the control of researchers or the scale at which the research is conducted may not generate a critical mass of knowledge/evidence needed to influence major policy decisions (required to achieve the vision of success).

Field research and analysis towards two ex post impact assessment studies was conducted as planned. This included the adoption and impact study on bean improvement research in Central America and Ecuador and cowpea improvement research in Senegal. Past and current research conducted by the Bean/Cowpea and Pulse CRSP on value addition, food science and human nutrition was reviewed with the aim of documenting all the outputs, outcomes and impacts from such investments. This enquiry did not lead to any new or encouraging information on the

commercial application of research outputs generated from CRSP research projects or evidence of their uptake/utilization by various actors in the value chain (i.e., processors, traders, consumers).

Towards implementing an integrated impact evaluation strategy as part of the CRSP project design, the lead PI of this project interacted with several CRSP project PIs to explore opportunities and feasibility of conducting impact evaluation research. Four such opportunities for data collection and investigative research with the aim of addressing questions of what works, where, why and why not, were identified and included as part of the Workplan for FY 2012.

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.

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**.[3] 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.

Results, Achievements and Outputs of Research

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

Towards this objective, this project finalized the following two activities and gave an oral presentation and an overview of results to the MO staff in November 2011.

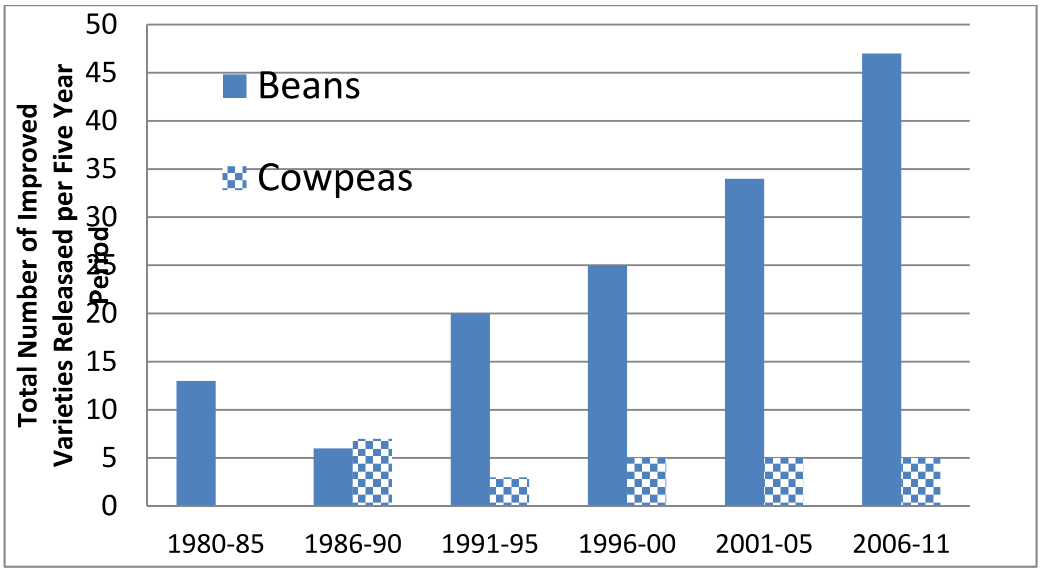
[3] Although in the evaluation profession, the terms impact assessment and impact evaluation are used synonymously, in this project we make a nuanced distinction between ex post impact assessment and impact evaluation based on the timing of when they are conducted, the scale at which they occur and the motivation for doing an assessment (Maredia 2009).

1a. An Inventory of Past Outputs and Documented Impacts

Under this activity, the project team has completed the compilation of two databases: a) Database of improved varieties of beans and cowpeas in countries where the Bean/Cowpea CRSP has been historically involved in crop improvement research, and b) the database of socio-economic studies and impact assessments conducted by the DGP (and its predecessor) CRSP to date. Both these databases have been developed in MS Access with reports generated and available in MS Word and Excel.

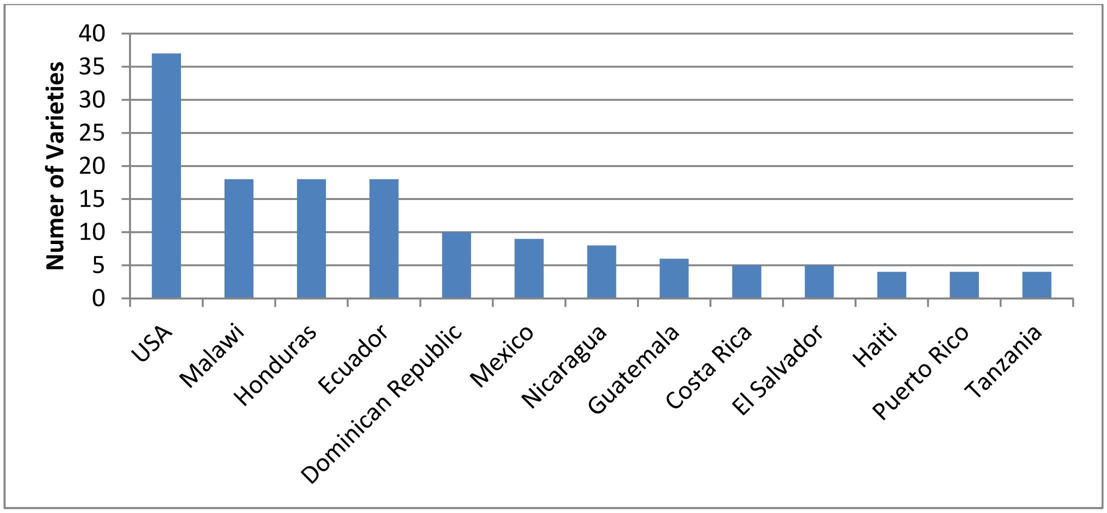
Figure 1 presents the number of bean and cowpea improved varieties released from 1980-2011 per five-year period by host country partners that received CRSP funding. Over the past 30 years, a total of 145 improved bean varieties and 25 improved cowpea varieties released in the U.S and many CRSP partner countries can be attributed as outputs of CRSP funded research projects. For beans the number of varieties released at an aggregate global level shows an upward trend, increasing from an average of about 2 varieties per year in 1980s to almost 10 per year in 2006-11. A major source of this upward trend in CRSP supported bean varietal release is the region of Central America and the Caribbean. Figure 2 shows the breakdown of the 145 bean varieties by country of release. Not surprisingly, many of the countries on the higher end are USA, Hoduras, Ecuador and Malawi where the CRSP has historically played an important role in supporting collaborative research programs in bean breeding.

Compared to beans, the number of cowpea improved varieties attributed to CRSP support has remained stable at about 5 varieties per 5 year period (or an average of 1 per year) since mid-1980s (Figure 1). Over the past 25 years, CRSP can be credited for the release of 8 cowpea varieties in Senegal (the highest in any country), 7 in Burkina Faso, 4 in the U.S., 3 in Ghana, 2 in Cameroon and 1 on Sudan (Figure 3).



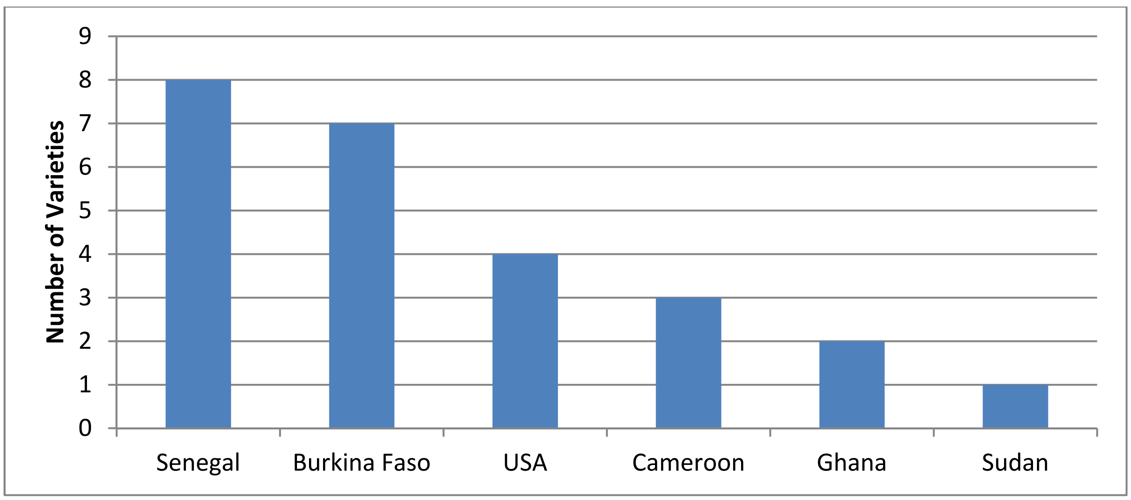
Source: Variety database compiled by CRSP IA team, 2011

Figure 1. Trend in the number of improved bean and cowpea varieties released in CRSP partner countries (including USA) by breeding programs that received CRSP funding, 1980-2011



Source: Variety database compiled by CRSP IA team, 2011

Figure 2. Number of CRSP supported improved bean varieties released in different countries, 1980-2011



Source: Variety database compiled by CRSP IA team, 2011

Figure 3. Number of CRSP supported improved cowpea varieties released in different countries, 1986-2010

The impact database contains a list of 40+ studies of varying focus and rigor on quantitative assessment of impacts. Not surprisingly, a majority of studies assess the ex post adoption or farm level benefits of varietal outputs of CRSP research. However, there are also a few studies that examine the impact of cowpea storage technology in Africa and IPM research. The database on improved varieties and the impact studies will be further scrutinized to conduct the meta-analysis planned in FY 12.

1b. Trajectory of Outputs and Potential Outcomes/Impacts of Ongoing Investments by the Pulse CRSP

This activity, completed in FY 11 and presented to the MO in November 2011, was similar in scope to activity 1a, except that it was a forward looking exercise, since the focus was on ongoing CRSP projects in Phase 2 and 3. Table 1 gives a summary of the impact pathway analysis for each of the Phase 2 and 3 projects. This analysis is based on the information provided by individual project team in a spreadsheet that was developed to capture the project's outputs, outcomes and impact. The impact pathway analysis gives a synopsis of the types of outputs to be generated by different research projects by the end of FY 2012, potential scale or impacts envisioned by the research team in the next five years, impact pathway and indicators along that pathway to achieve developmental outcomes (in the form of impacts at the beneficiary/adopter level). The last column of this table presents our subjective assessment of the potential for realizing the long-term impacts in the form of aggregate level benefits to the society at large. Based on this analysis, the 10 CRSP Phase 2 and 3 projects can be grouped into three types—1) projects for which the prognosis for achieving development impacts is positive contingent upon successfully scaling up the application of outputs; 2) projects for which the potential for long-term impacts is low based on their current scope and scale; and 3) projects for which the potential for long-term impacts is uncertain because the realization of the vision of success depends on many factors outside the control of researchers or the scale at which the research is conducted may not generate a critical mass of knowledge/evidence needed to change major policy decisions (required to achieve the vision of success).

Table 1. Impact Pathway Analysis of the Dry Grain Pulses CRSP Phase II and Phase III Projects – Prognosis for Development Impacts

Project (Name of Lead PIs)	Types of outputs	Potential Scale of impacts envisioned by PIs in the next 5 years	Impact indicators and pathway to achieve developmental outcomes	Potential for long-term impacts (per USAID's expectations) (subjective analysis)
PII-ISU-1 (Mazur)	New methods and approaches	Small--District level (Kamuli, Uganda)	Higher yield→increased income	Yes—if the methods/approaches are scaled up by the NGO (currently this vision is not explicit)
PII-MSU-2 (Bernsten / Donovan)	Information systems	Small—pilot scale (regions within a country)	Increased access to market at higher price→increased income	Yes—if the system is scaled up by partners (currently this vision is not explicit) and if research shows evidence of impact indicators and pathway
PII-PSU-1 (Lynch / Findeis)	New materials for breeding programs and	Not specified	Improved materials→adopted by breeders→new varieties with root traits→increased yields by adopted farmers→increased income and production	Yes—if breeders integrate the materials in bean breeding program. But PI expressed frustration on the lack of interest from breeders
	Knowledge on seed system	Local impacts in bean growing region (Mozambique)	Changes in national policy→reduction in constraints to low-P bean seed diffusion	Low--Difficult to change policy with one small scale study
PII-UCR-1 (Roberts)	New materials (advanced lines and varieties)	Medium—sub-regions in multiple countries (Senegal, BF, Mali, Niger)	Increased productivity → increased income and production	Yes – if breeders play an active role (as a partner) in seed multiplication and dissemination efforts
PII-UIUC-1 (Pittendrigh)	New materials released (Biocontrol agents) And	Medium—thousands of farmers across multiple countries (BF, Mali, Niger, Nigeria)	Biocontrol agents→ decrease in pests →increased yield → increased income and production	Yes—if research shows evidence of impact indicators identified in the pathway
	New strategies, information systems and extension materials		New information→adoption of new on-farm practices→decrease in yield loss→increased income and production	
PII-UPR-1 (Beaver)	New materials (markers, parental lines and varieties)	Large (100,000 farmers in multiple countries)	Increased adoption→increased yield→increased income and production	Yes—if the FtF technology transfer project in Central America is successful

Project (Name of Lead PIs)	Types of outputs	Potential Scale of impacts envisioned by PIs in the next 5 years	Impact indicators and pathway to achieve developmental outcomes	Potential for long-term impacts (per USAID's expectations) (subjective analysis)
PIII-ISU-2 (Westgate)	New knowledge, recommendations (innoculums) and materials (QTLs and germplasm)	Large (multiple countries, 15% of farmers)	Adoption of recommendations and materials→increased productivity→increased income/production, environmental impacts	Yes—if research shows evidence of impact indicators and pathway (and adoption occurs as predicted)
PIII-MSU-3 (Bennink)	New knowledge on how pulse consumption reduces markers of chronic disease and New knowledge on how pulse consumption reduces markers of chronic disease improved nutritional and immunological status	None (PI sees this project as achieving impacts over long-term—30-35 years)	Consumers and commodity advocates instigate change in nutritional recommendations by national and international agencies→ recommendations are implemented at grassroots→ Changes in food choices→improved health and reduction in health costs Donors provide funds for large scale multi-national testing of nutritional intervention for PLHA→ policy change and commitment of resources for nutritional support and not just for drugs→ changes in food choices and increased consumption of pulses and essential nutrients → improved health and reduction in health costs	Uncertain—it depends on changing behavior and attitudes of many players along the pathway. Also, not sure if the knowledge generated by one study at such a small scale can influence national and international policies; Need a critical mass of 'knowledge' pool to influence change in policy and consumer behavior
PIII-KSU-1 (Amanor-Boadu)	New information, knowledge and ideas (on bean and cowpea supply chains and adoption protocols to enhance the relationship	None	New information→ improved governance system in supply chain → higher value accretion→ higher income accruing to female producers→ improved household food and nutrition security	Uncertain—not sure about the realization of the pathway from outputs to impacts

Project (Name of Lead PIs)	Types of outputs	Potential Scale of impacts envisioned by PIs in the next 5 years	Impact indicators and pathway to achieve developmental outcomes	Potential for long-term impacts (per USAID's expectations) (subjective analysis)
	between value accretion and gender)			
PIII-TAMU-1 (Awika)	New knowledge (effect of food processing on cowpea bioactives)	None	Community outreach targeting consumers, policymakers and farmers→Increase in demand and use of cowpeas with enhanced health attributes→ Improved health and food security among vulnerable groups and Improvement in income for cowpea farmers	Uncertain—it depends on many factors outside the control of researchers. Also, not sure if the knowledge generated by this one study can influence consumers.
	New materials (cowpea lines, improved varieties with bioactivity traits)	None	Development of varieties with high phytochemical content and enhanced health benefits → adoption by farmers →increased production and consumption of nutritionally enhanced cowpeas	

The impact pathway analysis and the prognosis for development impacts of current research projects presented in Table 1, highlights the fact that the CRSP portfolio is made up research projects that fall on different trajectories of types of outputs, outcomes and impacts and are at varying distance from the goal of achieving development impacts. Since the Pulse CRSP is funded by USAID under the banner of 'development assistance,' this prognosis has important implications on funding decisions and balancing the research portfolio along the spectrum from research to development. Some type of research supported by the Pulse CRSP by nature is fundamental/basic research and thus farther away (in time dimension) from the vision of achieving large scale development impacts. This type of research is critical in advancing the knowledge frontier in small increments, which cumulatively and over time may lead to applications, technologies, practices and policies that can positively impact people's lives. But can the CRSP afford to invest in research that has a 25-35 year time horizon for achieving impacts? What should be the mix and balance between applied research that can lead to development impacts within the life span of a CRSP grant and basic research that may not even generate outputs in 5 years? These are the types of questions which the Pulse CRSP MO will be facing in the coming year as it prepares for the next five year phase. We hope the impact pathway analysis of the current and prospective research projects can serve as an input in guiding research investments in pulse crops for the next five years.

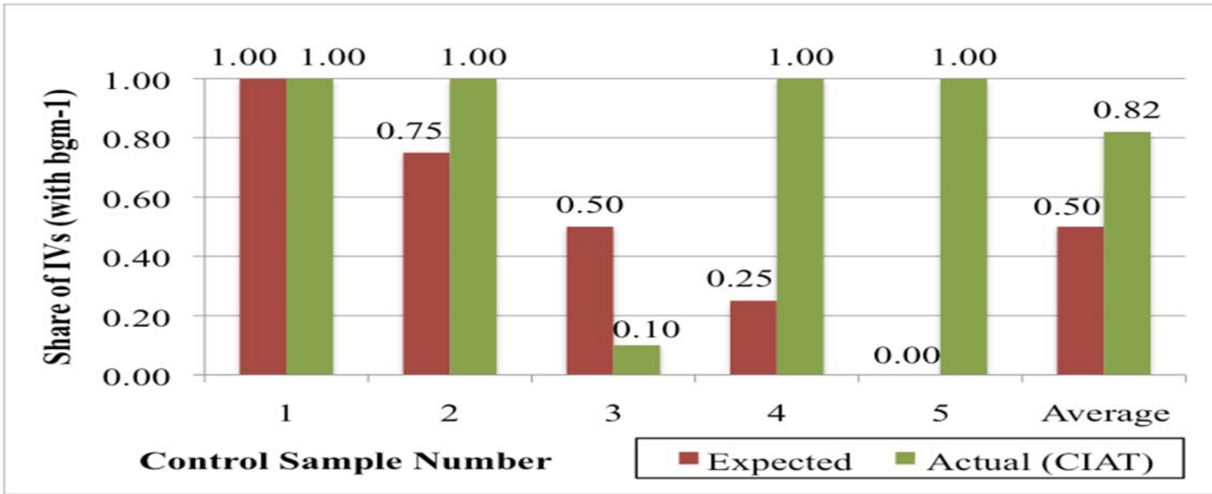
<u>Objective 2:</u> Conduct ex post impact assessment of Bean/Cowpea and Dry Grain Pulses CRSP investments in research, institutional capacity building and technology dissemination in Africa, Latin America and the U.S.

2a. Synthesis and Update Study on the Adoption and Impact of CRSP's Bean Improvement Efforts in the LAC Region.

The general objective of the study was to assess the *ex post* impact of Bean Cowpea (B/C) and Dry Grain Pulses (DGP) CRSP investments in research, institutional capacity building and technology dissemination in Latin America, focusing on Honduras, Guatemala, El Salvador, Nicaragua, Costa Rica, and Ecuador. To achieve these objectives, a rapid appraisal methodology was used: five types of bean sector key informants were interviewed and secondary data were collected from FAOSTAT and National Statistical Offices (NSO) in each country during 2010. A total of 67 key informants were interviewed and the data were analyzed using Excel and STATA. Adoption levels were estimated using (a) estimations of bean experts and (b) seed distribution / sales data. Key informants provided research cost data. To estimate the magnitude of the effect of using improved varieties (IVs) vs. traditional varieties, key informants provided estimations of yield loss averted by farmers when planting improved seed. In addition, experimental data are being analyzed to estimate yield gains over time.

As part of the impact evaluation methodology, several bean samples from three markets in Tegucigalpa were collected and sent to CIAT for evaluation of the presence of the *bgm-1* gene, which, if present, would confirm that the seed came from an IV. In addition, control samples (with known proportions of IVs and traditional varieties' seed) were included in the sample to test the accuracy of the results. This method could potentially generate information about the share of IVs sold in these markets.[4] The results suggest that, in order to be able to successfully use this technique, more research needs to be done since, as Figure 4 shows, the differences in the results of the analysis of the control samples (i.e., samples of IV provided by Dr. Rosas) and the *bgm-1* test conducted at CIAT were large. It was expected that, on average, the control samples would have 50% of the seed with the *bgm-1* gene; however, the results from CIAT estimated that 82% of the seeds in these (control) samples had this gene; thus, overestimating the share of IVs in the samples. Therefore, using this methodology in a larger scale was not pursued since the results would, most likely, overestimate the presence of the *bgm-1* gene.

[4] Since the samples were collected during one weekend, these results can not be used to make inferences regarding the adoption of IV's in Honduras. Ideally, grain samples should have been collected over the year to obtain a representative sample of grain that would allow making valid inferences.



As mentioned, bean production and trade data from two sources were analyzed. The differences between FAO vs. NSO data were small (although in a few cases statistically significant) for bean planted area, production, and exports. However, for El Salvador, Guatemala, and Ecuador, the differences between these two sources of data were statistically significant for bean imports. The data suggest that among the six countries, only Nicaragua (the largest) and Ecuador were net bean exporters.

Although all breeding programs have the same research priorities they had 20 years ago, the work in these areas has intensified and the programs have incorporated a few new research priorities. In Central America, new priorities include selecting for resistance to other biotic (e.g. Web Blight, ALS) and abiotic (e.g. droughts) stresses and high nutritional value. In contrast, in Ecuador, new priorities include research on climbing beans, additional market classes, and processing properties (for canned beans). Furthermore, in 2010, although Zamorano's breeding program in Honduras, ICTA's breeding program in Guatemala, and INIAP's breeding program in Ecuador were making crosses, only Zamorano's bean program was supplying lines to other bean programs in Central America. This highlighted the high dependence of the Central American programs on Zamorano. The main reasons why the other bean programs don't do crosses included a lack of (1) funds, since doing this activity is expensive, and (2) trained staff.

In 2010, a little more than one-half of the bean programs used molecular markers during the breeding process. Furthermore, more than two-thirds were implementing participatory breeding, which demonstrated the increased collaboration between scientists and producers (Table 2).

Table 2. Degree of farmer participation during the breeding process. 2010.

				If YES,[2]			
						# groups doing PB in	
Country	Program Name[1]	Does PB?[2]	If NO, Why not?	Does PPB?	Does PVS?	2005	2010
Costa Rica	INTA-CR	YES		Rarely	YES	6	6
Ecuador	INIAP	YES		Rarely	YES	4	6
El Salvador	CENTA	YES		NO	YES	0	3
Guatemala	ICTA	NO	Only include farmers in acceptability trials; no connections with farmer groups.				
Honduras	DICTA	NO	Lack of time and staff				
Honduras	Zamorano	YES		YES	YES	15	15
Nicaragua	INTA	YES		NO	YES	40	40

Sources: DGP CRSP Key Informant Interviews (2010a).
[1] All programs except Zamorano's are government programs.
[2] PB = Participatory Breeding; PPB = Participatory Plant Breeding; PVS = Participatory Varietal Selection.

The bean programs had between two and four sources of funding. As expected, the program with the most funding was Zamorano's, followed far behind by INIAP's and CENTA's. In contrast, DICTA's bean program had the least funds available for bean research (Table 3). Furthermore, while INTA-CR's[5] three sources of funding have all increased over time, all of DICTA's funding sources have decreased over time. Clearly, the financial stability of Zamorano's bean program has allowed it to provide the necessary germplasm for the region's bean programs (i.e. regional nurseries) and to assist them in other research areas.

On average, each bean program was collaborating with six institutions in research-related activities. The main factors that have positively affected this collaboration include: (1) common research interests; (2) a constant flow of funding; (3) the availability of good personal and professional relationships; (4) the availability of good materials (i.e. varieties); and (5) the availability of trained human resources and access to experts' technical assistance (e.g. INIAP-MSU relationship). However, several factors threat future collaboration, including: (1) institutional instability regarding the continuity of staff and the focus of the research; (2) a lack (discontinuity) of funding; (3) a high dependence on Zamorano for germplasm; and (4) donors' lack of interest in the region overall (Central American case).

[5] The cost data presented only reflects INTA-CR's budget. It excludes the budget of the University of Costa Rica and other members of the PITTA-Frijol network. Thus, these budget data greatly underestimates Costa Rica's investment in bean research.

Table 3. Bean programs' funding in 2010.

Country	Program Name[1]	Total # of sources of funding	Total USD funds available in 2010	% of sources of funding that have: Decreased	Remained constant	Increased / New funds	Total USD includes salaries?
Costa Rica	INTA-CR	3	23,000	0	0	100	NO
Ecuador	INIAP	3	72,000	33	33	33	NO
El Salvador	CENTA	3	52,200	33	33	33	NO
Guatemala	ICTA	4	39,658	0	25	75	YES [2]
Honduras	DICTA	2	5,992	100	0	0	NO
Honduras	Zamorano	3	215,339	0	33	67	YES [3]
Nicaragua	INTA	4	35,500	25	75	0	NO

Sources: DGP CRSP Key Informant Interviews (2010a).

[1] All programs except Zamorano's are government-sponsored programs.

[2] Only includes the salary of one of the researchers, excludes all other salaries.

[3] Excludes salary of breeder, but salaries of all other staff are included.

In 2010, there were a total of 124 people (76% permanent and 24% temporary) working on bean-related activities in these programs--approximately 90% were male and on average, these staff devoted 72% of their time to bean-related activities. The programs with the highest percent of (total) female staff were Zamorano's (25% female) and INIAP's (19% female). In contrast, none of CENTA's or DICTA's staff was female. In 2010, INTA had the highest number of permanent staff (total and bean time-equivalents) and DICTA had the lowest number of permanent staff working on bean research (Figure 5). Furthermore, among all staff working on bean research, almost 54% had earned a bachelor's degree, which proves that the quality of the human resources in these programs is high.

While job stability and collaboration with other institutions have strengthened the bean programs, the size of the staff and small budget were the major weaknesses of these programs. Furthermore, the major threats to the programs' success included the difficulty of renewing personnel (especially program leaders who will soon retire) and the possibility that collaboration with other institutions could be interrupted.

Although 99 IVs were released in the six countries between 1990-2010, several varieties were released in more than one country. Thus, 85 unique bean IVs were released during the period, most of which were small red (N=46), followed by black (N=13), and red mottled (N=10) varieties. Furthermore, 53% of the 85 IVs were developed using direct or indirect CRSP funding. While Ecuador was the country with most IVs released (N=26) during the period, El Salvador (N=9) and Guatemala (N=9) released the fewest IVs. While El Salvador has released half of its IVs after 2000, Guatemala has not released any new IV since 1998 because the government cut its support to the bean program in 2002.

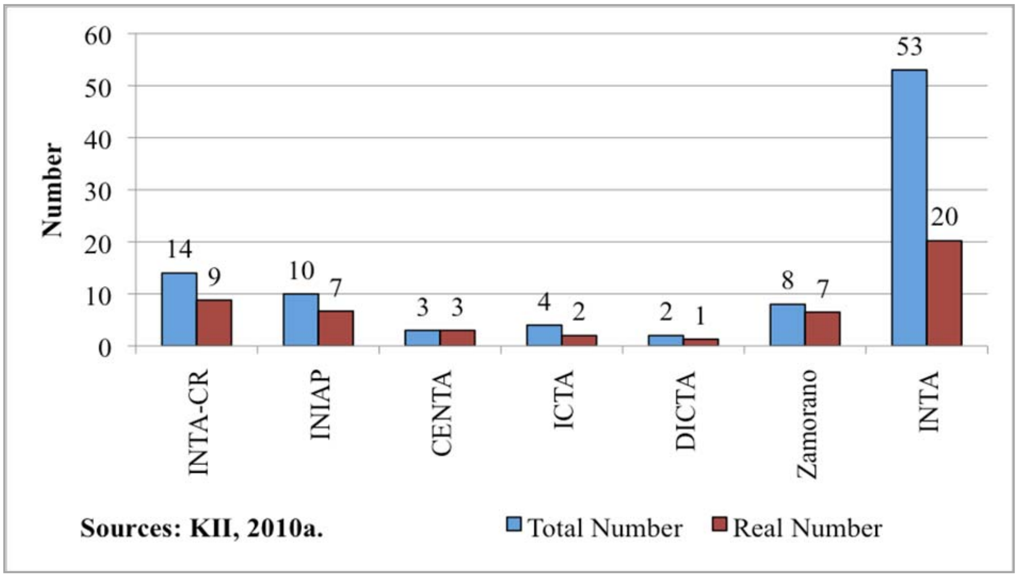


Fig. 1b

Fig. 1a

While farmers could access certified seed in most countries, in Ecuador and El Salvador, alternative seed types exist because the cost and requirements needed to certify seed make it impractical to produce certified seed. Since purchasing seed is expensive (regardless of the type), alternative ways of making high-quality, low-cost seed available to farmers are necessary. In Costa Rica and Nicaragua, the bean programs are already promoting the production of alternative (low cost) types of seed.

In four of the six countries, the governments have implemented free or subsidized seed-distribution programs, which have greatly contributed to increasing the adoption rates. However, some of these programs are distributing low-quality (see Figure 6) seed and have transparency problems. Thus, there is a need to invest resources in guaranteeing the quality of the seed that is distributed through these programs. Furthermore, the existence of these programs (which are unsustainable in the long term) may discourage farmers from purchasing seed and has created artificial seed markets (i.e. bubble markets). Moreover, farmers who produce seed for these (government) programs complained that it take months for them to get paid after they deliver the seed to these programs.

Bean experts (key informants) estimated that in the 09/10 AY, on average, 54% of the bean area was planted to IVs. In contrast, seed production data suggest that, on average, only 19% of the bean area was planted to IVs. Furthermore, both the expert's estimations and seed data suggest that Guatemala had the lowest adoption rates. In contrast, while expert estimates suggest that Nicaragua had the highest adoption rate (80%), seed data suggest that Honduras has the highest adoption rate (37%). It is suspected that expert's estimates of the adoption rates in Nicaragua are overestimated. Seed production data suggest that *Amadeus 77* was the most widely-planted IV in the region--approximately 52,520 ha or 6.8% of the total bean area in the Central American countries[6] was planted to this IV in 2010.

Bean experts estimated that the most important biotic stresses affecting the bean crop were Web Blight (WB), Angular Leaf Spot (ALS), Bean Golden Yellow Mosaic Virus (BGYMV), and Common Bacterial Blight (CBB). Among these, the former two stresses are important in all countries and the latter two are important in four of the six countries. While BGYMV was not a problem in Costa Rica and Ecuador, CBB was not a problem in Costa Rica and Nicaragua. For Web Blight, bean researchers estimated that in a typical year, on average,[7] farmers could lose 77% of their production if they planted susceptible varieties vs. only 40% if they planted resistant IVs, representing a 37% production loss averted by planting resistant IVs. For ALS, on average,[8] farmers could lose 33% of their production if they planted susceptible varieties vs. only 23% if they planted resistant IVs.

Similarly, on average,[9] farmers could lose up to 78% of production to BGYMV if they planted susceptible varieties vs. zero percent if they planted IVs. Finally, on average,[10] farmers could lose up to 29% of their production to CBB if they planted susceptible varieties vs. 21% if they planted resistant IVs, representing an eight percent production loss averted planting resistant IVs (Table 3). However, bean experts reported that, during the last ten years, there have been no major outbreaks of these stresses.

Although there were no abiotic stresses common to all countries, key informants reported that intra-season drought was the most important factor affecting the bean crop in three of the six countries (i.e., Ecuador, Guatemala and Nicaragua). In contrast to biotic stresses, outbreaks of abiotic stresses are more common. For example, intra-season drought was a serious problem, on average, in one of the last ten years. Bean researchers estimated that in a typical year, on

[6] Sum of area planted in Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua.
[7] Average excludes Costa Rica because the bean breeder couldn't estimate the share that could be lost to Web Blight if farmers planted susceptible varieties (thus, N=5).
[8] Average includes all countries (i.e. N=6).
[9] Average excludes Nicaragua because the bean breeder couldn't estimate the share that could be lost to BGYMV if farmers planted susceptible varieties (thus, N=3).
[10] Average includes all countries where CBB is important (N=4).

average,[11] farmers could lose up to 64% of their production due to intra-season droughts if they planted susceptible varieties vs. only 17% if they planted resistant IVs, representing a 47% production loss averted by planting resistant IVs (Table 4). Although there were outbreaks of drought during the last ten years, breeders could not estimate the share of production lost to this stress in these special cases. Thus, one can only assume that, during years with severe inter-seasonal drought, production losses are greater than during a typical drought year.

Table 4. Production lost (%) to the most important biotic and abiotic stresses when planting susceptible vs. resistant varieties. 2010.

Most important stress [1]	Average production lost (%) with […] varieties		Production loss averted (%) when planting IVs [2]
	Susceptible	Resistant	
Biotic:			
Web Blight	77	40	37
ALS	33	23	10
BGYMV	78	0	78
CBB	29	21	8
Abiotic:			

Currently, experimental data is being analyzed to estimate yield gains associated with IVs released since 1999. Furthermore, adoption curves are being estimated for the most widely-adopted IVs in each country. Using the above information, within the next month, the graduate student in charge of this study will be able to estimate the economic impact of bean research in these countries.

[11] Average includes all countries where intra-season droughts are a problem (i.e. N=3).

Intra-season Droughts	64	17	47

Sources: DGP CRSP Key Informant Interviews (2010a).

[1] ALS = Angular Leaf Spot; BGYMV = Bean Golden Yellow Mosaic Virus; CBB = Common Bacterial Blight.

[2] Difference in production loss by planting susceptible vs. resistant varieties.

2b. Global Contribution of CRSP to Genetic Improvement of Common Bean (Including the U.S., LAC and SSA)

The CRSP varietal database described under objective 1a was assembled to make an inventory of varietal outputs in major bean producing countries around the world. This database includes 525 varieties (some may be multiple releases of the same genetic material in different countries) identified from literature review and personal contacts with bean breeders from the CRSP community and CIAT. The database includes the name of the variety, country of release, year of release, releasing institution, parental line, characteristics, and other observations/notes. Unfortunately, we could not collect information on all the variables for all the 525 varieties. For the CRSP funded varieties, the information is more complete than the non-CRSP varieties. Also, for varieties releases in LAC and North America, the data is more complete than for varieties released in SSA.

Due to early and pre-matured departure of the graduate student from MSU who was going to lead this study as a thesis research, this study has not progressed as planned. We plan to use the data and information gathered thus far to do a descriptive analysis of the database and use the information as an input in the meta-analysis study planned in FY 12.

2c. Benefits of Genetic Improvement of Cowpea in Senegal and West Africa.

Study in Senegal: Two main activities were commissioned during the reporting period:

1. A field survey 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. This survey was implemented by the Directorate of Analysis, Forecasting, and Statistics (DAPS) of the Ministry of Agriculture.
2. Collection of information on improved cowpea seed production and dissemination system, the costs of seed distribution activities, and 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. This phase of the study was carried out by Ms. Josiane Diatta, a master's student attached to the ISRA research station at Bambey

Both of the above activities were focused on the three principal regions and departments in which CRSP-produced cowpea varieties have been disseminated. These regions are Diourbel, Louga, and Thiès. The sample for survey consisted of two groups: (1) farmers interviewed during the 2010 nationwide DAPS survey who indicated that they used "improved seed" for cowpea (781); and (2) an additional sample of 584 households drawn randomly from the same survey enumeration areas, sufficient to give a total of 7 households per local enumeration area. These households were interviewed in March/April 2011. Of the total intended sample of 1,365 households, 72 were not covered, giving an actual total sample of 1,293 households. Questions asked of both sets of farmers included:

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.

Delays in survey implementation and data entry resulted in delivery of the final data set in early August, rather than June as planned. Subsequent review of the data files revealed missing data. Issues involved are being compiled, and will be referred to DAPS staff in Senegal for assistance in further cleaning and recovery of missing data.

The second part of the study, carried out by Ms. Diatta, was implemented in May and June. The terms of reference for the draft report were:

<u>TOR 1: To gather information on the production and dissemination of improved cowpea seed, and the costs of these activities. Specifically:</u>

1. Description of the cowpea seed system in Senegal
2. For the three main CRSP varieties—Melakh, Mouride and Yacine—document the seed multiplication and distribution efforts in the past 5 years (or more if possible).
3. Interview each of the organizations identified in 2 to collect the following information:
   a. Their name, location, type of organization
   b. How long have they been involved in cowpea seed production/dissemination system
   c. Do they produce/distribute seeds of other crops (if so, list).
   d. What role did they play in the cowpea seed production and dissemination
   e. How much cowpea seed and what variety of cowpea seeds have they produced/disseminated in the past 5 years
   f. What type of cowpea seed was produced/multiplied –e.g., foundation, certified, quality declared, registered, etc.)
   g. How do they produce seed – for e.g., contract seed growers or other NGOs, produce on their own farms/fields, etc.
   h. To whom (i.e., geographic locations, farm communities) did they distribute the seeds?
   i. What method was used to distribute the seed (e.g., free distribution, sold to a private seed trader or sold directly to farmers, etc.)
   j. If seeds were sold, at what price were they sold?
   k. What are the organization’s costs of producing and disseminating cowpea seeds?

l. Name of other organizations/groups/companies producing cowpea seed in Senegal
m. Opinions:
   i. What factors have contributed most to farmer adoption of improved cowpea varieties?
   ii. Are there any weaknesses in the cowpea seed distribution system that limit making high-quality seed available to small farmers?
   iii. What could be done to increase farmer adoption of improved cowpea varieties?
   iv. What factors could contribute most to strengthening the cowpea seed production system in Senegal?

<u>TOR 2: To gather information on the advantages (in the form of enhanced yield, grain 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. Specifically:</u>

1. Information from reports on experiments conducted on research stations or in farmers' fields
2. General information on cowpea seed planting practices at farm level.

Computer and other difficulties experienced by Ms. Diatta resulted in a delay in report preparation. The draft report was received in mid-September. The draft report is relatively complete with respect to TOR 1, but contains little related to TOR 2. This will need further attention during the next few months.

2d. Review and Assessment of Bean/Cowpea And Pulse CRSP Investments in Value Addition and Food Science Research.

Over the past 20 years, the predecessor Bean/Cowpea CRSP has made substantial investments in food science research with the aim of developing new value added products to benefit both producers of beans and cowpeas in terms of more market opportunities and consumers in the form of convenient and nutritious food products based on beans and cowpeas. To a lesser extent investments in this line of research has also continued in the new Pulse CRSP. Despite long-term investments, this type of research has not generated the same level of outputs, outcomes and measurable development impacts as investments in crop improvement research. Thus, not surprisingly, there are hardly any studies that try to document impacts of food science research on value addition. The only study conducted on this topic in the CRSP program as confirmed by the impact assessment database mentioned under objective 1b was by Tomokazu Nagai a few years ago. The results of that study basically confirmed the lack of significant impact of research on value-addition in Ghana. The lack of evidence of impact of value addition research has repeatedly raised the question—what is the value of investments by a CRSP program on food science and nutrition research?

To address this question, this project undertook a review of past and current research conducted by the Bean/Cowpea and Pulse CRSP on value addition and food science, and documented all the outputs, outcomes and impacts from such investments. The review included CRSP reports of relevant projects/components in the past 10 years, literature search using keywords (for bean and cowpea based products and research outputs identified from the CRSP reports) and authors (i.e., PIs) associated with past and current CRSP projects on food science and nutrition research. A comprehensive list of all the CRSP research activities and outputs generated from investments in food science, food technology and human nutrition research since 1997 that fall in the four categories described in Table 5 was compiled by the project team. Principal investigators of relevant CRSP projects (i.e., led by UGA, Purdue, Texas A&M, and MSU) were contacted to enquire about the status and updates on the uptake or adoption of any outputs their research had generated in the past (esp., in categories 2 and 3--improved processing and storage technology and new bean or cowpea based food products/ingredients). However, this enquiry did not lead to any new or encouraging information on the commercial application of research outputs generated from CRSP research projects or evidence of their use/utilization by various actors in the value chain (i.e., processors, traders, consumers).

This investigation thus confirmed the lack of documented evidence of ‘adoption’, ‘uptake’ and utilization of outputs of food science research by participants in the bean and cowpea value chains in host countries (or even in the U.S.). It should be mentioned that the research in food science and human nutrition has generated many publications and scholarly outputs both in peer reviewed venues and in the form of theses and dissertations. This speaks of the high quality of scientific research underlying the CRSP supported projects. However, the question still remains as to what is the value addition of food science research in the Pulse CRSP portfolio? We have been informed that the TMAC is planning to develop a ‘white paper’ on the contribution of food science research. Based on the review of past efforts conducted by this team thus far and the anticipated white paper, as a next step, we will identify factors that were present / absent in the pathway of identified research outputs to better understand why past investments were not successful in generating impacts. The goal of this exercise will be to derive lessons for guiding future investments by the CRSP in this line of research.

Table 5: Major categories of food science and human nutrition related research conducted by the Bean/Cowpea CRSP and examples of research outputs generated

Categories	Examples of research outputs
1. Analysis of chemical, functional, and nutritional characteristics of processed bean/cowpea products	• Determine protein quality and protein digestibility-corrected amino acid score and the iron and zinc bioavailability of black bean-rice-based products processed by either microbial fermentation or germination • Determine the extent of decrease in oligosaccharide content of dry beans achieved with fermentation the beans, and the acceptability of bean-rice weaning food made with fermented • Development of a method for evaluation of cooking properties of cowpeas • Effect of hard-to-cook phenomenon on cooking and physicochemical characteristics of cowpeas
2. Improvements in the technology of bean/cowpea processing and storage	• Artisanal processing of cowpeas in Nigeria • Hydrothermal processing of dry (unsoaked) cowpeas • Hydrothermal treatment of whole seeds - its impact on storage stability and food quality • Effect of tempering/pre-conditioning in a solution of monovalent cations and micronization on cooking characteristics of hard-to-cook cowpeas
3. Development of processed bean/cowpea products	• Developing and evaluating consumer acceptability of cowpea-fortified gari and cowpea-fortified fermented corn flour • Creation and testing of weaning foods • Develop a bean-based food with a stable shelf-life to be eaten in a non-traditional way • Develop nutritious, highly acceptable bean-based granola bars and cereal • Developing extruded /expanded snack/ convenience foods • Low-cost, fortified supplementary foods from locally available ingredients • Modifying/adapting traditional cowpea-based foods • Nutritious convenience/snack foods
4. Consumer/producer and demand analysis of processed bean/cowpea products	• Assessment of consumer acceptance of bean ingredients and products • Assessment of potential demand for cowpea-based processed products in West Africa • Bean use patterns and preferences of farmers • Consumer acceptability of cowpea-fortified gari and cowpea-fortified fermented corn flour at the institutional level • Consumer acceptance, nutritional value and economic potential of bean based ingredients and products • Cowpea flour production and use in Benin

Objective 3: Investigate opportunities to integrate baseline data collection and impact evaluation strategies as part of the CRSP project design.

As described under the impact pathway analysis activity described in 1b, CRSP investments in "research for development" (R4D) fall across the wide spectrum of activities ranging from basic/fundamental research to applied/adaptive research to technology transfer. 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 this goal requires some forethought on the design of field activities and a strategy for collecting appropriate data or making use of available data. The purpose of such strategizing is to make sure that at the end of an intervention/activity, opportunity to assess the cause-effect relationship between a research project and indicators of outcomes/impact is not lost. This is the underlying goal of "impact evaluation" research in the context of development projects.

Towards implementing an integrated impact evaluation strategy as part of the CRSP project design, the lead PI of this project interacted with several PIs, especially those directly related to technology transfer interventions to explore opportunities and feasibility of conducting impact evaluation research. Four such opportunities for data collection and investigative research with the aim of addressing questions of what works, where, why and why not, were identified and included as part of the Workplan for FY 2012. The research underlying these four proposed activities will be conducted in close collaboration with the respective CRSP project PIs. These activities, to be jointly conducted to address the impact evaluation questions, include:

1. Baseline assessment of the economic effects of pest problems on cowpea growing areas in Burkina Faso (with PII-UIUC-1)
2. Impact evaluation to test the effectiveness and impacts of methods of extension to disseminate materials for IPM of cowpea pests (with PII-UIUC-1)
3. Benefit/Cost (B/C) analysis of the bean-based nutrition intervention in Tanzania (with PIII-MSU-3)
4. Case study of the bean seed multiplication and distribution system in Central America (with host country partners in Nicaragua participating in the CRSP Associate Award)

<u>Objective 4:</u> 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:

1. Field activities under objective 2 were conducted in collaboration with HC PIs and partners.
2. Activities under objectives 1 and 3 are conducted in close collaboration with the U.S. and HC PIs from existing CRSP projects.
3. The activities planned under this project involved four 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:
   a. Byron Reyes, a citizen of Ecuador
   b. Nelissa Jamora, a citizen of the Philippines
   c. Ben Megan, a citizen of USA
   d. David deYoung, a citizen of USA

Explanation for Changes

Objective 2b will not be achieved as planned because of the early departure of Nelissa Jamora from MSU to pursue her Ph.D. degree at another institution.

Networking and Linkages with Stakeholders
None to report in FY11

Leveraged Funds
$6000 -- Dissertation Completion Fellowship from the College of Agriculture and Natural Resources, MSU for Byron Reyes

Scholarly Activities and Accomplishments
Maredia, M.K. 2011. M&E and Impact Evaluation of Agricultural Research: Challenges and Best Practices. Presentation made at the USAID/USDA/APLU organized “Feed the Future” Planning Workshop, Purdue University, January 12-13, 2011.

In April 2011 Richard Bernsten (co-PI of this project) received *The Ralph H. Smuckler Award for Advancing International Studies and Programs at MSU***,** The award recognizes and rewards a faculty member each year for his/her significant and lasting impact on the advancement of international scholarship, teaching, and public service.

Reyes, Byron. 2011. “Economic Impact Evaluation of Improved Bean Varieties in Central America.” Presentation made at the Symposium “Diminishing Latin America’s Inequalities: Land, Food and Human Health Strategies” April 2011. This symposium was organized by the Center for Latin America and Caribbean Studies at MSU.

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

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Abstract of Research Achievements and Impacts
Evidence indicates that legumes may contain compounds that have health benefits against chronic diseases like cancer and cardiovascular disease. However, not much information is available on the type of compounds in cowpea and their bioactive properties. Based on our screening studies in Year 1, we conducted a detailed characterization on 10 diverse cowpea lines to determine phytochemical composition and properties using spectroscopy advanced UPLC-MS^n. We then tested select line for anti-inflammatory and oxidative stress reduction properties using non-malignant colonic myofibroblasts CCD-18Co cells. We also tested antiproliferative activity of select lines against human colon cancer cells *in vitro*. The major phenolic compounds in all cowpea varieties were flavonoids. Important phenotypic differences were observed; light brown (cream) lines generally contained mostly flavan-3-ols; red lines contained mostly flavonols (especially quercetin glycosides); black varieties contained mostly anthocyanin pigments; whereas the white varieties lacked flavan-3-ols, but had modest quantities of flavonols. Thirty eight new compounds were identified in cowpea, in addition to 18 previously reported. Light brown cowpea lines were most effective oxidative stress inhibitors, whereas the black and red lines were most effective against various anti-inflammatory markers. This indicates that the type of compounds accumulated in the seed have an impact on specific potential health benefits. Most samples tested were effective at low concentrations (2ug/mL) which suggests possible relevance to human consumption levels. Additional investigations on minimum effective dose and effect of cooking are underway. Our research was recognized by peers and received a highly competitive award at the American Association of Cereal Chemists International, as the best graduate research presentation and paper at the 2011 annual meeting. The data reported involved collaborative effort of the HC Institutions and Texas A&M, which indicates that the training and equipment availed to HC Institutions in Year 1 have been put to good use. A total of 24 HC personnel were also trained during the year.

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. For example, recent data indicate that obesity among urban Kenyan women is approaching 30% (Christensen et al., 2008), with similar trend in other African countries.

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*.

Results, Achievements and Outputs of Research

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

The goal was to determine genetic variability in cowpeas for the types and levels of key bioactive components as well as protein content and quality. Association between these traits and seed color and seed characteristics were determined.

Based on our previous data where we determined how phenotype (particularly seed coat color) influence phenol content of cowpea, we selected a set of lines that represent the broad spectrum of cowpea phenotypes for more focused investigation. Selected samples from Kenya, Zambia, South Africa, and USA, were analyzed for phenolic content to confirm previous findings. A select subset of 10 among these samples (Table 1) were used flavonoid profiling and bioactives screening as outlined in the following sections.

HPLC and Mass spectrometry analysis

Extract purification. The cowpea phenolics extracted with 70% acetone acidified with 1% formic acid were fractionated on a Sep-Pak Solid Phase Octadecylsilane (C18) cartridges into ethyl-acetate and methanol fractions following methods described by Prior *et al*. (Prior et al., 2001) and Monagas *et al*. (Monagas et al., 2003) with some modifications.

UPLC-ESI/MS Analysis. A Waters - ACQUITY UPLC/MS system (Waters Corp., Milford, MA) equipped with a binary solvent manager, sample manager, column heater, photodiode array eλ interfaced with a Mass Spectrometer, a tandem quadrupole (TQD) electrospray ionization (ESI) detector was used. Mass spectrometric data of the column eluant were acquired in positive mode for anthocyanins and negative mode for flavonol glycosides and flavan-3-ols. The spectra were monitored at 280 nm for phenolic acids and flavanols; at 360 nm for flavonols and isoflavonoids; and at 520 nm for anthocyanins. The mobile phases were 2% formic acid in H_2O (solvent A) and acetonitrile (solvent B) for anthocyanin analysis; and 0.05% formic acid in H_2O (solvent A) and acetonitrile (solvent B) for other phenolics. Data acquisition and processing were performed using *Empower 2* software. Optimization of ionization conditions was based on the intensity of the mass signals of protonated/deprotonated molecules and aglycones fragments, and was performed for each individual peak/compound detected.

Quantification of anthocyanins, flavan-3-ols and flavonols. Quantification was based on LC peak area, authentic standards were used to obtain standard curve. Where standards were not available, molar absorptivity for the compound was assumed to be equivalent to that of the aglycon or closest glycoside structure. The flavonoids were expressed as micrograms of flavonoid per gram of cowpea flour (μg/g) on a dry weight basis.

Determination of total phenols content (TPC) and condensed tannins content (CTC). The total phenols content (TPC) was determined by a Folin-Ciocalteu assay described by Kaluza *et al.* (Kaluza et al., 1980) using gallic acid (GA) as the standard and expressed as µg GAE/g on dry weight basis. The condensed tannin content (CTC) analysis was performed according to the method of Broadhurst and Jones (Broadhurst and Jones, 1978) with slight modification, and expressed as mg CAE/g on dry weight basis.

Protein content and quality. These tests were conducted on elite cultivars selected for crossing, and their selected progeny. To obtain relevant data from this procedure, samples will initially be cooked by boiling in water for 75 min, and then drying at 45 – 50 ^{o}C. Protein content was measured using the combustion method (AOAC Method 990.03). Complete amino acid profile was measured using the AOAC method 982.30, whereas available lysine was measured using the OAC Method 975.44. In vitro protein digestibility was determined by pepsin/pancreatin digestion method.

Results

Flavonoid composition of cowpea

The UPLC-MS system is a newly available separation and chemical characterization system that involves use of very high pressure and improved sensitivity not achievable in standard HPLC-MS system. The high pressure limit allows for use of very fine column packing (1.2 microns) which leads to better resolution (peak separation). The department of Soil & Crop Science at Texas A&M acquired this system in 2010, and it is located in Dr. Awika’s lab. This new tool has enabled us to provide detailed characterization of cowpea flavonoids in a way that was not previously achievable. Thus we identified a host of new compounds which will hopefully improve our understanding of how cowpea bioactives composition influences human health.

a) **Anthocyanins.** A total of 8 anthocyanin compounds were detected in cowpea. Anthocyanins were only detected in black IT95K-1105-5 (2095 μg/g), black IT98K-1092-1 (1,676 μg/g) and green TX2028-1-3-1 (876 μg/g) cowpea varieties. The levels of individual anthocyanins were in the following order: delphinidin-3-*O*-glucoside, cyanidin-3-*O*-glucoside, petunidin-3-*O*-glucoside, malvidin-3-*O*-glucoside, delphinidin-3-*O*-galactoside, cyanidin-3-*O*-galactoside, peonidin-3-*O*-glucoside and finally petunidin-3-*O*-galactoside. Literature (Ha et al., 2010) reports indicated that cyanidin-3-*O*-glucoside, delphinidin-3-*O*-glucoside, petunidin-3-*O*-glucoside, and malvidin-3-*O*-glucoside were the major anthocyanins in black seeded cowpeas. From this study, petunidin-3-*O*-galactoside was found for the first time in the black and green cowpeas.

b) **Flavonols.** The majority of flavonol compounds identified in cowpea were quercetin glycosides (**Table 2**). Myricetin glycosides were only found in black (IT95K-1105-1 and IT98K-1092-1), red (IT82D-889 and IT97K-1042-3) and green TX2028-1-3-1 varieties; while kaempferol glucoside was only detected in the black (IT95K-1105-1 and IT98K-1092-1), golden brown (Ife Brown and IT84S-2246), light brown IAR-48 and white Early Acre varieties. Total flavonol content was lowest in light brown 09FCV-CC27M (168 μg/g) and higher in the red IT97K-1042-3 variety (1063 μg/g) (Tables 3&4). In general it is apparent that the red cowpea phenotypes accumulate the highest levels of flavonols, whereas the green and white varieties accumulate the lowest. Another interesting observation was that among the light brown varieties, accumulation of flavonols was inversely proportional to accumulation of flavan-3-ols (see part (c) below). The light brown variety (09FCV-CC27M) that accumulated exceptionally high levels of flavan-3-ols also had the lowest level of flavanols.

c) **Flavan-3-ols.** The flavan-3-ol compounds identified in cowpea were mainly catechin/epicatechin, catechin-3-*O*-glucoside, procyanidin dimer B-type, procyanidin dimer-3,7-diglucoside, procyanidin trimer C1, procyanidin trimer T2 and procyanidin tetramer A-type. Four of the isolated flavan-3-ols are still unidentified. Among all the cowpea varieties, the light brown 09FCV-CC27M had the highest flavan-3-ols (9001 μg/g), followed by golden brown Ife Brown (3347 μg/g) and red IT97K-1092-1 (3340 μg/g). The light brown 09FCV-CC27M had especially high levels of oligomeric flavan-3-ols (dimers to tetramers) that were present in the other samples at low levels **(**Tables 2- 3). Moderate levels of flavan-3-ols were found in the black IT95K-1105-5 (3090 μg/g) and light brown IAR-48 (3078 μg/g) cowpea varieties. The golden brown IT84S-2246 variety contained the least amount of total flavan-3-ols (1610 μg/g). There were no flavan-3-ols detected in the green TX2028-1-3-1 and white Early Acre cowpea varieties. Among the flavan-3-ol compounds, catechin-3-*O*-glucoside was the most dominant compound detected.

d) **Other flavonoids.** Examples of major flavonoid aglycones identified in cowpea included flavononols (e.g. taxifolin-glycosides), flavanone (e.g. eriodictyol glycosides), dihydrochalcone (e.g. phloretin 2′-glucoside) and phenolic acids (e.g. feruloylaldaric acid derivatives).

e) **Total flavonoid content.** Among all the samples, the light brown 09FCV-CC27M had the highest total flavonoid content (9169 μg/g) contributed by higher levels of flavan-3-ols in this variety; followed by the black IT95K-1105-5 (5862 μg/g) which contained mostly anthocyanins. The white and green variety had the least flavonoid content.

Gross phenol and condensed tannins content

The light brown 09FCV-CC27M variety had the highest TPC and CTC values (14.9 mg GAE/g and 12.6 mg CAE/g, respectively); while the white Early Acre and green TX2028-1-3-1 varieties had significantly ($p < 0.05$) lower TPC and CTC values (2.6 mg GAE/g and 0.3 mg CAE/g, respectively) compared to the other varieties. The differences in TPC and CTC values between varieties from the same phenotype suggest the observed differences in phenolic profiles subsequently affect their total phenolic compositions. In general, the TPC and CTC values for the cowpea varieties analyzed had the following trend: light brown > black > red > golden brown > green > white, suggesting cowpea phenolic composition may be highly influenced by seed coat color.

Summary

We were able to structurally characterize previously unidentified compounds in cowpea using the new sensitive UPLC-TQD MS system. From the results, it is apparent that seed coat color has a major influence on the type of phenolic compounds accumulated by cowpea. Even though most lines investigated had a mix of most of the compounds identified, important patterns were observed. For example, anthocyanins were exclusively found in black and green varieties,

whereas the white and green varieties had no flavan-3-ols. The dominant flavonoids in major cowpea phenotypes can be summarized as follows:

Light brown – **flavan-3-ols** (catechin and condensed tannin family)
Red – **flavonols** (quercetin family)
Black – **anthocyanins** (pigment family)
White – **flavonols** (with no flavan-3-ols)

These compositional variations will allow for studying specific biochemical pathways influenced by cowpea polyphenols, which will eventually lead to selection of cowpea for desired health attributes.

Darker-colored grains have been shown to contain higher levels of phenolic compounds than lighter-colored grains (Chang et al., 1994). However, from our observation, the association of dark-colors in cowpea with higher phenolic content may be misleading since the light brown 09FCV-CC27M cowpea variety is not dark-colored yet it contained the highest concentrations of total phenolics (mainly composed of flavan-3-ols) compared to the black seed coated varieties. *We are currently investigating effect of thermal treatment on the structure and levels of the compounds identified. This will allow for extrapolating effect of traditional cooking on cowpea phenolics and lead to designing strategies to optimize their levels in processed products.*

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

Approaches and Methods

The aim is to establish how the phytochemical profiles affect the ability of cowpeas to influence metabolic, cardiovascular and chemoprotective health predictors *in vitro*. The select samples were screened for predictors of bioactivity using the following methods:

Determination of Antioxidant Capacity

The scavenging activity of 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) radical cation (ABTS$^{\bullet}$+) was determined according to the method described by Re *et al.* (Re et al., 1999) with slight modifications. Oxygen Radical Absorbing Capacity (ORAC) assay was performed using a Biotek Synergy HT plate reader with automatic dispenser (Biotek, Winooski, VT) according to the method described by Talcott and Lee (Talcott and Lee, 2002) with slight modifications.
Glycemic properties. Procedures described by Goni et al (1997) were used to measure rate of *in vitro* starch hydrolysis in selected cowpea lines. Hydrolysis index and estimated glycemic index were calculated from area under curve (30 min intervals to 180 min digestion) as detailed by the authors, using fresh white bread as a control.

Cell culture studies

Cell Lines. Non-cancer colon CCD18Co cells purchased from the American Type Culture Collection (Manassas, VA) was cultured using high glucose Dulbecco's Modified Eagle Medium. The cells were incubated at 37°C in a humidified 5% CO_2 atmosphere. For cell culture assays, freeze-dried cooked cowpea extracts were re-dissolved in DMSO, and then diluted to known concentrations of total soluble polyphenolics ranging from 0 – 20 mg GAE/L.

Oxidative stress studies

Generation of Reactive Oxygen Species (ROS). The production of ROS was performed following methods described by Meng *et al*. (Meng et al., 2008), but with some modifications. A FLUOstar Omega plate reader (BMG Labtech Inc., Durhan, NC) was used to monitor the fluorescence signal at 520 nm emission and 480 nm excitation. Relative fluorescence units (RFU) were normalized to control cells not treated with cowpea extracts.

Anti-inflammatory studies

RNA extraction and Real-time PCR analysis of mRNAs. Cells seeded (8×10^5 onto a 12-well plate) and incubated for 24 hrs to allow cell attachment, were pre-treated with varying concentrations of crude cowpea polyphenolic and stimulated with a lipopolysaccharide, LPS (2 μg/mL) before lyses, followed by mRNA extraction and analysis. Total RNA was isolated according to the manufacturer's recommended protocol using the RNeasy Mini kit (Qiagen, Valencia, CA) for mRNA analysis. Samples were evaluated for nucleic acid quality and quantity using the NanoDrop® ND-1000. Isolated RNA was used to synthesize cDNA using a Reverse Transcription Kit (Invitrogen Corp., Grand Island, NY) according to the manufacturer's protocol. PCR-RT was carried out with the SYBR Green PCR Master Mix on an ABI-Prism 7900 Sequence Detection System (Applied Biosystems Inc, Foster City, CA). Inflammatory biomarkers used were IL-8, TNF-α, VCAM-1 and NF-κB. Three independent cell culture replicates were analyzed for gene expression (n=3).

Anti-cancer effects

Phase II detoxifying enzyme assay. This method is based on the fact that enhanced activity of enzymes that detoxify potential carcinogens will lead to prevention of cancer initiation. We will employ the NAD(P)H:quinone oxidoreductase (NQO) inducer activity as previously described (Yang *et al.* 2009). Murine hepatoma (Hepa 1c1c7) cells were incubated with various concentrations of cowpea extracts and NQO enzyme activity as well as cytotoxicity measured as described by Prochaska, et al. (1992). Sulforaphane were used as a positive control; this compound is a potent natural phase II enzyme inducer.

Anti-proliferation assays. These methods will measure how the various cowpea extracts affect growth of pre-formed cancer cells. We will use the widely studied HT-29 and Caco-2 human colon carcinoma cells for this assay following the viable cell (MTT) and DNA (PicoGreen) procedures as recently modified (Awika et al. 2009). Various concentrations of the cowpea extracts were incubated with the cells for 48 hr after which the MTT assay kit (Sigma, St Louis, MO) were used to measure viable cell population by established protocols. Double stranded DNA were measured using the PicoGreen Quant-iT assay kit (Invitrogen Inc, Carlsbad, CA) as described by Ahn et al (1996). Genistein were used a positive control in both assays. *Apoptosis* were assessed by analyzing in cells by analyzing PARP-cleavage as previously described (Chintharlapalli et al., 2009).

Results

a) **Antioxidant capacity.** The raw light brown 09FCV-CC-27M variety had significantly ($p < 0.05$) higher ORAC and ABTS values than the other varieties; while the black, red and golden brown varieties had intermediate levels of ORAC and ABTS values (Fig. 6). The green TX2028-1-3-1 and white Early Acre cowpea varieties had the lowest antioxidant activity (Fig. 1), which correlated with lower TPC and CTC values reported in these varieties. This suggests that different phytochemical profiles might have different degrees of contribution to the overall antioxidant activity. These results indicate that in addition to their traditional role of preventing protein malnutrition, intake of cowpea may have greater potential in managing and/or preventing degenerative diseases associated with oxidative damage. This information could increase public recognition of the health benefits of consuming specific phenotypes, which could increase the demand for food uses of cowpea and other legume seeds.

b) Boiling generally had modest effect on ORAC and ABTS values; however, the degree of reduction in antioxidant capacity values depended on individual cowpea variety. Boiling process that preserves the health benefits associated with the compounds identified in raw cowpeas is therefore recommended.

c) **Protective effects against Reactive Oxygen Species (ROS).** Oxidative damage by ROS is crucial in the initiation of cancer; therefore, the potential of cowpea extracts in protecting colon cells against ROS was investigated. At the lowest concentration (2 mg GAE/L), the flavonol-rich red IT97K-1042-3 and anthocyanin-rich black IT95K-1105-5 had the highest inhibitory effect on ROS (37.2 – 39.8% reduction), followed by the light brown 09FCV-CC27M (28.4% reduction) compared to the LPS-stimulated cells in the absence of extracts (Fig. 2). At highest concentration tested (20 mg GAE/L), the black IT95K-1105-5 had the highest effect on ROS inhibition (55.7%), followed by red IT97K-1042-3 (46.6%) and light brown 09FCV-CC27M (35.0%) compared to the LPS-stimulated cells in the absence of extracts (Fig. 2). Thus, the differences in structural features of the flavonoid present in these cowpea varieties have a significant effect in their capacity to abrogate the generation of ROS. In general, the protection against ROS production was achieved in a dose-dependent manner. Cancer cells proliferation and tumor progression increase with increase in ROS generation (Paul T, 2006). Therefore, inhibition of ROS generation may contribute to slowing down tumor progression. A similar study showed that flavonols, especially quercetin and kaempferol, had favorable inhibition of TNF-α-induced ROS generation in non-cancer human embryonic kidney HEK 293 cells (Soohyoung et al., 2009).

d) **Anti-inflammatory properties**. In general, cowpea has good anti-inflammatory properties even at low concentrations of 2 ug/mL; thus may lower risk of chronic inflammatory conditions. Reduction of mRNA expression of inflammatory biomarkers was dose-dependent. Varieties containing higher levels of flavan-3-ols showed the least reduction in VCAM-1 and NF-κB gene expression compared to varieties containing higher levels of anthocyanins and flavonols, suggesting cowpea phenolic composition may influence specific anti-inflammatory pathways. *Additional pathways are under investigation*.

e) **Antiproliferation.** Two samples from Africa, Agrinawa (red) and Blackeye were used for this investigation. In general, a dose response was observed for cancer cell growth inhibition by both extracts, indicating the compounds in these cowpea varieties may contribute anticarcinogenic properties. Cooking samples modestly reduced the potency of the extracts against cancer cell inhibition, which may be related to reduction in polyphenol content previously reported. The red cowpea sample had lower IC_{50} (was more potent) against cancer cell inhibition (Table 4). Effect of simulated enzyme digestion on bioactivity of these samples is currently under investigation.

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

Approaches and Methods

This objective will help determine the mode of inheritance and the extent of genetic associations of key bioactive traits in cowpea. This will open opportunities for genetic selection and improvement efforts as well as using modern molecular techniques to develop specific specialty cowpea lines for targeted health benefits.

The parents used in the greenhouse crosses were: Early acre, 889, 2028, 1042-3, 205-8 and GEC.

Each cross involves a parent with one low and one high antioxidant activity. The crosses that were made are

- Early Acre (low antioxidant) x 889 (high antioxidant)
- 2028 (low antioxidant) x 1042-3 (high antioxidant)
- 205-8 (low antioxidant) x 1042-3 (high antioxidant)
- GEC (low antioxidant) x 1042-3 (high antioxidant)

All the F2 seeds were planted in greenhouse with a set of parents and F1 hybrids in the month of Spring 2011 in greenhouse situated in the Institute for Plant Genomics and Biotechnology, Texas A&M University. Initial greenhouse crosses to obtain F1 hybrids were conducted in early Fall 2010 (Oct –Nov). Hybridization to obtain F1 seeds were done meticulously by emasculating the anthers of the female parent and dusting the desired pollen collected from the flower of the male plant. The dusted flower was secured with a tape and tagged. Higher night temperatures are not conducive to flowering and seed set, hence cooler months of the year were chosen for such experiments. Crossing experiments were done in the mornings before 10 am, after these the pollen become sticky and the crosses are known to show low success.

These traits that were recorded include the seed coat pattern: speckled/dotted, patched and solid colored seed coat. Seed size was also considered in addition. Seed size was recorded using the length of seed using a vernier calipers. A size scale of < 5 mm for small, 5mm-8mm for medium and >8 for large seeds was used to group seeds into three size groups.

Results

Results indicate that all seeds of F1 hybrids the eye color restrict the seed coat color of either parents in seeds of F1 hybrid and the seeds take the color of the eye of the parent. However, all the seed coat colors existing in the parents, segregate in the F2 generation (F3 seeds) obtained by selfing F1 hybrid. In every cross the seed coat color segregates into patterned seeds and solid color seeds.

In general, preliminary investigation reveals that seed coat color and texture (rough vs smooth) are reliable indicators of antioxidant activity, thus heritability of these seed coat traits explains most of variability in antioxidant. This was observed in both African and TAMU crosses. We are currently studying phenolic profiles of selected progeny to determine if accumulation of major compounds changes.

However, among light brown varieties, flavonoid composition and antioxidant activity vary significantly – hence there is a need investigate the pathways involved in flavonoid accumulation in these varieties and the genetics involved. We have observed that light brown lines that accumulate very high levels flavan-3-ols have very low flavonol content and vice versa.

<u>Objective 4:</u> Institutional capacity building

<u>Degree Training</u>

<u>PhD Student 1</u>
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

<u>PhD Student 2</u>
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: December 2011
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

PhD Student 4
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: December 2012
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

MS Student 1
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: December 2011

Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

Short Term Training

Short term training in Zambia did not occur due to change in personnel midyear. The training is scheduled for May 2012.

Type of Training: Short term workshop and hands on laboratory training
Description of Training Activity: Workshop explaining preliminary findings and what they mean to cowpea promotion strategy; hands on laboratory training on methods of phytochemical analysis.

Status of this Activity as of September 30, 2011: completed
When did the Short Term Training Activity occur? May 24 – 27, 2011
Location of Short Term Training: Nairobi & Egerton, Njoro, Kenya
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Government officials, NGO representatives, academic and extension staff of Egerton and KARI

Number of Beneficiaries by Gender: Male- 11
Female- 13
Total- 24

Explanation for Changes

Short term training (through workshop) of HC personnel and stakeholders that was scheduled to take place in Zambia did not occur this year due to change in PI that occurred. This was unexpected and we needed some time for the new PI took understand the project status and effectively move forward. We have rescheduled the training for May 2012. The New PI (Dr John Shindano) is on track and we believe the delays will have a minor impact on project completion.

Networking and Linkages with Stakeholders

During the year, we (Joseph Awika and Susanne Talcott from TAMU, and Abdul Faraj from Egerton) visited the USAID mission in Nairobi and had a fruitful discussion with the USAID country director for Agriculture, Business and Envirnment, Mr. Mervyn Farroe. Also in attendance were Dr. Peter Ewell, Regioanal Agricultural Advisor, Ms. Brooke Patterson, Private Sector Specialist, Mr. Kaarli Sundsmo, Regional Food Security Coordinator, and Mr. Samson Okumu, Food Aid Specialist. The discussions concentrated around how to leverage our project to contribute to on-going USAID country endeavors, as well as the Feed the Future program. The CRSP project was well received, especially for its potential to contribute to economic and nutrition security in semi arid regions of Kenya (classified as SR2 by USAID).

We also had meetings with various Government of Kenya officials, including Ms. Veronica Kirogo, head of nutrition programs under the Ministry of Agriculture. She emphasized *that sound scientific evidence was essential to effectively influence government policy*. She said cowpea had a big potential as a complement and substitute for beans which are always in short supply in the country.

Leveraged Funds

Name of PI receiving leveraged funds: Joseph Awika
Brief description of leveraged project and purpose: Currently three graduate students are working with the PI on cowpea projects that directly contribute to the CRSP project goal. Two of the students are funded through departmental funds and a fellowship. The future potential of cowpea as a crop for climate change and nutrition improvement is particularly interesting and Texas A&M has commited significant resources to lay the research foundation. Additionally, Dr. BB Singh (who was invited to Texas A&M to specifically work on cowpea) is paid by the department to work on this project and related cowpea projects at no cost to the project.

Dollar Amount: $125,000
Funding Source: Texas AgriLife Research, CoNACYT, McKnight Foundation

Scholarly Activities and Accomplishments

Awards

1. Leonnard Ojwang, PhD candidate, Texas A&M University. Best graduate research award. Presented at; American Association of Cereal Chemists International annual meeting, Palm Springs, CA, October 15 – 18. Title of presentation: **Anti-inflammatory properties of cowpea phenotypes with different phenolic profiles.**

Published abstracts

Archana Gawde, B. B. Singh, J. Ehlers**, J. M. Awika**. 2011. Associating *Vigna unguiculata* phenotypes with composition of bioactive compounds. *CFW*, 56, A41-A42.

Leonnard O. Ojwang and **Joseph M Awika**. 2011. Anti-inflammatory properties of cowpea phenotypes with different phenolic profiles*. CFW*, 56, A3-A4.

Joseph Awika, Archana Gawde, Leonnard Ojwang , B. B. Singh. **Potential of Cowpea as a Health Promoting Food to Prevent Chronic Disease. Presented at the 2011 US National Cowpea Improvement Association Meeting February 6, 2011, Corpus Christi, Texas.**

Archana Gawde, B. B. Singh, Jeff Ehlers and Joseph Awika. Seed phenotypes show high correlation with nutritional compounds in *Vigna unguiculata.* At the 2011 US National Cowpea Improvement Association Meeting February 6, 2011, Corpus Christi, Texas.

B.B. Singh. Cowpea as a Major Food Legume in the 21st Century. Presented at the 2011 US National Cowpea Improvement Association Meeting February 6, 2011, Corpus Christi, Texas.

Tables and Figures

Table 1: Description of cultivars selected for flavonoid fingerprinting

Variety	Seed coat property
IT95K-1105-5	Black, smooth, white-eyes
IT98K-1092-1	Black, smooth, white-eyes
IT82D-889	Red, smooth, white eyes
IT97K-1042-3	Red, smooth, white eyes
TX2028-1-3-1	Green, freckled, black-eyes
IAR-48	Light brown, rough, white eyes
09FCV-CC-27M	Light brown, smooth, white eyes
IFE BROWN	Golden brown, rough, white eyes
IT84S-2246	Golden brown, smooth, white eyes
EARLY ACRE	White, freckled, brown eyes

Table 2: Compositions (μg/g of cowpea flour) flavonols and flavan-3-ols in light brown cowpea varieties

Compound	IAR-48	09FCV-CC-27M
Quercetin-3-*O*-glucoside-7-*O*-diglucoside	27.5 ± 1.74	23.7 ± 2.90
Quercetin-3-*O*-arabinoside-7-*O*-diglucoside	75.4 ± 4.88	ND
Quercetin-3,7-diglucoside	314 ± 3.15	21.4 ± 2.83
Quercetin-3-*O*-malonyldeoxyglucoside	212 ± 5.03	24.7 ± 4.37
Quercetin-3-*O*-galactoside	17.7 ± 1.91	ND
Quercetin-3-*O*-glucoside	6.79 ± 0.32	ND
Quercetin-3-*O*-diglucoside	ND	16.1 ± 2.77
Quercetin-3-*O*-arabinosylglucoside	ND	23.9 ± 3.06
Quercetin-3-(6″-feruloyl)-diglucoside	20.03 ± 0.32	ND
Quercetin-3-(6″-diacetoyl)-diglucoside	21.48 ± 1.57	ND
Quercetin-3-*O*-glucosylrhamnoside	ND	23.2 ± 3.38
Quercetin-3-*O*-galactosylrhamnoside	ND	34.7 ± 4.73
Subtotal quercetin	**695 ± 18.9**	**167 ± 24.4**
Catechin-3-*O*-glucoside	1977 ± 11	2023 ± 2.7
Procyanidin dimer B-type	676 ± 6.2	2657 ± 9.5
Catechin/epicatechin	70.3 ± 1.7	1090 ± 9.9
Procyanidin trimer T2	110 ± 6.0	1597 ± 9.5
Procyanidin trimer C1	163 ± 7.3	1633 ± 4.7
Procyanidin tetramer A-type	82.4 ± 6.7	ND
Total Flavan-3-ols	**3078 ± 61**	**9001 ± 36**

Data are expressed as mean ± standard deviation (n = 3) on a dry weight basis (μg/g of cowpea flour).

Table 3: Compositions (μg/g of cowpea flour) flavonols and flavan-3-ols in red cowpea varieties

Compound	IT82D-889	IT97K-1042-3
Quercetin-3-*O*-glucoside-7-*O*-diglucoside	106 ± 7.90	24.0 ± 3.12
Quercetin-3-*O*-galactoglucoside	12.5 ± 1.19	ND
Quercetin-3-*O*-arabinoside-7-*O*-diglucoside	ND	93.0 ± 3.89
Quercetin-3,7-diglucoside	102 ± 7.01	ND
Quercetin-3-*O*-malonyldeoxyglucoside	313 ± 6.18	70.9 ± 2.25
Quercetin-3-*O*-galactoside	144 ± 3.05	ND
Quercetin-7-*O*-glucoside	ND	122 ± 3.93
Quercetin-3-*O*-glucoside	ND	90 ± 2.48
Quercetin-3-*O*-diglucoside	46.5 ± 3.10	334 ± 5.79
Quercetin	5.71 ± 0.56	ND
Quercetin-3-(6″-malonoyl)-glucoside	ND	120 ± 4.10
Subtotal quercetin	**730 ± 28**	**853 ± 26**

Myricetin-3-*O*-diglucoside	129 ± 6.19	138 ± 5.55
Myricetin-3-*O*-glucoside	ND	71.4 ± 2.39
Subtotal myricetin	**129 ± 6.19**	**210 ± 7.94**
Grand Total Flavonols	**859 ± 35.2**	**1063 ± 33.5**
Catechin-3-*O*-glucoside	2198 ± 8.3	2264 ± 10.3
Procyanidin dimer B-type	ND	465 ± 9.6
Catechin/epicatechin	ND	86.1 ± 4.4
Procyanidin trimer T2	ND	526 ± 8.48
Total Flavan-3-ols	**2198 ± 8.3**	**3340 ± 32.7**

Data are expressed as mean ± standard deviation (n = 3) on a dry weight basis (μg/g of cowpea flour).

Table 4: Antiproliferation properties (IC_{50}) of blackeye and red cowpea varieties against human colon cancer cell lines *in vitro*

Cell line	**HT-29**		**Caco-2**	
	Raw	Cooked	Raw	Cooked
Blackeye	925	910	1840	1490
Agrinawa (red)	480	980	300	1100

Values are ug extract/mL needed to inhibit 50% of cell growth; Samples were incubated with cells for 48 hr; PicoGreen DNA assay was used. Coefficient of variability = 6.2%

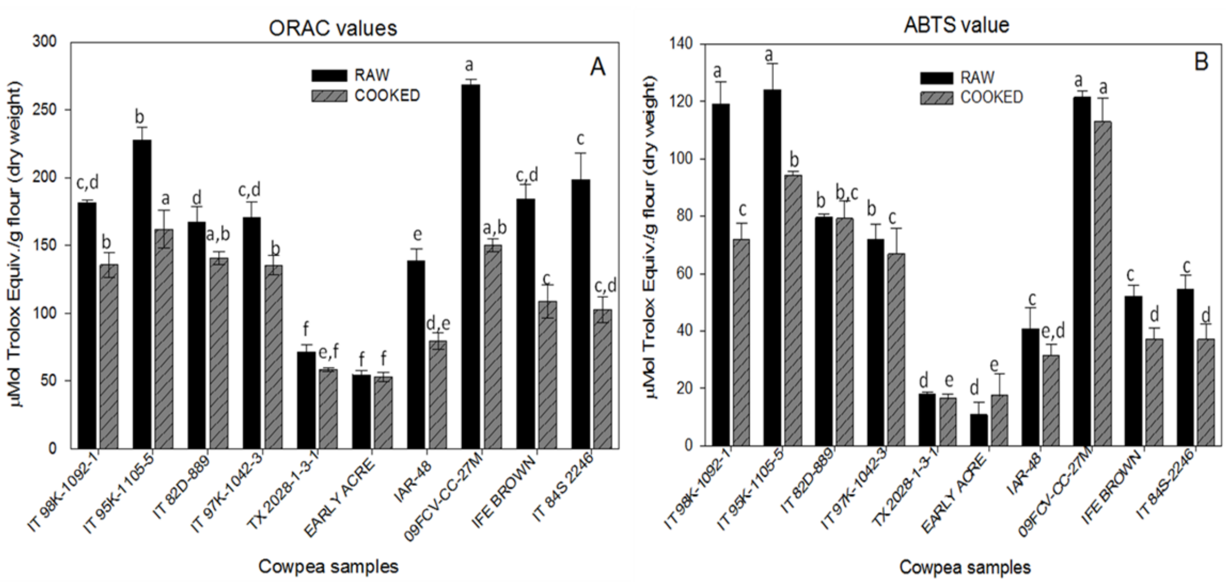

Figure 1. Antioxidant activities of various raw and cooked cowpeas varieties: ORAC values, **A**; and ABTS values, **B**. Bar data are expressed as mean ± standard deviation (n = 3) on dry weight basis. Values marked above the same color bars with the same letter are not significantly different (p < 0.05)

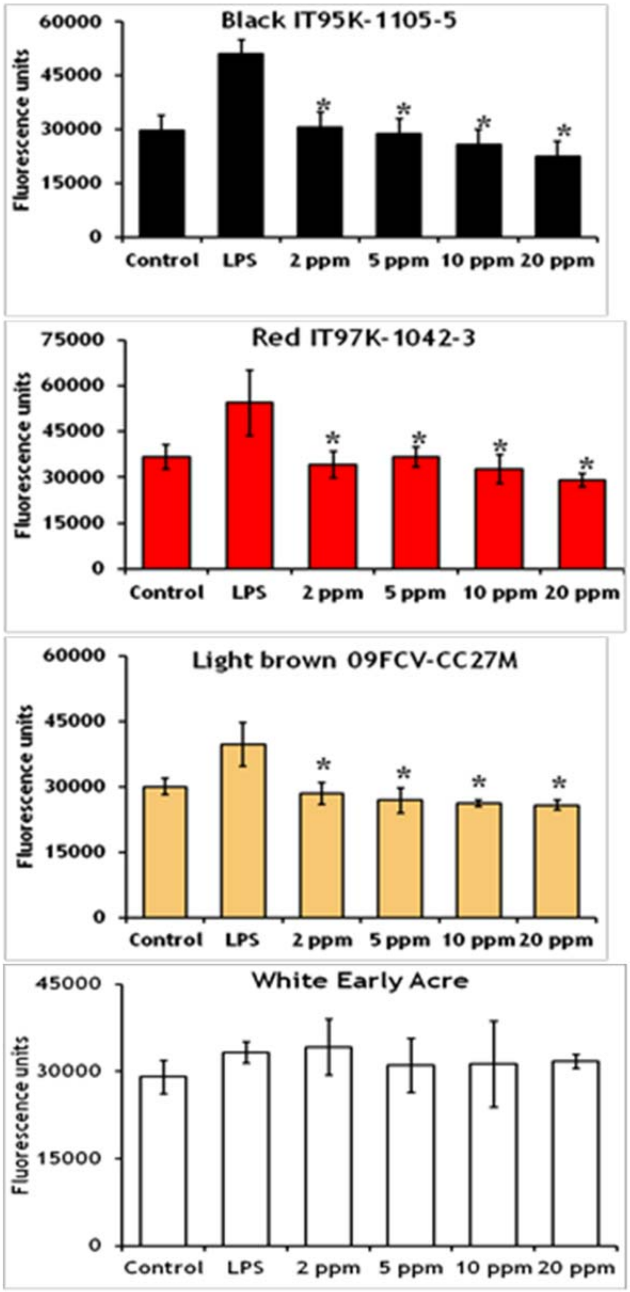

Figure 2. Generation of reactive oxygen species (ROS) after LPS-induced oxidative damage in non-cancer colonic myofibroblasts CCD-18Co cells. Cells were pretreated with cowpea polyphenolics for 24 hrs before induction of ROS. Values are means ± SD (n = 3); Bars marked with (*) indicate significance at $p < 0.05$.

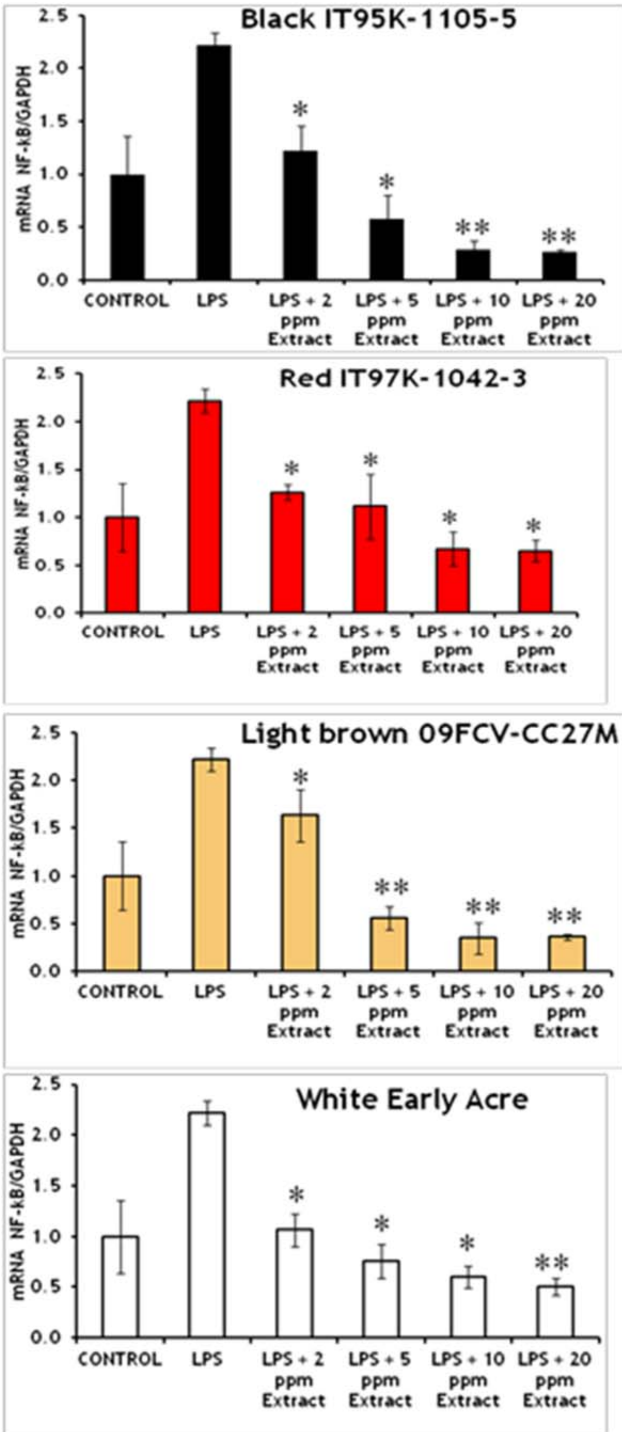

Figure 3. CCD-18Co gene expression of NF-κB was analyzed by real time q-RT-PCR as ratio to GAPDH mRNA. CCD-18Co cells were treated with cowpea extracts during 24 hrs; values are means ± SE (n = 3). Bars with (*) and (**) are significant at $p < 0.05$ and $p < 0.01$, respectively.

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Contribution to Gender Equity

Currently 2 females (from Kenya and Zambia) working on their PhD are directly funded on this project. In addition, of the 24 people who received short term training in Kenya this year, 13 were females. We will continue to actively engage females throughout the project.

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Dry Grain Pulses CRSP

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

(For the Period: October 1, 2010 -- September 30, 2011)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2011

Project Title: *Increasing utilization of cowpeas to promote health and food security in Africa*

	Abbreviated name of institutions																	
	TAMU			UNZA			EGER			UP			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***	**9/30/11**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Phytates	X			0			0			0			0			0		
Protein content	0			0			0			0			0			0		
Protein quality and digestibility	0	x		X		x	0			X	x		0			0		
0	0			0			0			0			0			0		
Screening backcrosses:	0			0			0			0			0			0		
Phenolic tests	X	x		0	x		0	x		0			0			0		
SET and HAT	X	x		0			0			0			0			0		
Objective 2																		
Bile acid binding assay	0			0			X	x		0			0			0		
Inhibition of LDL oxidation	0			0			0			X	x		0			0		
Glycemic Index	0	x		X	x		0			0			0			0		
Phase II	X	x		0			0			0			0			0		
Anti-proliferation	x	x		0			0			0			0			0		
Biomarkers for inflammation	X	x		0			0			0			0			0		
Antioxidant biomarkers	x	x		0			0			0			0			0		
Objective 3																		
Perform relevant crosses	0			0			0			0			0			0		
Obtain F3 seed	x	x		x			0	x		0			0			0		
Conduct field trials	x	x		x	x		0	x		0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 4																		
HC stakeholder workshops	x	x		x		x	x	x		0			0			0		
Graduate training (PhD)	x	x		0			0			x	x		0			0		
Graduate training (MS)	0			0			0	x		0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Name of the PI reporting on benchmarks by institution																		
Name of the U.S. Lead PI submitting this Report to the MO	Joseph Awika																	

#####

Signature **Date**

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2010 -- September 30, 2011)

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 (October 1, 2010-Sept 30, 2011)	2011 Actual (October 1, 2010-Sept 30, 2011)
Degree Training: Number of individuals enrolled in degree training		
Number of women	2	2
Number of men	1	1
Short-term Training: Number of individuals who received short-term training		
Number of women	15	11
Number of men	15	15
Technologies and Policies		
Number of technologies and management practices under research	4	4
Number of technologies and management practices under field testing	1	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	3
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	0

Pulse Value Chain Initiative—Zambia (PVCI-Z)

Principal Investigator
Vincent Amanor-Boadu, Kansas State University, USA

Collaborating Scientists
Gelson Tembo, University of Zambia, Zambia
Mukwiti Mwiinga, University of Zambia, Zambia
Prisilla Hamukwala, University of Zambia, Zambia
Rebecca Lubinda, University of Zambia, Zambia
Tim Dalton, Kansas State University, USA
Allen Featherstone, Kansas State University, USA
Kara Ross, Kansas State University, USA

Abstract of Research Achievements and Impacts
The first year of operation has been trying in developing systems for operations – protocols, bank accounts, invoicing systems, etc. We have finally completed these and have completed the producer-level data collection. Additionally, the six undergraduate students completed their programs successfully, with a couple receiving merit awards and having graduated with distinctions. These students have produced six theses on various dimensions of beans and cowpeas in Zambia. One of the sponsored MS students has also graduated and is currently working with the World Food Program in Lusaka. The MAB students sponsored by the project have already started making impact in their organizations, implementing solutions to problems using the concepts and tools they are acquiring in their classes. Finally, PVCI-Z has successfully developed relationship with Zambia National Farmers Union (ZNFU) and with the Southern Africa Bean Research Network (SABREN) to work on improving understanding and operation of the bean and cowpea value chain. The second year of the project is devoted to the completion of the research component of the project objectives.

Project Problem Statement and Justification
Pulses are important in concentrated locations in Zambia. Zambian Central Statistics Office (CSO) data show that while the Northern Province accounts for the majority of bean production (62 percent), the Southern Province accounts for the majority (58 percent) of cowpea production. The remainder of the top-four producing provinces for beans includes Northwestern (8 percent); Central (7 percent); and Luapala (6 percent). For cowpeas, the remaining of the top-four producing provinces are Central (11 percent), Northern (9 percent), and Lusaka (6 percent). Despite this concentration, pulses are also important to the Zambian food economy because they are planted in all provinces, probably because they are more drought tolerant than the traditional maize crop.

Despite their importance in the country, knowledge about bean and cowpea value chains is overwhelmingly anecdotal. It is particularly unclear what effect internal and trans-border trade arrangements for beans and cowpeas have on the efficiency of current supply chains, the value they create and the distribution of that value against the costs incurred across the different supply chains used by producers to get product to market. Additionally, it is unknown how much value is created at the different stages of the production process, i.e., leaves, green pods, dry grain, and the relative contributions of these stages to overall profitability of production activities. Securing more and better information about these would contribute to better understanding of these crops in the welfare of Zambian producers and others in their value chains. This information should contribute to the development of better policies aimed at poverty alleviation and reduction in food security risks as well as enhancing producer incomes.

The Pulse Value Chain Initiative—Zambia (PVCI-Z) vision is to contribute to poverty alleviation and improve food and nutrition security through research, education and engagement. This project aims to achieve this vision by (1) conducting research to address the identified knowledge gaps about bean and cowpea value chains in Zambia; (2) determine the most efficacious value chains given producer and partner characteristics; and (3) work with industry to develop and construct value chains that help increase producer incomes, improve food and nutrition security and improve efficiency along the supply chain. This ensures that all partners along the chain are beneficiaries of improvements in chain performance and the distribution of new value created is done in an equitable and fair manner. The foregoing is in line with the Dry Grain Pulses CRSP overall goal of alleviating poverty and enhancing food and nutrition security. The lessons and tools emanating from this research will be applicable to other countries in the region and to other crops within Zambia and across southern Africa. The project's success, therefore, contributes to the Global Hunger and Food Security Initiative of the USAID.

The project has two principal components: research and human capacity development. The project's research component is divided into two distinct but related categories: Development of Baseline Knowledge and Benchmark Metrics; and Exploration of Effects of Alternative Governance Systems on Value Creation.

Development of Baseline Knowledge and Benchmark Metrics

Under first category, we seek to achieve the following objectives:

1. Identify the different supply chains used by the Zambian pulse industry and describe the characteristics of those using them at the different loci of the supply chains.
2. Identify and estimate the effects of stakeholder characteristics on producers' supply chain participation decisions.
3. Describe and estimate the pecuniary and non-pecuniary value for different supply chain participants.
4. 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.
5. Based on the results from the foregoing, develop and deliver education and outreach programs targeting specific stakeholders and provide policy recommendations to facilitate solutions.

Exploration of Effects of Alternative Governance Systems on Value Creation

The second category involves conducting supply chain management experiments to identify the factors that influence success in value creation. It involves the following specific objectives:

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

It is expected that upon achieving these objectives, the PVCI-Z project will contribute knowledge and understanding of the structure, conduct and performance of supply chains in the Zambian bean and cowpea industry. It will specifically provide knowledge about how the different players—farmers, traders, retailers, customers, etc.— in the market define and create value and identify how that value is distributed along the chain. One of its major contributions will be identifying and valuing the non-market components of the bean and cowpea chain in Zambia in order to develop a more complete economic picture of the industry. From policy development and implementation perspective, the achievement of the foregoing objectives would facilitate targeting the appropriate policies to achieve the highest pay-offs by producer characteristics. Additionally, the preferred value chain governance mechanisms will be identified and policy makers could be encouraged to support producers to engage in the ones that are most preferred to minimize governance related transaction costs and maximize total value accruing to chain participants. This knowledge should help collaborating institutions and organizations – government and public policymakers, industry and trade association, and NGOs and others seeking to help improve the wellbeing of African smallholder producers – develop a better appreciation of how to organize value chains to achieve their desired objectives .

Results, Achievements and Outputs of Research

Primary data is used to achieve the objectives of the first category objectives described above. A two-stage stratified cluster sampling procedure was used. The first stage involved probability sampling of the standard enumeration areas (SEAs) of Zambia with weights designed to reflect bean and cowpea growing regions. The second stage used systematic sampling of households from each selected SEA. Additionally, commercial producers were targeted and included in the sample to ensure the different types of producers were covered in the data collection process. The sampling processes also ensured that female producers were adequately represented.

Objective 1

Incomplete. No results to be reported.

Objective 2

Incomplete. No results to be reported.

Objective 3

Incomplete. No results to be reported.

Objective 4
Incomplete. No results to be reported.

Objective 5
Incomplete. No results to be reported.

Objective 6: Institutional capacity building

Degree Training
The following students supported by the project, defined by their name, citizenship, gender, discipline and supervising PI, have completed their degree program at the University of Zambia.

First	Last	Citizenship	Gender	Program	Supervising PI
Esther	Zulu	Zambian	Female	BS Ag Econ	Gelson Tembo
Agness	Myece	Zambian	Female	BS Ag Econ	Gelson Tembo
Natasha	Chilundika	Zambian	Female	BS Ag Econ	Gelson Tembo
Chimuka	Samboko	Zambian	Male	BS Ag Econ	Gelson Tembo & Mukwiti Mwiinga
Edna	Ngoma	Zambian	Female	BS Ag Econ	Gelson Tembo & Mukwiti Mwiinga
Chalwe	Sunga	Zambian	Female	BS Ag Econ	Gelson Tembo & Mukwiti Mwiinga
Susan	Chiona	Zambian	Female	MS	Gelson Tembo

The following are continuing their training programs towards their degrees. They are expected to be done by Spring 2013.

First	Last	Citizenship	Gender	Program	Institution & Supervising PI
Cornard	Chilala	Zambian	Male	MS Economics	UNZA, Gelson Tembo
Martin	Mwansa	Zambian	Male	MAB	KSU, Vincent Amanor-Boadu
Sosthenes	Mwansa	Zambian	Male	MAB	KSU, Allen Featherstone & Vincent Amanor-Boadu
Lydia	Mtsocha	Zambian	Female	MAB	KSU, Tim Dalton & Vincent Amanor-Boadu

Short-Term Training
We had planned three short-term training activities in our FY 2011 work plan.

- Statistical and econometric analysis for survey data: This training aimed at providing a refresher and an overview of the tools that may be used in analyzing survey data such as those we are collecting in this research. It was supposed to take place in Lusaka at the University of Zambia in spring 2011. It targeted students and faculty with invitations extended to the Central Statistics Office, Food Security Research Program and Ministry of Agriculture and Cooperatives. Staff limitation at HC institution, with Ms. Mukwiti Mwiingi's maternity leave and Dr. Tembo's responsibility for more undergraduate and graduate students than was expected made this impossible for the period it was scheduled.
- Introduction to governance systems for supply chains: This training aimed to provide an in-depth but simplified non-academic approach to understanding governance systems for supply chains. It was scheduled for either the summer or fall of 2011. It will be held on October 11, 2011 in Lusaka. This particular segment will focus on processors and traders in the pulses

supply chain as well as others in the agri-food system who may be interested. Another two training programs will be delivered to the producers who are selected to participate in the governance pilot projects once the primary data analyses and the downstream interviews are completed.

- Workshop on value chains: This training session was presented as a collaborative initiative with the Angola/Mozambique project led by Dr. Cynthia Donovan. Unfortunately, the discussions to move this project forward have not progressed too far. The U.S. and HC PIs both have an opportunity to spend about five days with Dr. Donovan in Lusaka this October and expect to complete the planning for this short-term training program.

Project Website

- The project website (http://valuechains.k-state.edu) was developed and launched at the end of November 2010. Populating the site is ongoing. This will accelerate as the project develops content from its own research activities.

Explanation for Changes

Objective 1 through Objective 5 under Category I

Achieving Objectives 1 through Objective 5 under Category 1 depended on completing the collection of the primary data at the farm level. The original work plan stipulated completing data collection by the end of spring 2011. However, numerous operational and institutional challenges forced the data collection to start late. These included completing setting up bank accounts at host institution to transfer money to facilitate data collection. When that was completed, there were communication problems at Kansas State University between the Comptroller's Office and the PI leading to delays in authorization to wire money to HC institution. There were also delays in procuring export authorizations for computers that were ordered for the HC to facilitate field work.

We have finally completed all these startup challenges and institutional logistics seem to be in place. The primary producer surveys were completed at the end of August 2011. Those data are being collated, cleaned and coded into Stata. Additionally, downstream buyers' information is being extracted from the primary data to facilitate conducting the downstream interviews this fall. We envisage these to go quickly since most of them will be conducted by phone and in Lusaka and a few central marketing places.

Finally, interviewing public policy makers as well as NGO agents involved in beans and cowpeas industries is expected to be completed by this fall to facilitate completion of Category I activities by November 2011. This is feasible now because the operational and logistics challenges that held us up at the beginning of the project seem to have been addressed.

Table 1: Revised Time Table for Objectives 1 through 4

Objective	Deliverable	Date	Revised Date
Objective 1	Data collection	April 2011	November 2011
Objective 2	Econometric analyses	May 2011	November 2011
Objective 3	Total value estimation	May 2011	November 2011
Objective 4	Public policy analyses	August 2011	November 2011

Networking and Linkages with Stakeholders

- Strategic planning session with collaborating organizations – ZNFU, Central Farmers Association and Central Statistics Office – September 28, 2010
- Visiting USAID Mission officials – October 4, 2010
- Worked with USAID Mission to help MAB students arrange for their U.S. Visas – December 2010
- Worked with SABREN in collecting primary farm level data during survey instrument development as well as sampling process
- Numerous meetings with Zambia National Farmers Union (ZNFU) and with the Southern Africa Bean Research Network (SABREN) on collaboration.

Leveraged Funds

None. SABREN provided in-kind support in the form of human resources to help with the data collection as well as evaluation of survey instruments and testing of the instrument. No cash was transferred but this non-cash in-kind support was a sign of SABREN's commitment to PVCI-Z project and its appreciation of the project's value in advancing a common purpose.

Scholarly Activities and Accomplishments

Edna Ngoma: Supply Chain Participation of Cowpea Producers in Zambia, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Esther Zulu: Profitability of Smallholder Cowpea Production in Zambia, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Agness Myece: Factors Influencing Cowpea Producers' Choice of Marketing Channels In Zambia, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Natasha Chilundika: Market Participation of Bean Smallholder Farmers in Zambia: A Gender-Based Approach, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Chimuka Samboko: An Assessment of Factors Influencing the Profitability of Bean Production in Zambian, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Chalwe Sunga: Market Information in the Bean and Cowpea Supply Chain in Zambia, B.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

Susan Chiona: Technical and Allocative Efficiency of Smallholder Maize Farmers in Zambia, M.Sc. Thesis, Department of Agricultural Economics, University of Zambia, 2011.

These studies are available on the project website, http://valuechains.k-state.edu.

Contribution of Project to Target USAID Performance Indicators

The number of individuals enrolled in degree programs were 12. Of these seven were females and five males. Seven students have completed their degree programs of study. Of these, six are females and one male. Six undergraduates and one MS completed their studies. The remaining five continue with their studies.

We have not conducted any short-term training and have, therefore, not met the targets specified.

We have proposed to conduct one policy study. We have completed seven of them under the project. These are specific student theses that focused on both understanding the pulses value chain and providing policy direction on how to address challenges that were identified. These studies are available on the project website (http://valuechains.k-state.edu).

For FY 2011, we had anticipated five businesses directly benefiting from our work. However, the delay in collecting data and analyzing them implies that we cannot claim these benefits in this fiscal year. The same goes for direct benefits of HC country partner institutions and organizations. The University of Zambia has benefited directly from the project by the support the project provided to students in both undergraduate and graduate programs. Additionally, SABREN has benefited from the collaboration it has developed with the project. Our three MAB students are all working in local organizations. Because of the structure of the program, these students bring work-related challenges to their classes and receive direct support from faculty in addressing those problems. This may be interpreted as directly providing benefits for these Zambian organizations that employ these student beneficiaries of the project.

(See attached chart, below.)

Contribution to Gender Equity Goal

Of the six undergraduate students supported by the project, five were females. Of the six graduate students, two are females. Thus, of the 12 students supported, seven of them were females. The sampling process was specifically weighted to ensure representation of equitable proportion of females in the sample. This will be reported when the analyses are completed.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 20010 -- September 30, 2011)

FY 2011 PERFORMANCE INDICATORS
for Foreign Assistance Framework and the Initiative to End Hunger in Africa (IEHA)

Project Title: Pulse Value Chain Initiative - Zambia
Lead U.S. PI and University: Vincent Amanor-Boadu, Kansas State University
Host Country(s): Zambia

Output Indicators	2011 Target	2011 Actual
	(October 1, 2010-Sept 30, 2011)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	7	7
Number of men	5	5
Short-term Training: Number of individuals who received short-term training		
Number of women	15	0
Number of men	30	0
Technologies and Policies		
Number of technologies and management practices under research		
Number of technologies and management practices under field testing		
Number of technologies and management practices made available for transfer		
Number of policy studies undertaken	1	7
Beneficiaries:		
Number of rural households benefiting directly		
Number of agricultural firms/enterprises benefiting	5	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	6	2
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices		

Dry Grain Pulses CRSP
Institutional Capacity Building and Human Resource Development
FY 2011 Summary Report

The Dry Grain Pulses CRSP seeks to build host country institutional capacity through three mechanisms—support for long-term degree training, short-term non-degree training and the purchase of equipment to enhance research capacities. The status of activities planned and undertaken under these three categories of capacity building activities is included in the annual technical progress reports of the individual Phase II and III projects. In this section we provide a summary of these FY 2011 activities for the entire Pulse CRSP program.

A. Degree Training

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 technical quality of Pulse CRSP research activities. 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 from October 1, 2007 through September 30, 2011. A total of 53 students were either fully or partially supported in graduate or undergraduate degree programs in FY 2011. A descriptive summary of the degree training activities supported by the Pulse CRSP is provided in Table 1.

An estimated 6 graduate students at U.S. universities in 2011 were "indirectly" supported by the Dry Grain Pulses CRSP. These are students with research assistantships who are conducting their research in the host countries in collaboration with the HC PIs. 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. Since these graduate level degree students are not "Participant Trainees", they are therefore included in the Pulse CRSP Trainee data base (Anex 1.) Subcontracted U.S. universities supporting graduate students on research assistantships are providing 25% match on their salaries and research expenses as they are viewed as a cost to complete the Phase II and III CRSP research projects.

It is noteworthy that 33 of the 53 degree students supported by the Pulse CRSP in FY 2011 were enrolled in universities either in Host Countries or in academically advanced institutions in other countries (e.g., South Africa, Brazil) than the U.S. By supporting graduate training at partner HC universities, HC PIs are able to assume a greater role in the advising and monitoring of the academic formation and research activities of Pulse CRSP trainees. Moreover, by supporting graduate degree students at HC universities, the CRSP is contributing to the ongoing strengthening of academic graduate programs at these institutions. U.S. PIs frequently provide guest lecturers and serve on the guidance committees of graduate students. Finally, economies are achieved by supporting the training of USAID sponsored at universities in countries in Africa and Latin America. The hope is that the quality of instruction is not compromised.

Table 1: Summary of Degree Training by the Dry Grain Pulses CRSP as of September 30, 2011.

	No.of Trainees
Training Status	
▪ Active (in FY 11):	53
▪ Delayed/Pending	4
▪ Discontinued/cancelled:	5
▪ Training Completed:	12
Profile of “Active” trainees (31)	
Gender	
▪ Male	22
▪ Female	31
Region of Origin	
▪ East Africa	10
▪ Southern Africa	28
▪ West Africa	10
▪ Latin America/Caribbean	3
▪ United States	2
Degree program	
▪ M.S.	27
▪ Ph.D.	16
• B.S.	10
Training Location	
▪ U.S.	20
▪ Host countries	30
▪ Third countries	3

B. Non-Degree and Short-term 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 2011, an estimated 920 individuals benefitted from short term training subcontracted through Phase II and III projects in the Dry Grain Pulses CRSP. Of these short term trainees, over 48% were female. Table 2 presents a listing of some of the short-term training activities completed in FY 2011. Experience has shown that short term training is an effective strategy to build the capacity of technical staff at NARS and agricultural universities. These individuals do not require an advanced degree to conduct their analytical work or technology dissemination activities. Technical staff also find it difficult to obtain release time for educational purposes for extended periods from their institutions. Thus short term training is an attractive option for HC institutions. Moreover, short term training is highly cost effective and provides opportunities for the U.S. and Host Country PIs to join forces in the design and implementation of training activities.

Examples of FY 2011 Short-term Training Activities Supported by the Pulse CRSP

Pulse CRSP Project: PII-MSU-1

Rwanda

- Training on seed multiplication (for 28 participants including researchers and technicians from Rwanda Agriculture Board (RAB) research and extension programs) was conducted in order to build their capacity in seed multiplication, increase the qualities of seed produced, and build a common understanding of some guidelines in the domain. These technicians are supposed to train farmers and other technicians from collaborators institutions and Community Based Organization (CBOs).
- A bean stakeholder meeting was organized in Rwanda as a starting point in the establishment of an innovation platform for bean producers and traders. Participants from different organizations attended the meeting including privates sectors working in seed production and commercialization (RWASECO and Win-Win), International and local NGOs (Africare, DERN, DRD, CSC). Farmer associations and individual farmers were also represented. Discussions were focused on the following themes: Updates on bean breeding in Rwanda, seed system, role of ISAR seed program in promoting improved seed uptake and linkages with stakeholders in the seed industry; updates on Rwanda and regional markets; small packs in dissemination of improved bean varieties; and update on Agriculture Extension and policies in Rwanda by Raphaël Rurangwa (MINAGRI, Planning Director General). Three working groups were formed to elaborate recommendations: Group1: Roles and responsibilities in technology development and dissemination; Group 2: Accessibility of information on improved bean production and

commercialization technologies to potential users; and Group 3: Seed increase of improved varieties and wide dissemination.

Pulse CRSP Project: PI-MSU-2

Mozambique

- Type of Training: Analysis of market price data
  Description of Training Activity: Participants will work with data from SIMA and complete analysis to understand analytical methods and research issues related to market prices
  When the Short-Term Training Activity occurred: November 2011
  Location of Short-Term Training: Maputo, Mozambique
  Benefactors of the Short-Term Training Activity: 12 staff (2 from UAN/Angola, 5 from IIAM, and 5 from Directorate of Economics/MINAG, which includes SIMA
  Numbers of Beneficiaries by Gender: Male 6, Female 6, Total 12

- Type of Training: Camtasia screen recording software
  Description of Training Activity: Taught participants how to use Camtasia software
  When the Short-Term Training Activity occurred: May 2011
  Location of Short-Term Training: IIAM, Maputo, Mozambique
  Who benefitted from this Short-Term Training Activity? IIAM and UJES
  Number of Beneficiaries by Gender: Male- 2, Female- 0, Total- 2

Pulse CRSP Project: PI-UIUC-1

Benin

- Type of Training: Internship
  Description of Training Activity: Biocontrol of cowpea pests
  Status of this Activity as of September 30, 2011: on-going
  When the Short Term Training Activity occurred: July – Oct 2011
  Location of Short Term Training: IITA Benin
  Number of Beneficiaries by Gender: Male- 2 Female- 3 Total- 5

- Type of Training: Training of technicians
  Description of Training Activity: Biocontrol of cowpea pests
  Status of this Activity as of September 30, 2011: on-going
  When did the Short Term Training Activity occur? FY11
  Location of Short Term Training: Burkina Faso and Niger
  Number of Beneficiaries by Gender: Male-2 Female-2 Total- 4

- Type of Training: Training of technicians
  Description of Training Activity: Farmer field flora
  Status of this Activity as of September 30, 2010: August-October
  When the Short Term Training Activity occurred: FY11
  Location of Short Term Training: Burkina Faso, Mali, Nigeria, and Niger
  Number of Beneficiaries by Gender: Male- >250 Female- >250 Total- >500

Burkina Faso, Mali, Nigeria and Niger

- Type of Training: Online Video Materials on SusDeViKI, SAWBO site, e-mail distribution, in country distribution, media exposure, and YouTube views
  Description of Training Activity: Individual and groups wishing to access video-based training materials on the Internet (some of these are just views on the web and some are actual use of cell-phone ready videos).
  Status of this Activity as of September 30, 2011: February-ongoing
  When did the Short Term Training Activity occur? FY11
  Location of Short Term Training: Burkina Faso, Mali, Nigeria, and Niger, and other countries across West Africa (and countries beyond West Africa including Rwanda)
  Number of Beneficiaries by Gender:
    The PII-UIUC-1 project team was not able to record the gender of participants but believed that there were nearly equal females as males.
    SusDeViKI views of CRSP videos across the world - >10,000
    SusDeViKI downloads of cell phone ready SAWBO/CRSP videos – >1200
    YouTube views of various Scientific Animations Without Borders Videos - >16,757
    SAWBO views and download of videos (only up since the beginning of September) – >200 views and downloads
    The SAWBO and SusDeViKI sites have been shared online (via e-mail introductions) with over 300 NGOs, governmental agencies, universities, and other potentially interested organizations.
    Voice of America has released several articles on SAWBO including YouTube videos – the "hits" to date include 4,747 views in the English version and 1,159 views for the Vietnamese version.
    An incomplete list of the all the media articles on SAWBO can be found at https://sib.illinois.edu/pittendrigh/sawbo/news

Pulse CRSP Project: PI-UPR-1

Honduras

- Type of training: Workshop for technicians in NARS bean research programs in Central America
  Description of training activity: Participatory Plant Breeding- Common beans.
  Location: EAP-Zamorano, Honduras
  Duration: 3 days
  Participants/Beneficiaries of Training Activity: 15
  Numbers of Beneficiaries (male and female): 9M and 6F

Pulse CRSP Project: PIII-TAMU-1

Zambia

- Type of Training: Short term workshop and hands on laboratory training
  Description of Training Activity: Workshop explaining preliminary findings and what they mean to cowpea promotion strategy; hands on laboratory training on methods of phytochemical analysis.
  When the Short Term Training Activity occurred: May 24 – 27, 2011
  Location of Short Term Training: Nairobi & Egerton, Njoro, Kenya

Institutions benefitting from Short Term Training Activity: Government officials, NGO representatives, academic and extension staff of Egerton and KARI
Number of Beneficiaries by Gender: Male- 11 Female- 13 Total- 24

C. Equipment for Host Country Capacity Building

The Dry Grain Pulses CRSP recognizes that National Agriculture Research Systems (NARS) and agriculture universities need to acquire and maintain cutting edge research and extension capacity 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. 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 needs of agricultural research institutions in USAID priority countries which may be future collaborators.

In FY 2011, the Management Office (MO) in consultation with the Technical Management Advisory Committee (TMAC) approved the award of 4 supplemental activities totaling $175,000 that would enhance the capacity of host country institutions in strategic areas (e.g., production of *Rhizobium* inoculants to enhance BNF, development and deployment of IPM instructional videos that can be send to cell phones, audio-visual equipment for training of extension agents, etc.) and provide direction to future productivity enhancing research investments in Pulses (See Annex 2).

Annex 1: Status of degree training planned and executed in FY 2011

Project	Given name	Last name	Country of citizenship	Gender	Training institute	Degree	Discipline	**Training status as of 09/30/11**	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	Completed	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	Completed	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	Completed	2010	Mar-11	Full
PI-CU-1	Stanley	Onyango	Kenya	M	University of Nairobi	M.S.	Food Technology & Nutrition	Completed	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		
PII-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			
PII-ISU-1	Martin	Matambuka	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Active	Jan-09	May-12	Partial
PII-ISU-1	Aisha Nakitto	Musaazi	Uganda	F	Makerere University	M.S.	Food Science & Technology	Active	Aug-08	Dec-10	Partial
PII-ISU-1	Simon	Okiror	Uganda	M	Makerere University	M.S.	Agricultural Economics/Agribusiness	Completed	Aug-08	Dec-10	Partial
PI1-ISU-1	Catherine	Ndagire	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Active	Aug-09	Aug-11	Partial
PII-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
PII-ISU-1	Marie Grace	Nkundabombi	Rwanda	F	Makerere University	M.S.	Food Science & Nutrition	Active	Aug-11	Aug-12	Partial
PI-MSU-1	Gerardine	Mukeshimana	Rwanda	F	Michigan State University	Ph.D.	Plant Breeding and Genetics	Active	Aug-08	Aug-12	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
PI-MSU-1	Krita	Iaacs	USA	F	Michigan State University	Ph.D.	Ecology and Nutrition	Active	Aug-08	/ayg-12	Partial
PII-MSU-2	Maria da Luz	Quinhentos	Mozambique	F	Michigan State University	M.S.	Agricultural Economics	Canceled			
PII-MSU-2	Ana Lidia	Gungulo	Mozambique	F	University of Pretoria, South Africa	M.S.	Agricultural Economics	Active	Feb-09	Dec-11	Full
PII-MSU-2	Estaveo	Chaves	Angola	M	University Federal Vicosa, Brazil	M.S.	Agricultural Economics	Completed	Apr-09	Jul-11	Full
PII-PSU-1	Samuel	Camilo	Mozambique	M	Penn State	M.S.	Agronomy	Active	May-11	?	Full
PII-PSU-1	Virginia	Chesale	Malawi	F	Penn State	M.S.	Plant Nutrition	Active	2009	2012	Partial
PI-UPR-1	Ronald	Dorcinvil	Haiti	M	University of Puerto Rico	M.S.	Soil Sciences	Completed	Aug-06	May-09	Partial
PII-UPR-1	Monica	Mbui Martins	Angola	F	University of Puerto Rico	M.S.	Plant breeding	Completed	Aug-09	Aug-11	Full
PII-UPR-1	Jorge	Diaz	Peru	M	EAP-Zamorano	B.S.	Crop Science	Active	Jan-11	Dec-11	Partial
PII-UPR-1	Luis	Moncaño	Ecuador	M	EAP-Zamorano	B.S.	Crop Science	Active	Jan-11	Dec-11	Partial
PI-UCR-1	Manuel	Costa	Angola	M	University of Puerto Rico	M.S.	Plant Breeding/Pathology	Canceled			
PII-UCR-1	Mame Penda	Sarr	Senegal	F	University of Dakar	Ph.D.	Plant Breeding/Pathology	Active	Oct-10	Oct-13	Full
PII-UCR-1	Marti	Portorff	USA	M	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Active	Oct-08	Mar-12	Full
PII-UCR-1	Antonio	David	Angola	M	University of Puerto Rico	M.S.	Plant Breeding	Completed	Aug-09	Aug-11	Full
PII-UIUC-1	Traore	Fousseni	Burkina Faso	M	University of Ouagadougou	M.S.	Entomology	Active	Sep-08	Aug-12	Full
PII-UIUC-1	Sanou	Appoline	Burkina Faso	F	University of Ouagadougou	Ph.D.	Entomology	Active	2010	Jul-14	Partial
PII-UIUC-1	Hermann	Somakpon	Benin	M	IITA-Benin	M.S.	Entomology	Active	Jul-09	Jul-11	Partial
PII-UIUC-1	Joelle	Toffa	Benin	F	IITA-Benin	Ph.D.	Entomology	Active	Jul-10	Jul-12	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
PII-UIUC-1	Elie	Dannon	Benin	M	IITA-Benin	Ph.D.	Entomology	Active	Sep-09	Mar-11	Partial
PII-UIUC-1	Laouali	Karimou	Niger	M	University of Niamey	M.S.	Entomology	Active	Sep-10	Aug-11	Partial
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	Partial
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
PIII-MSU-3	Sharon	Hooper	Jamaica	F	Michigan State University	Ph.D.	Food Science	Active	Aug-09	Aug-12	Partial
PIII-MSU-3	Sacred	Jacob	Tanzania	M	Sokoine University of Agriculture	M.S.	Nutrition	Active	2011	Feb-12	Partial
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	Dec-11	Partial
PIII-TAMU-1	Archana	Gawde	?	F	Texas A&M University	Ph.D.	Molecular/Env. Plant Sci	Active	Jan-09	Dec-12	Partial
PIII-TAMU-1	Billy	Kiprop	Kenya	M	Egerton University	M.S.	Biochemistry	Active	Jan-10	Dec-11	Partial
PIII-KSU-1	Esther	Zulu	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Agness	Myece	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Natasha	Chilundika	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Chimuka	Samboko	Zambian	M	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	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-KSU-1	Edna	Ngoma	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Chalwe	Sunga	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Susan	Chiona	Zambian	F	University of Zambia	M.S.	Agriculture Economics	Completed	2010	2011	Full
PIII-KSU-1	Cornard	Chilala	Zambian	M	University of Zambia	M.S.	Economics	Active	2010	2013	Full
PIII-KSU-1	Martin	Mwansa	Zambian	M	University of Zambia	MBA	Business Administration	Active	2010	2013	Full
PIII-KSU-1	Sosthenes	Mwansa	Zambian	M	University of Zambia	MBA	Business Administration	Active	2010	2013	Full
PIII-KSU-1	Lydia	Mtsocha	Zambian	F	University of Zambia	MBA	Business Administration	Active	2010	2013	Full

Annex 2. Dry Grain Pulses CRSP FY 2011 Investments in Institutional Capacity Building

PII-UPR-1: Building Capacity for Enhancing Biological Nitrogen Fixation in Bean Production Systems in Central America, Haiti, Angola and Mozambique

Amount Awarded: $27,700

Participants received training in small-scale *Rhizobium* inoculant production and inoculation. This was a hands-on training with practical exercises of isolating *Rhizobia* bacteria from nodules and soil, selection of *Rhizobia* strains for speed of nodulation and efficiency to fix nitrogen. The most probable number count method was taught to determine the soil *Rhizobial* numbers to predict the response to inoculation. Hands-on instruction was provided on small-scale peat-based inoculant production starting with increasing *Rhizobia* in culture media, control of contamination, peat preparation and sterilization, inoculation of *Rhizobia* in a peat carrier, quantifying *Rhizobia* in an inoculant and quality control.

Activities: Two workshops were funded: (1) One for NARS bean researchers from Central American and the Caribbean region at the Escuela Agrícola Panamericana (Zamorano) in Honduras (scheduled for November 2011); (2) the second workshop for NARS bean program scientists from IIA-Angola and IIAM-Mozambique to be hosted by IIAM in Maputo, Mozambique in late 2011.

PII-MSU-2: Video Equipment for IIAM, Mozambique

Award Amount: $25,300

Simple video equipment, including a web camara and a camcorder, along with a laptop computer and required software were purchased. This equipment is needed by IIAM scientists to train technicians, extension agents and NGO staff at IIAM zonal agriculture research centers. Cost of travel from Maputo to the regional centers limits critical training which could be arranged if audio-visual equipment were available.

Local specialists will be used to train the participants on using this simple technology to link video/audio equipment to Power Point and other presentation methods, creating low cost communication tools. This activity is designed as a combined activity, lead by IIAM-Mozambique with participation by UAN (Universidade of Augustine Neto) staff conducted in Maputo, using specialists from the University of Eduardo Mondlane's Technology Center. UAN will send two participants and IIAM with the MINAG Documentation Center will also participate in the 10 day intensive training.

PII-UIUC-1: **An assessment of the availability of cell-phones among extension agents, NGO staff and farmers and of their skill sets and abilities to use the video and Bluetooth capacities of their phones in Burkina Faso and Niger to receive and deploy IPM messages for management of insect pests in cowpea.**

Award Amount: $22,000

Insect pest attack on cowpea crops in West Africa represents the biggest biological constraint on this crop. The PII-UIUC-1 project is focused on the development and the deployment of practical technologies that can be used by small-holder farmers to optimize their cowpea production by minimizing insect attack. A deployment strategy that utilizes simple IPM video messages that can received and viewed by extension agents and farmers with cell phones that have video/Bluetooth capability has the potential to be a highly cost effective way to get this information quickly to large numbers of rural farmers when there is risk of intense insect infestation. It also represents a strategy that can be expanded into other countries, in many cases by doing additional language voice overlays.

Five new videos (dealing with pest control strategies – viral and neem-based sprays as well as procedures for safe handling of pesticides) will be developed and provided to host country collaborators at INERA, Burkina Faso. These will be completed in the first six months of the project (FY11). A survey of women's access and use of cell phones will occur over the first year and a half (FY11 and FY12). Pending the outcome of the assessment studies, workshops will be planned and held to train extension agents, NGOs, and INERA staff/collaborators during FY 2012 in the most effective strategies to enable maximal deployment of these videos.

PII-PSU-1: Workshop on "Enhancing Pulse Productivity on Problem Soils by Smallholder Farmers- Challenges and Opportunities", The Pennsylvania State University, August 14-18, 2011.

Award Amount: $100,000

This workshop was hosted by Dr. Jonathan Lynch at the Pennsylvania State University with co-sponsorship by the Dry Grain Pulses CRSP, CIAT, IITA and ICRISAT and financial support from the Bureau of Food Security, Office of Agriculture, Research and Technology, USAID.

The goal of this workshop was to formulate recommendations on future research foci to achieve major increases in pulse productivity under edaphic and abiotic stress conditions in small-holder farm settings. Over 50 leading scientists, experts and stakeholders from both the U.S, and developing countries with interest in and knowledge of global grain legume production (primarily common bean, cowpea, etc.) were assembled to contribute to this research visioning and priority setting exercise. The recommendations resulted from the workshop were articulated in written Executive Summary) that was presented to USAID and USDA/ARS for consideration in making future investments in grain legume research under Feed the Future.

Specific Workshop Objectives

1. Discuss and describe the imperative of increasing grain legume productivity to achieve food and nutritional security, sustainability of cropping systems and resilience to climate change. Priority consideration will be given to focal developing countries under Feed the Future in Africa, Latin America and Asia (www.feedthefuture.gov/) where grain legumes are commonly grown and consumed.

2. Discuss and describe edaphic, abiotic and production costs/returns constraints to achieving high yields of grain legumes by small-holder resource-poor farmers on degraded/problem soils. Specific attention will be given to the following cropping systems in developing

countries; lowland cereal-bean production system with high rainfall and temperatures; hillside bean production systems irregular rainfall and degraded soils, highland bean production systems, cowpea production in the Sahel and Savanna regions, etc.

3. Explore the potential to increase productivity and reduce risk afforded by technologies and current knowledge of (1) plant biology, (2) environmental stress physiology, (3) molecular genetics and crop breeding, (4) soil fertility and water management, (5) biological nitrogen fixation, and (6) integrated crop management. Identify knowledge gaps and bottlenecks to technical progress in each area.

4. Formulate a list of research approaches in each of the 6 areas that have high potential to effectively and successfully contribute to substantial gains in productivity of grain legumes under the small holder farm situations identified in point (2). Prioritize these approaches for their potential to substantially increase grain legume productivity with adequate sustained research investment.

5. List the high priority training and institutional capacity building needs that may be concomitantly required for institutions in the countries listed in point (1) to achieve these research goals.

6. Identify technologies and management practices which may be ready for deployment with adaptive research and which could contribute to grain legume productivity gains and the amelioration of edaphic/abiotic stresses in the production systems identified in point (2).

7. Identify research and training capacities, timelines, and resources required as well as coordination by public and private partners (U.S. and Host Country agriculture research institutions (NARS and universities), IARCs (CIAT, IITA, etc.), and private sector) to achieve the research listed in point (4) in a timely and efficient manner.

The Executive Summary of the Workshop can be accessed from the Pulse CRSP's website www.pulsecrsp.msu.edu/.

Total FY 2011 Investment by Dry Grain Pulses CRSP in Institutional Capacity Building- $ 175,000

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