FY 2012 TECHNICAL PROGRESS REPORTS

October 1, 2011–September 30, 2012

Dry Grain Pulses Collaborative Research Support Program (CRSP)

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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 final year have produced important achievements with regard to project research and development goals. Efforts to improve bean quality and yield (objective 1) involved continued research on complex interactions of bean variety and fertilizer. Participatory research with farmers has enabled us to develop extension materials using print and video media that have been refined and translated into local languages. These have been utilized in training nearly 1000 farmers (70% women) in 60 demonstration sites, and providing seed for two improved varieties. Training covered germination testing; plant spacing; manure application; pest and disease management; harvesting, threshing, drying, and moisture testing; solarization and triple bagging; and sorting and seed selection. Capacity building continued for six groups involved in community based production and sale of quality seed to ensure success and sustainability.

To enhance nutritional value, appeal and consumption of beans (objective 2), we have developed appealing bean-based products, and taught farmers about nutrient-enhancing ways to prepare beans for home meals. We also taught farmer groups to prepare more shelf-stable value-added bean-based products. As a result, rural microenterprises have been created, selling snacks to school going children and at/for special occasions in the community such as parties and weddings. Research had been performed to determine the influence of pre-processing methods on starch and protein digestibility, micronutrient bioavailability and the sensory acceptability of a bean based porridge for supplementary feeding. Tests were also performed to screen the culinary and sensory characteristics of 7 local and 18 improved bean varieties in Uganda and 16 improved varieties in Rwanda. 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.

Project households have increased the area planted in beans, market participation, and income. The project strengthened the collective marketing capabilities of farmer groups (objective 3) through enhanced understanding of market price variations, skills to obtain higher prices resulting from improved post-harvest grain handling, better coordination of grain bulking and storage at community level, and negotiation skills. In addition, the project provided assistance to farmer groups to develop business plans, to improve record keeping and analysis, to promote gender equity and better functional group dynamics. A multi-stakeholder bean value chain forum

has been established to enable participants to identify key constraints and solutions for broad-based successful market participation.

Project Problem Statement and Justification

Agriculture in East Africa is characterized by women and men working in small scale, rain-fed fields of poor soil fertility, averaging two 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 access to 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 cooking time 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, germination, and extrusion cooking) can enhance digestibility and nutritional value by reducing phytates and polyphenols that limit iron uptake, and create value-added bean-based products.

Prospects of marketing increased quantities of beans and new agro-processed bean products within the Ugandan and regional markets require careful examining of 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 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 (SL) 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 initially only a few (20%) sold beans. 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: To Improve Harvested Bean Yields and Quality

Improve Yield and Quality through Evaluation of Better Production and Management Practices

Based on significant local variation in soil fertility conditions which produced large genotype x environment interactions for the priority varieties evaluated, overall bean productivity remains well below genetic potential. Soils in the test sites were low in phosphorous and often unresponsive to supplemental Nitrogen fertilizer. We therefore tested the hypothesis that incorporating varying amounts of inorganic phosphorous into the soil prior to planting will help identify the level required to generate a profitable return on seed and N-fertilizer investment.

The genotypes tested are: Kanyebwa - local variety common in Kamuli, southeast Uganda, and NABE4 - improved variety released by NaCRRI. Phosphorus application rates were: 0, 60, 120 and 180 kg/ha. Increasing rates of phosphorus were used to test whether increased supply of phosphorus would lead to better agronomic performance on low nutrient soils common in Uganda. Phosphorus was applied in bands along the rows at planting.

The experiments were carried out on stations at Nakabango Variety Testing Center, near Jinja in southeastern Uganda, at NaCRRI's main fields in Namulonge in central Uganda, and at the Mbarara Zonal Agricultural Research and Development Institute (ZARDI) in southwestern Uganda. The experiments were organized in split plot design with the varieties as the main plots and the phosphorus rates as subplots. The fields were managed according to standard agronomic practices for common beans in Uganda. At physiological maturity, data on yield and its components were collected. In 2012, trials were not set at Mbarara ZARDI. Data was subjected to analysis of variance in PROC GLM using SAS statistical package.

2011 Second Season (B)

Table 1: Response of Two Common Bean Varieties – NABE4 and Kanyebwa to Increasing Levels of Phosphorus at Nakabango, Southeastern Uganda – 2011 Second Season (B)

Variety	Phosphorus Rate (kg/ha)	Yield (kg/ha)	Pods/ Plant	Seeds/ Pod	100 Seed wt(g)	Harvest Index	Plants / m^2
Kanyebwa	0	613.0A	7.7B	3.0A	38.8A	57B	10.0A
	60	482.4A	10.7A	3.0A	38.6A	80A	9.0A
	120	563.2A	11.0A	3.0A	41.1A	77AB	9.0A
	180	526.9A	11.0A	2.3A	39.5A	73AB	9.3A
NABE4	0	740.6A	11.7A	3.0A	52.8B	60A	12.0A
	60	733.6A	9.7A	3.0A	51.7B	60A	11.3A
	120	963.6A	11.7A	3.0A	56.7A	60A	11.7A
	180	883.5A	11.0A	3.3A	50.8B	53A	10.0A

Means with the same letter down column within each variety are not significantly different (p> 0.1)

Table 2: Response of 2 Common Bean Varieties – NABE4 and Kanyebwa to Increasing Levels of Phosphorus at NaCRRI Namulonge, Central Uganda – 2011 Second Season (B)

Variety	Phosphorus Rate (kg/ha)	Yield (kg/ha)	Pods/ Plant	Seeds /Pod	100 Seed wt(g)	Harvest Index	Plants / m^2
Kanyebwa	**0**	150.6A	3.3A	2.7A	38.0A	40A	11.0A
	60	146.3A	4.0A	2.3A	43.2A	40A	9.0A
	120	142.9A	4.3A	2.3A	36.7A	40A	11.0A
	180	152.6A	3.7A	2.7A	39.3A	40A	9.3A
NABE4	**0**	146.2A	4.3A	2.7A	36.1A	37B	8.3A
	60	147.9A	4.0A	2.3A	39.4A	40A	7.7A
	120	128.0A	3.7A	2.3A	38.7A	40A	6.3A
	180	157.5A	5.0A	1.7A	37.6A	40A	8.3A

Means with the same letter down column within each variety are not significantly different (p> 0.1)

Table 3: Response of Two Common Bean Varieties – NABE4 and Kanyebwa to Increasing Levels of Phosphorus at Mbarara ZARDI, Southwestern Uganda – 2011 Second Season (B)

Variety	Phosphorus Rate (kg/ha)	Yield (kg/ha)	Pods/ Plant	Seeds /Pod	100 Seed wt(g)	Harvest Index	Plants / m^2
Kanyebwa	**0**	528.7B	9.3A	2.7B	42.4A	46.7AB	11.7A
	60	586.0AB	9.0A	2.7B	43.4A	40.0AB	8.3A
	120	760.9A	9.3A	3.7A	43.3A	36.7B	12.7A
	180	524.1B	7.7A	2.7B	42.9A	60.0A	11.3A
NABE4	**0**	761.8A	9.7AB	3.0A	44.2A	46.7A	11.3A
	60	746.8A	10.3AB	2.7AB	44.9A	46.7A	9.3A
	120	634.3A	12.0A	2.3B	46.0A	56.7A	7.3A
	180	646.6A	8.7B	3.0A	45.9A	63.3A	10.7A

Means with the same letter down column within each variety
are not significantly different (p> 0.1)

In Nakabango (Table 1), results showed that there were significant differences in yield, seeds per pod and plants harvested per square meter for all phosphorus rates. The number of plants harvested per square meter was, however, less than the optimum plant population for beans of 20 plants/m^2. The number of pods per plant was significantly higher with addition of phosphorus than the control for Kanyebwa.

Phosphorus fertilizers did not have significant effects on 100 seed weight for Kanyebwa. The 100 seed weight for NABE4 at 120 kg/ha was significantly higher than the other phosphorus rates. There were no significant effects of phosphorus on the harvest index for NABE4. However, the harvest index for Kanyebwa at 60 kg/ha was significantly higher than that for the control.

At NaCRRI-Namulonge, (Table 2), increasing rates of phosphorus did not have significant effects on yield, pods per plant, seeds per pod, 100 seed weight and plants harvested per square meter. Further, there was no significant effect of phosphorus on the harvest index for Kanyebwa. For NABE4; the harvest index with addition of phosphorus fertilizer was significantly higher than the control. However, the number of plants harvested was lower than the optimum plant population of 20 plants/m^2.

At Mbarara ZARDI (Table 3), results showed that for Kanyebwa, yield at 120 kg/ha of phosphorus was significantly higher than that of the control and for 180 kg/ha of phosphorus. There were no significant effects of phosphorus on the yield of NABE4. There were no significant effects of phosphorus on the number of pods per plant for Kanyebwa. However, for NABE4 the number of pods per plant at 120 kg/ha of phosphorus was significantly higher than that at 180 kg/ha of phosphorus. The number of seeds per pod was significantly higher at 120 kg/ha of phosphorus than the other phosphorus rates. There were no significant effects of phosphorus on the 100 seed weight and plants harvested per square meter for both varieties. The harvest index for Kanyebwa at 180 kg/ha of phosphorus was significantly higher than that of 120 kg/ha of phosphorus. However, for NABE4, no significant effects of phosphorus on harvest index were observed.

2012 First Season (A)

Table 4: Response of Two Common Bean Varieties – NABE4 and Kanyebwa - to Increasing Levels of Phosphorus at Nakabango, Southeastern Uganda – 2012 First Season (A)

Variety	Phosphorus Rate (Kg/ha)	Yield (kg/ha)	Pods/ Plant	Seeds /Pod	100 Seed wt (g)	Harvest Index	Plants/ m^2
Kanyebwa	**0**	666.7A	7.7A	2.7A	49.9A	48.6A	11.0A
	60	893.3A	7.0A	2.7A	50.2A	51.4A	13.8A
	120	973.3A	7.6A	3.5A	52.6A	49.2A	13.8A
	180	960.0A	9.1A	2.7A	52.3A	52.6A	13.0A
NABE4	**0**	520.0A	7.1A	2.5A	54.6B	61.4A	14.4AB
	60	546.7A	7.2A	2.6A	53.7B	51.5A	11.9B
	120	950.0A	7.8A	3.1A	53.6B	53.7A	14.9A
	180	946.7A	8.4A	2.8A	58.8A	51.5A	14.8A

Means with the same letter down column within each variety are not significantly different (p> 0.1)

Table 5: Response of Two Common Bean Varieties – NABE4 and Kanyebwa - to Increasing Levels of Phosphorus at NaCRRI-Namulonge, Central Uganda – 2012 First Season (A)

Variety	Phosphorus Rate (kg/ha)	Yield (kg/ha)	Pods/ Plant	Seeds/ Pod	100 Seed wt (g)	Harvest Index	Plants/ m^2
Kanyebwa	**0**	536.7A	4.5A	2.5A	45.3A	52.3A	14.4A
	60	580.0A	4.5A	2.7A	48.0A	53.6A	19.6A
	120	448.0A	4.4A	1.8B	48.8A	57.4A	16.8A
	180	540.0A	5.2A	1.7B	48.7A	52.0A	19.3A
NABE4	**0**	453.3AB	4.1B	2.3AB	56.4A	73.1AB	19.0A
	60	463.3AB	5.2A	2.7A	53.6A	66.8B	15.5A
	120	353.3B	5.0A	2.1B	50.8A	78.0A	15.2A
	180	560.0A	5.5A	2.6AB	55.9A	62.8C	14.4A

Means with the same letter down column within each variety
are not significantly different (p> 0.1)

At Nakabango, results showed that there were no significant effects of variety, phosphorus rates and on variety X phosphorus interaction on yield and all the other measured yield parameters

(Table 4). Yields, however, tended to increase with higher phosphorus rates. Yields at 180 kg/ha were 44% and 82% higher than the control which had no addition of phosphorus. For NABE 4, the number of plants harvested at 120 and 180 kg/ha of phosphorus was significantly higher than that at 60 kg/ha. The number of plants harvested per square meter was lower than the optimum plant population of 20 plants/m^2.

At NaCRRI, results showed that phosphorus fertilizers did not have a significant effect on all measured traits except the number of seeds per pod for Kanyebwa (Table 5). The number of seeds per pod at 120 and 180 kg/ha of phosphorus were higher than those at 0 and 60 kg/ha of phosphorus for Kanyebwa. For NABE4, yield at 180 kg/ha of phosphorus was significantly higher than that at the lower phosphorus rates. Phosphorus addition further led to significantly higher number of pods per plant than the control for NABE4. The number of seeds per pod at 60 kg/ha of phosphorus was significantly higher than that at 120 kg/ha. Phosphorus addition did not significantly affect the 100 seed weight and number of plants harvested per square meter for NABE4. The harvest index for NABE4 at 180 kg/ha was, however, significantly lower than that of other phosphorus rates studied.

Summary and Implications

Responses to phosphorus fertilization were mixed. 2012A was the third season for repeated application of phosphorus. The low yields observed indicate that phosphorus levels in the soil may still have not built up sufficiently and/or other factors still limit productivity even under seemingly better management of the beans on station. At Nakabango, yields tended to increase with increase in phosphorus for both Kanyebwa and NABE4. At NaCRRI, P fertilization effects were muted and yields were lower than at other trial sites. At Mbarara ZARDI, results showed that yields increased for Kanyebwa while NABE4 had a slight decrease in yield with increasing phosphorus levels. Comparison of seasonal yields shows that yields in 2012A were higher than 2011B at several P levels. At Nakabango, yields for Kanyebwa in 2012A were higher than in 2011B. At the same time, yields for both varieties at NaCRRI in 2012A were generally at least 3times higher than those in 2011B. This could be due to increased available phosphorus or season differences in weather. Phosphorus application did not have a significant effect on plant population (plants/m^2). Generally, the harvest population was lower than the optimum of 20plants/m^2.The low yields observed indicate that phosphorus fertilization alone may not be the answer to the low yields. Further, most of the applied phosphorus may be fixed by the soil, thus making it unavailable for plant growth. It has been reported that aluminum plus iron oxides/hydroxides and calcium compounds absorb phosphorus under acidic and alkaline soil pH conditions, respectively (Turner et al. 2007).

Variety Performance and Farmer Acceptability

Important qualities that farmers consider in accepting varieties include adaptability to a range of soil fertility conditions, tolerance/resistance to heavy rainfall or drought, early maturity, yield, marketability, quick cooking requiring less firewood energy, and taste. Farmers in Kamuli prefer red to pink mottled varieties similar to the local variety (Kanyebwa) that is commonly grown but prone to diseases. NaCRRI tested eight early maturing red and pink mottled varieties. These varieties were not widely accepted by farmers in Kamuli due to low tolerance to drought and/or high levels of rainfall. More varieties will be tested in the coming season for farmer preferences.

Kanyebwa remains farmers' preferred bean variety, being a traditional variety with a very short maturation period (60 days). Of the improved varieties, K132 is the best accepted, followed by NABE and then K131, the variety most tolerant to disease and water stress. K132 is the most preferred improved variety because of its high yielding potential and higher grain weight. Reports about farmers' preferences are being used by breeders to develop varieties which are of acceptable qualities for consumption and marketing. The NaCRRI bean program recently released seven bush bean varieties which are all early maturing with tolerance to drought. These will be tested in Kamuli in the coming seasons for their acceptability in addition to other promising bean lines.

Support Community Based Seed Production by Farmer Groups and Associations

Significant improvements have been recognized as necessary in seed management to effect a successful transition from household-based bean production to market-oriented production. The strategy of community based seed production (CBSP) is being used by farmer groups in Kamuli to achieve two important goals: create viable agriculture based enterprises, and help other farmers access improved seeds in a reliable and timely manner, and at lower cost compared to conventional means. To establish systems for community based production of quality seed that can enable many other farmers to access quality seed, we have trained and supported six farmer groups committed to bean production in accordance with established seed quality standards.

We have been using participatory methods to engage farmers in this process and establish viable and sustainable protocols for seed production, quality control, and storage. Seed producers have been trained in record keeping regarding production costs to accurately determine appropriate selling prices and timing of sale of their produce that result in a profit margin. To ensure sustainability in seed production, refresher trainings in institutional development, collective marketing and establishment of linkages to other existing seed producers and buyers have been done. The training and extension guide for CBSP is complete with modules on agronomy, farm record keeping, and institutional development. Local capabilities have been further strengthened through supervision by the technical specialists from NaCRRI and by information sharing about performances of bean varieties.

Farmer Group

These six farmer groups have been multiplying two preferred improved bean varieties – NABE4 and K132 – during five successive growing seasons. They have increased the acreage for group fields, and even more so on their own household fields. Upon harvest, they retain seed for subsequent planting on both group and household fields, sell some to VEDCO to be used for new demonstration gardens and distribution to other farmers, and sell to institutions, traders and at the market.

Reducing Post-Harvest Losses through Solarization and Hermetic Storage (Triple Bagging)
Solarization and triple bagging have been proposed as effective remedies to maintain grain quality post-harvest. Triple bagging is a technique of storage of grains in air tight environment (hermetic storage) using three bags, one on the inside of the other (two inner HDPE plastic bags and a strong outer woven polypropylene sack/bag). Solarization is a technique of killing insects and larvae by exposure to high temperatures. In this study, effects of triple bagging storage and solarization on beans and maize post-harvest losses and germinability were studied. Maize and beans obtained from local markets were dried to 12-13% moisture content. 20 kg of grain were inoculated with 20 live insects obtained from badly damaged beans and maize.

Beans and maize were triple bagged and stored for seven months. Moisture content, broken grains, foreign material, insect damage, number of live/dead insects and germinability were determined periodically. Triple bagged bean and maize samples retained > 80 % germinability and grain quality after three months of storage (Tables 6 and 7). After four months, germinability reduced to 75%, but grain quality remained constant. However, the bean control sample (a single woven plastic bag) showed significant deterioration in quality after four months, with germinability reducing to 56%, moisture content increasing to 15%, and with significant numbers of live and dead insects. Triple bagging was even more effective for maize, maintaining grain quality and germinability (> 90%) even after seven months of storage. Maize control samples significantly deteriorated in quality after seven months of storage with germinability dropping to 36%, moisture content increasing to 14%, with significant numbers of live and dead insects.

Table 6: Germinability and Grain Quality Parameters of Triple Bagged Beans by Storage Time

Time (mo.)	Germinability (%)	Moisture Content (%)	Live Insects (number)	Dead Insects (number)	Damaged and Split (g/250g)	Foreign Matter (g/250g)
0	87.0 ± 2.646^a	13.0 ± 0.773^a	0.0 ± 0.000^a	0.0 ± 0.000^a	3.32 ± 0.027^a	0.37 ± 0.035^a
1	82.0 ± 4.359^a	13.1 ± 0.153^a	0.0 ± 0.000^a	0.0 ± 0.000^a	2.72 ± 0.035^a	0.54 ± 0.020^b
2	80.0 ± 3.606^a	13.2 ± 0.200^a	0.0 ± 0.000^a	0.0 ± 0.000^a	1.08 ± 0.030^a	0.37 ± 0.062^a
3	83.0 ± 1.000^a	13.1 ± 0.520^a	0.0 ± 0.000^a	0.0 ± 0.000^a	1.82 ± 0.027^a	0.45 ± 0.026^a
4	75.0 ± 4.823^b	12.9 ± 0.173^a	0.0 ± 0.000^a	0.0 ± 0.000^a	0.07 ± 0.017^b	0.08 ± 0.030^a

Figures in a column with different letters as their superscript are significantly different.

Table 7: Germinability and Grain Quality Parameters of Triple Bagged Maize by Storage Time

Time (mo.)	Germinability (%)	Moisture Content (%)	Live Insects (number)	Dead Insects (number)	Insect Damaged (g/250g)	#BCFM (g/250g)
0	96.0 ± 0.577[a]	12.6 ± 0.100[a]	0.0 ±0.000[a]	0.0 ± 0.000[a]	0.23 ± 0.025[a]	0.26 ± 0.046[a]
1	97.0 ± 1.000[a]	12.8 ± 0.100[a]	0.0 ±0.000[a]	0.0 ± 0.000[a]	0.33 ± 0.046[a]	0.32 ± 0.053[a]
3	95.0 ± 1.000[a]	13.1 ± 0.100[a]	0.0 ±0.000[a]	3.0 ± 2.646[b]	0.60 ± 0.036[b]	0.56 ± 0.035[b]
5	93.0 ± 1.000[a]	13.6 ± 0.000[b]	0.0 ±0.000[a]	0.0 ± 0.000[a]	0.32 ± 0.036[a]	0.57 ± 0.020[b]
6	91.0 ± 2.517[a]	13.2 ± 0.200[b]	0.0 ±0.000[a]	0.0 ± 0.000[a]	0.72 ± 0.044[a]	0.24 ± 0.017[a]
7	91.0 ± 1.000[a]	13.4 ± 0.265[b]	0.0 ±0.000[a]	0.0 ± 0.000[a]	0.11 ± 0.053[a]	0.07 ± 0.035[b]

Figures in a column with different letters as their superscript are significantly different.
#BCFM- Broken Corn Foreign Material

Solarization of beans and maize, inoculating with live insects, was achieved by placing 1cm thick layer of grain on black polythene, covered by transparent polythene under the sun. The effects of solarization were studied through hourly determination of dead and live insects in the grain over a period of six hours. Solarization led to death of inoculated insects after six hours, more so in beans than in maize probably due to the dark colors of bean seed coats that better absorb and retain heat (Tables 8 and 9). In conclusion, solarization and triple bagging are effective technologies in reducing post-harvest losses in beans and maize. The effect of solarization on the viability of beans needs to be assessed before recommending the method as suitable for handling seed in addition to handling grain.

Table 8: Effect of Solarization on Insect Viability in Bean Grain

Time (hours)	Temperature (^{0}C)	Dead Insects (number)	Observations
1	29	0	Moving insects
2	48	0	Moving insects
3	54	4	Both dormant and moving insects
4	64	9	Both dormant and moving insects, a few dead
5	75	16	Most dead, remaining dead
6	82	20	All dead

Table 9: Effect of Solarization on Insect Viability in Maize Grain

Time (hours)	Temperature (^{0}C)	Dead Insects (number)	Observations
1	32	0	Moving insects
2	45	0	Moving insects
3	53	2	Both dormant and moving insects
4	58	5	Both dormant and moving insects, a few dead
5	68	14	Many dead remaining dead
6	78	20	All dead

Evaluate Adoption of Improved Integrated Crop Management Practices and Technologies
Nearly 1000 farmers have participated in on-farm training sessions for many of the integrated crop management practices and technologies. Many were supported with materials to implement these practices, though budget limitations did not allow complete support for all farmers who received training. Extension materials (posters, PowerPoint slides, locally shot and animated video clips) have been finalized and translated into Luganda for the integrated crop management practices that have proven to be effective and feasible for smallholder farm production of common beans in Uganda. These included improved field site selection, incorporation of compost and manure into soils, optimizing plant and row spacing, scheduling of weeding, integrated pest management, grain harvest/threshing, post-harvest drying on tarpaulins, grain moisture monitoring and grading, and hermetically-sealed triple-bag storage. Training involved interactive discussion, multi-media tools, and own-farm demonstrations.

We view triple bagging as a suitable method for long-term (3-6 months) storage of seed and grain that minimizes qualitative and quantitative losses of product. The triple bagging technique has numerous advantages, including flexible storage volume, re-usability of bags, and manageable volume of individual bags (50-100 kg). This flexible storage approach is being evaluated as a means of meeting the emerging need for bulk storage on farm or at community collection sites for collective marketing to increase farmer access to emerging markets.

In mid-2012, a sample survey was conducted of farm households (n=132), which varied in terms of the number of growing seasons since their training. The results concerning awareness and implementation of production, post-harvest, processing and marketing practices are presented in Table 6.

Table 9: Awareness and Implementation of Production, Post-Harvest, Processing &Marketing Practices

CROP MANAGEMENT PRACTICES	Awareness Level	Implementation Level		
	Taught Others or Received Training	Already Do	Definitely Will	Interested
PRODUCTION				
Manure Application	87.8	34.1	4.5	47.7
Germination Test	84.9	41.2	2.3	48.1
Field Preparation	93.2	62.9	1.5	33.3
Line Planting	96.2	61.4	0.8	35.6
Timely Weeding	95.5	63.6	0.8	34.8
Pest Management	87.3	42.4	2.3	42.4
Disease Management	76.5	40.9	2.3	43.9
POST-HARVEST				
Timely Harvesting	91.7	61.4	1.5	35.6
Drying on Tarpaulin	87.1	50.8	3.0	38.6
Gently Threshing	84.0	59.1	0.8	31.1
Solarization	80.3	48.5	3.0	38.6
Cleaning	91.0	56.8	0.8	39.4
Airtight Storage	83.4	50.8	0.8	42.4
PROCESSING				
Soaking and Malting	65.2	31.8	6.1	42.4
Flour Making	68.9	30.3	6.1	43.2
Make Snacks/Cakes for Sale	68.1	29.5	4.5	46.2
COLLECTIVE MARKETING				
Participate in Group Sales	79.6	40.2	8.3	40.2
Active Leadership Role	71.8	34.6	7.7	44.6
Packaging and Labeling	67.2	33.6	6.9	43.5

Nearly all households received training in production and post-harvest management practices. Moreover, many among them were involved in demonstrating the practices to other farmers. Among these, the vast majority of farmers already do engage in these practices, definitely will, or are interested in doing so. Practices that demonstrate the highest level of current implementation concern field preparation, line planting, timely weeding, timely harvesting, drying on tarpaulins, gentle threshing, cleaning, and hermetic storage. Those with somewhat lower current levels of adoption involve material costs (manure application, germination test, pest and disease management, and solarization), though interest in them is also high. Approximately two-thirds of the farmers received training in processing (soaking and malting, flour making, and making snacks/cakes for sale), with just under one-half of them already engaged in these practices, with a larger proportion interested in beginning to do so. Collective marketing activities (participation in group sales, active role in leadership, and packaging and labeling) are similarly characterized, with slightly higher current levels of implementation. Among the relatively small number of farmers who are not likely to adopt these practices, three reasons were equally common - can't access materials, can’t afford the materials, or not worth the effort/time/cost involved.

Strengthen Learning and Sharing of Innovative Practices

The project team has organized three meetings to share results from our research and development efforts, and to strengthen the learning network. The first was a value chain stakeholder forum in Jinja (near Kamuli District) in May 2012. The Forum had three main objectives: characterize the bean value chain in the context of Kamuli; engage key stakeholders in the identification of current functioning, opportunities for improvement and constraints; and develop a realistic action plan delineating the way forward in chain development. Forum participants were farmers, input dealers, traders (wholesalers and retailers), credit providers (FINCA and Finance Trust), institutional consumers (schools, hotels, health units), NGOs (VEDCO, Africa 2000, RUCODE), local government (Chief Administrative Officer, District Health Officer, District Agricultural Production Officer, NAADS Coordinator), research and academia (NaCRRI and Makerere University), processors (Nutreal), nutritionists and sales outlets (supermarkets). Important opportunities for improvement that will benefit all value chain actors were identified by participants: input suppliers (more effective communication with farmers, training of input dealers by the Uganda National Agro-Input Dealers Association, and government regulation of the seed industry), traders (dissemination of market information, training of farmers and other traders to separate varieties and maintain high quality), market information suppliers (wider dissemination of information, training farmers to strengthen their interpretation of market data), and processors (scaling up production, linkages with research and financial institutions, packaging).

Value Chain Forum

The second sharing activity was our project dissemination workshop held in Kampala in July with a range of key stakeholders participating. Complementing members of the five project institutions were researchers from other disciplines and institutions, representatives of the Ministries of Agriculture and Health, CIAT, HarvestPlus/IFPRI, Farm Radio, TechnoServe, and USAID. Workshop participants suggested involving additional value chain actors at initial project stages and enhancing gender dimensions in project design and implementation. They expressed interest in building on the project’s successes: promote value addition processing; enhance the nutritional content of bean based products; include other bean varieties in future experiments; investigate expanded markets for beans; broadcast project findings through Farm Radio Africa; and facilitate access to microfinance among farmer groups.

Dissemination Workshop

The third sharing activity is the final Farmer Field Day to demonstrate and disseminate recommended management practices and technologies for integrated crop management. This will take place at the end of the second season in 2012, on November 27, 2012.The theme is "*Enhancing Sustainable Agriculture Technologies for Food and Nutrition Security through Knowledge Transfer*." Training modules and materials have been compiled for production, post-harvest handling, processing, and marketing. Community Based Trainers (CBTs) in the CSRL Sustainable Rural Livelihoods Program in Kamuli have completed the Training-of-Trainers activities. Farmers and CBTs will lead the dissemination of innovative management practices and technologies. Participants will include farmers, district agriculture and community development officers. We anticipate that these activities will inform, inspire and benefit hundreds of additional farmers in Kamuli.

Scaling up dissemination and adoption of recommended practices and technologies has already begun in Uganda. Specific practices that are already incorporated into VEDCO project activities in some other districts, funded by various donors, are: establishing direct links between project communities and NaCRRI to obtain high quality seed and varieties for farmer-based experimentation; use of training materials developed through the CRSP project; community based seed production systems; and hermetic storage of grain and seed. Given that farmers' and consumers' preferences for bean varieties tend to be region specific, on-site participatory trials and local capacity building are essential, particularly if community based seed production is envisioned as a key element in a strategy to increase quality and quantity of grain for consumption, collective marketing, and processing. A community based extension system, such as that currently used by VEDCO, complemented and amplified by information and communication technologies, also seems essential. Institutional capacity building of researchers and NGO extension officers can occur through workshops and linkages with other beans projects.

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

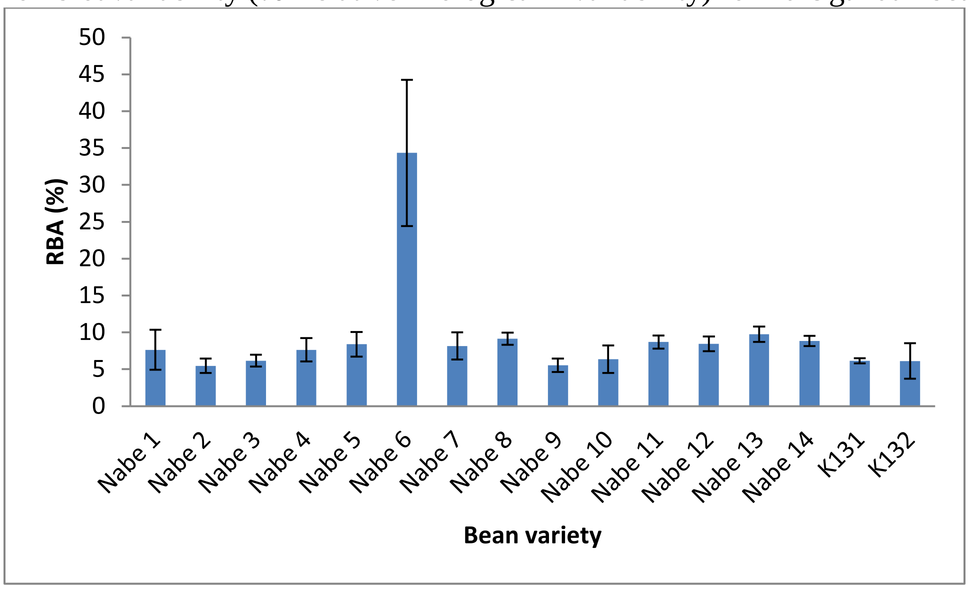
During phase I, our pre-processing methods developed bean flour with significantly reduced cooking times (15 minutes). Recipes utilizing the fast-cooking bean flour in rural communities were developed through a participatory community based competition and field day in 2010. In Phase II, we sought to promote increased bean consumption among farming communities and urban consumers who can realize the nutritional and health benefits, and benefit from reduced cooking time and monotony in the diet. The first component involved understanding and communicating consumer preferences regarding culinary properties and sensory characteristics of existing and improved bean varieties to national bean breeding programs and the private business sector. The second component involved engaging the private business sector in value addition and commercialization of bean products to open up new markets for bean producers. The third component, reflecting the opportunity to enhance children's daily nutrient intake through increased consumption of beans and bean products, we developed products that are practical, useful in school settings, and acceptable to students. Institutional buyers such as schools, hospitals, and humanitarian agencies have been identified as potential markets for beans and bean products.

Modeling Iron Bioavailability in Beans and Establishing Effect of Extrusion Cooking

Beans are high in iron content (30-90ppm) and are an important source of iron in developing countries. However, the iron has very low bioavailability (2-5%) due to the high content of polyphenols and phytates, factors known to inhibit iron bioavailability. Strategies to improve beans' contribution to iron nutrition include (1) increasing iron concentration, (2) improving bioavailability or (3) increasing both. Our research screened for iron bioavailability in Ugandan bean varieties and established effects of extrusion cooking. Iron bioavailability of beans was determined using an *in-vitro* digestion/Caco-2 cell culture model and modeled with respect to bean phyto ferritin, iron, polyphenol and phytic acid content (Proulx & Reddy 2006). There were significant differences in the chemical composition and iron bioavailability of the bean varieties ($p < 0.05$). Polyphenol content ranged from 0.2-1.76 mg/g; phytate, 0.19-1.6%; iron, 57.3-90.6 µg/g; bean ferritin, 285-495 µg/g, and relative biological availability (RBA) from 5.5 to 34.3%. RBA of white seed coat varieties (34.3%) was significantly higher ($p < 0.0001$) than in colored seed coat varieties (5-10%; Figure 1). A fixed effects multiple regression model showed that polyphenol content, iron content and their interaction were significant model terms. Linear effects of polyphenol and iron content decreased iron bioavailability while their interaction increased it.

Effect of extrusion cooking on iron bioavailability of NABE6, a Ugandan white seed coat bean variety, was also determined. Three extrusion cooking process variables; raw material moisture content (15-35% wb), extruder die temperature (120-175^{0}C) and feed flow rate (1.8-3 kg/h) were varied and Response Surface Methodology (RSM) techniques used to optimize process variables with respect to final viscosity, consumer acceptability and iron bioavailability. RBA of extruded beans was 54-389%, a 1.5-10 fold increase on that of conventionally cooked white beans (34.3%). Extruder die temperature had a significant effect on each significant model; its linear effect decreasing overall consumer acceptability, expansion ratio and pasting profile but increasing iron bioavailability. The optimal combination of extrusion variables was 15% moisture content, 120^{0}C die temperature and 3 kg/h feed flow rate. Model validation experiments' results revealed that all responses with significant models can be reliably predicted.

Figure 1: Iron bioavailability (% Relative Biological Availability) for 16 Ugandan bean varieties



Differences significant at $p < 0.0001$; data shown as Mean ± SD

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

We hypothesized that availability of acceptable alternative ways of preparing beans will result in increased bean consumption. The central hypothesis regarding farmers' adoption, adaptation and sustained use is that a coordinated strategy of technological innovation to facilitate ease of utilization of bean-based foods and ongoing evidence of nutritional and economic benefits of beans are likely to create sustainable increased consumption of beans within communities. Moreover, Phase I results revealed a disparity between breeding for agronomic hardiness and end user requirements, since new high yielding bean varieties were not necessarily of optimal nutrition and consumer acceptability. Phase II analyzed consumers' sensory, culinary and processing requirements and informed national breeding programs. We hypothesized that interfacing with bean breeders and providing critical information on expectations of end users (consumers and processors) will, over time, lead to development of sustainable and consumer acceptable varieties.

Key Phase II activities involved developing and utilizing appropriate extension information education and communication (IEC) approaches (nutrition, processing of bean based products) for rural community nutrition and health workers to accelerate and multiply positive rural development impacts. In both Uganda and Rwanda, manuals and posters on improved methods of bean preparation (soaking and germination) that enhance cookability and nutrient bioavailability were developed. Further, a manual on feeding children ages 6-59 months was developed to increase awareness of the benefits for children of adequate feeding practices involving adequate nutrient and energy intake, and to enhance capabilities in doing so. In Uganda, a brochure (translated into Luganda) was prepared, based on the manual explaining the improved methods of cooking beans. This brochure explained the processes of soaking, germination and cooking. Another manual was developed to facilitate training mothers on preparation of porridge using bean-based composite flour, covering the ingredients and processing protocols. Print media (posters and brochures) will be used by VEDCO during its training sessions and disseminated during community and stakeholders' meetings.


Village Food Preparation


Baked-Fried Foods

In Rwanda, KIST faculty, staff (Nutritionists - Food Processing) and two final year B.Sc. students trained 60 Community Health Workers (CHWs) from three Health Centers - Rukomo, Mimuli and Nyakigando. Nyagatare District has 20 Health Centers, indicating ready potential for scaling up impact. Posters were prepared in local languages and distributed during training of 60 Community Health Workers at Nyagatare. Topics covered included nutrition and its relationship to health, importance of their role as volunteer health workers, bean flour pre-treatments and processing, bean-based soup processing, and utilization of simple ‘cold extrusion’ technology (using hand-operated presses) at community level with processed (sprouted, fermented) beans and maize.

Village Food Preparation Training

Village Taste Test

Analyze Culinary Properties, Sensory Characteristics, & Consumer Acceptability of Improved Varieties

Linkages between academic research institutions and national agricultural research institutions responsible for bean breeding are important to increase the likelihood that the results of breeding program efforts correspond to traits and characteristics that consumers accept and prefer. Toward this end, project researchers analyzed culinary properties of improved bean varieties and their sensory characteristics (color, texture, taste, flavor, etc.) and assessed consumer acceptability of improved bean varieties in Uganda (from NaCRRI) and in Rwanda (from ISAR/RAB).

Culinary and sensory properties of 18 improved varieties were screened in order to inform the breeding programs regarding consumer acceptability of new varieties. A rapid method for screening cooking qualities of beans and cowpeas (provided by Dr. Amanda Minnaar at the University of Pretoria) was used to evaluate the culinary properties. An untrained consumer panel evaluated sensory properties instead of a trained panel. Culinary properties studied include weight gain after soaking and cooking, solids content (^{0}Brix) of soaking water and the cooking broth, degree of pigment leaching into soaking water, number of split seed coats and cotyledons after cooking as well as determining the cooking time. Solids content of soaking and cooking water and broth were measure using a hand-held refractometer (AOAC 2012). The improved varieties studied were: NARBL 110-2, NARBL53-3, NARBL-60, NARBL 224-1, NARBL 220, NARBL 252, NABE 2, NABE 3, NABE 5, NABE 7C, NABE 8C, NABE 9C, NABE10C,NABE 11, NABE 13, NABE 14, NABE 16 and K131. The local varieties studied were: White, Masavu, Kahura, Nambale-long, Nambale-short, Kanyebwa, Kankulyembaluke, Yellow-short and Yellow-long. Makerere University, Department of Food Technology & Nutrition has acquired a Mattson bean cooker which will be used to precisely verify cooking time characteristics.

Overall, the local varieties were significantly preferred in terms of color, texture, flavor as well as taste compared to the improved varieties. Consumer rating of taste of improved varieties ranged from 6.3 to 7.5 on a 9 point hedonic scale (where 1 = dislike extremely and 9 =like extremely) while that of local varieties ranged from 7-8.9. Overall, acceptability of improved varieties ranged from 5.6-7.6 while that of local varieties ranged from 7-8.8. Consumers' liking for color, flavor, texture, consistency and broth color followed a similar trend, with local varieties generally preferred to improved ones. There was, however, no significant difference ($p>0.05$) between consistency, broth color and overall acceptability of the local and improved bean varieties.

Bean weight gain on soaking ranged from 22-38% and did not correlate with cooking time. Generally, improved bean varieties gained slightly more water than local ones. Leaching of solids on soaking and on cooking was higher in improved varieties than local ones, though the difference was not statistically significant (Figure 2).

Generally, improved bean cooked in a shorter time than local varieties (Figure 3). The majority of improved varieties (NABE 3, NABE 7, NABE 13, NABE 7C, NABE 2, NABE 14, NABE 11, NABE 8C, NARBL 220, NARBL 53-3) cooked within 60 minutes, while the majority of the local varieties (White, Kahura, Nambale-long, Nambale-short, Yellow-short, Yellow-long and Kankulyembaluke) required more than 60 but less than 120 minutes. Protein, zinc and iron content of local and improved varieties were also determined. Overall, improved varieties showed higher protein content but lower zinc content than local ones, though differences in composition were not statistically significant. Protein content of improved and local varieties ranged from 20-25% and 19-24%, respectively; these differences were not statistically significantly ($p>0.05$).

Figure 2: Brix of Soaking Water and the Broth in Degrees, Local and Improved Bean Varieties

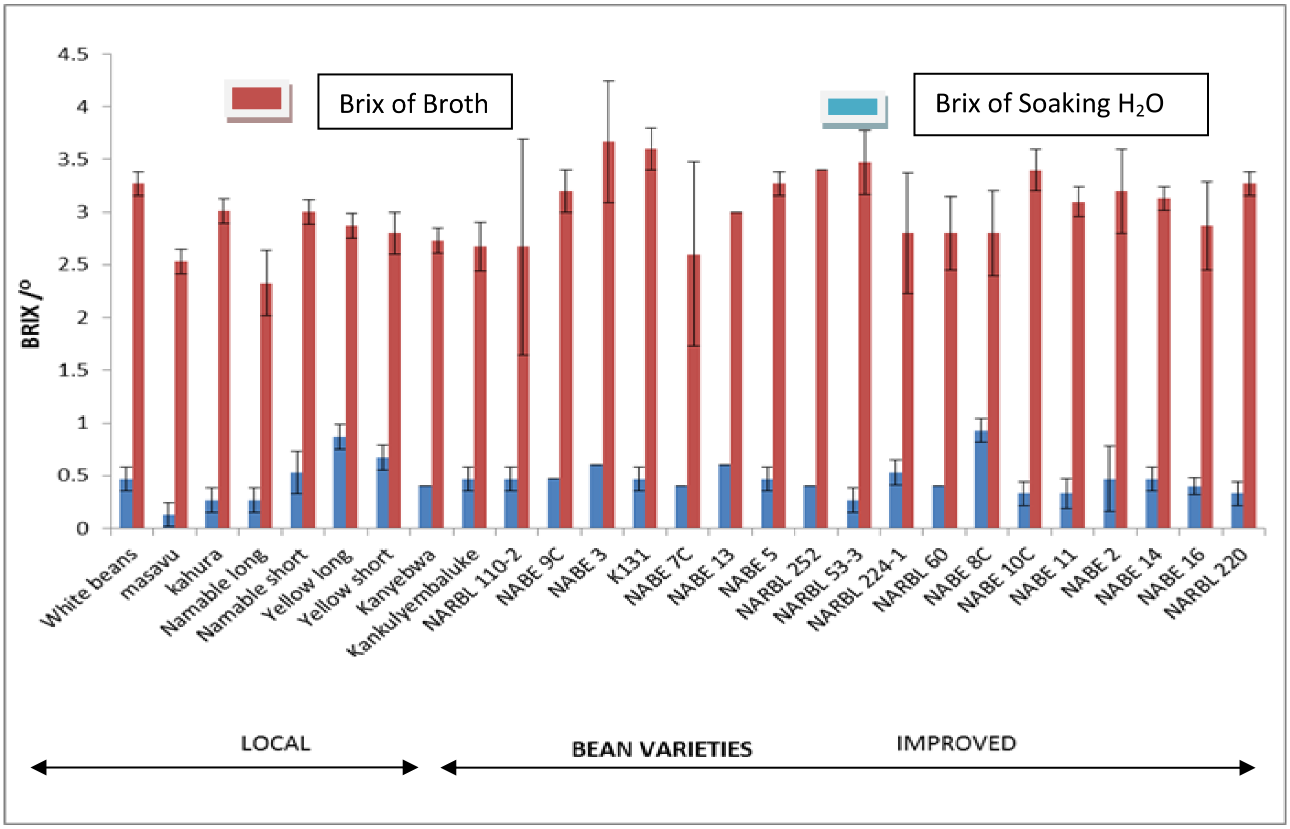
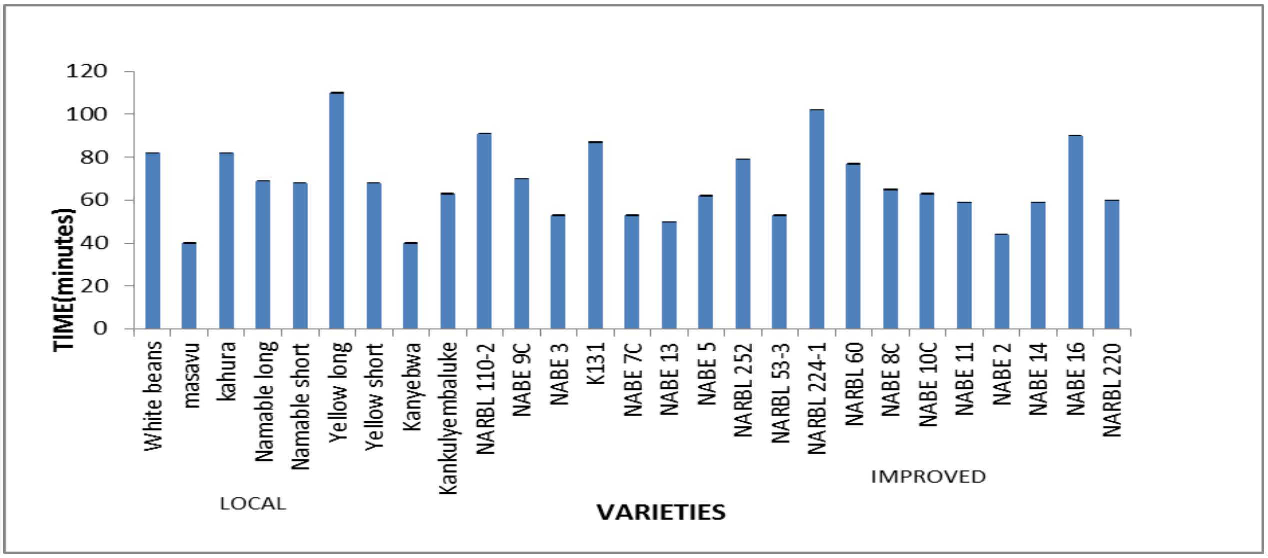


Figure 3: Cooking Time of Local and Improved Bean Varieties



Iron content of the improved and local varieties ranged from 10-14.5 mg / 100g and 9.9-13 mg / 100g respectively and the difference was not statistically significant ($p > 0.05$). Zinc content, on the other hand, ranged from 1.6-4 mg / 100g and 1.9-4.4 mg / 100g for improved bean and local varieties, respectively, but was not statistically significantly different ($p > 0.05$). The results were not surprising since the improved varieties analyzed did not include any of the micronutrient enhanced varieties.

Two B.Sc. students in Food Technology & Nutrition at Makerere University conducted research on the culinary traits and sensory characteristics of local and improved bean varieties (Nassozi & Mbaziira 2012). The students' final report was shared with team members at NaCRRI: Dr. Michael Ugen, Principal Research Officer of Bean Research and Development Program; Dr. Michael Otim, Research Office/Crop Entomologist, National Cereals and Beans Research Programs; and Dr. Stanley Nkalubo, bean breeder. Applied Human Nutrition M.Sc. student, Rose Nkundabombi from KIST (Rwanda), is furthering the research on culinary and sensory properties of local and improved bean varieties. The results of her work will also be communicated to the stakeholders. In parallel research, three B.Sc. students in Food Science & Technology at the Kigali Institute of Science and Technology evaluated culinary properties of 16 bean varieties newly released by ISAR in Rwanda (Mushabe, Ndahabwa and Ndayisaba 2012). Information derived from analysis at KIST of culinary and sensory properties of the 16 improved bean varieties was incorporated into training of 60 Community Health Workers in Nyagatare District, Rwanda.

The tactile method typically used to measure cooking time of local and improved bean varieties is subjective and may not provide consistent results. The Mattson cooker, which measures cooking time using weighted plungers, is objective and much more precise. An automated Mattson Bean cooker, designed by the Canadian Grain Council, was custom made and purchased from the manufacturer (Customized Machining and Hydraulics Limited, Winnpeg, Manitoba, Canada). Electronic parts for the cooker were supplied by Holowich Electronics Inc., Manitoba, Canada. The mechanical cooker has been tested. The cooker will be fully functional with the pending arrival of the special boiling pan, hotplate, digital input/output card from Measurement Computing, Norton, Massachusetts, USA, and software license from the Canadian Grain Council.

A Memorandum of Agreement was signed in September 2012 between CIAT/PABRA and Makerere University, College of Agricultural and Environmental Sciences. The aim of the collaboration is to implement activities leading to improvement of food and nutrition security for vulnerable communities. Specifically, MUK Department of Food Technology & Nutrition will:

- Develop value-added products consumable by vulnerable groups, such as bean flour and bean-based flour from high iron bean varieties.
- Assess the effect of processing on aflatoxin levels in bean products.
- Evaluate the nutritional and physical-chemical properties of the bean-based products, including sensory, nutritional and shelf-stability; macro- and micro-nutrient retention will be determined.
- Develop bean recipes incorporating the developed bean and bean-based flours and translate them into local languages. The developed recipes will be promoted in schools and to NGO partners.
- Test the acceptability of foods from the developed recipes among target consumers.
- Assess culinary and sensory properties of pre-released and new improved bean varieties.

In addition, a research concept has been requested by HarvestPlus for R&D on iron-enhanced beans (efficacy and other studies), and is being developed by faculty in Makerere University's Department of Food Technology & Nutrition.

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

The project team has established a partnership with the private business sector to promote adoption of value addition to increase bean consumption and create new market outlets. Bean varieties that are high yielding and stress resistant but have low consumer acceptability and are prone to being hard-to-cook were selected for value addition and product development in phase I. In phase II, processing protocols were refined and up-scaled through the Technology Business Incubator (TBI) model to promote technology transfer to the private sector. TBIs are effective frameworks for fostering industrial uptake of new technologies by providing entrepreneurs with a supportive environment to help establish and develop their projects (Lalkaka 1996). We hypothesized that by providing services (product refinement and optimization, up scaling, test marketing, access to funding/loans) on a 'one-stop-center' basis and enabling overhead costs to be reduced by sharing facilities, the TBI model will significantly improve the establishment and growth prospects of bean processing enterprises in their early stages of development. Through project activities, private sector partners are now better linked to farmer organizations for mutual benefit in value addition activities.

Bean flour production was piloted in Makerere University's FTBIC in partnership with Nutreal Ltd. Six month shelf-life studies of the bean-based flour were completed by a B.Sc. Food Science & Technology student, with support from the project. Bean-based flour was test-marketed in the Food Parlour at the School of Food Technology, Nutrition & Bio-engineering at Makerere University. Sales are growing steadily as consumers become aware of and try the bean-based flour, both for sauce and porridge. Appropriate packaging materials have been developed and tested. The major considerations for selecting the appropriate packaging materials were: the moisture content of the flour (9.2%); the proximate, specifically fat composition (2.6%, as all grains were milled whole), and the intention to add no preservatives to the products. Bi-layer packaging was therefore selected to reduce moisture pick up and lipid oxidation during storage. Paper bags (100 gm / m^2) with a slightly glossy surface were tested as secondary package and together with Biaxially Oriented Polypropylene (BOPP) film as primary packaging. BOPP was selected for its unique combination of properties, including printability, seal-ability and moisture barrier. Printability was important because of the widespread existence of counterfeit products in the Uganda and regional markets. The primary package was therefore branded to reduce the chances of counterfeiting. Seal-ability was important to ensure fast holding of the heat seal. Good moisture barrier properties were important, to reduce moisture pick up from the environment during storage.

The private sector partner, Nutreal Ltd., invested in bulk production of packaging materials and human resource. The pre-tested packaging materials were finalized (secondary paper packages were graphically designed, printed and formed into paper bags). The BOPP film (primary packaging) was designed, printed and formed into tube rolls. Staff (both casual and technical) was hired and production of the bean-based flour up-scaled at Makerere's FTBIC. Two distribution systems for the products have been tested - through an intermediate food product distribution company and directly through a merchandiser hired by Nutreal branded products are being sold in 15 of the largest supermarkets in Kampala city. The merchandiser promoted products at the sales outlets. Bean soup and porridge were prepared and served to potential customers for tasting. Information leaflets were distributed and customer questions answered. Promotion and marketing through a nutritionist was also piloted. An M.Sc. Applied Human Nutrition student, who developed the bean flour processing protocol, was engaged for four months, to promote the bean-based products. She approached organizations and institutions such as corporate companies, schools, hospitals and clinics, to introduce the product and educate potential consumers on its nutrition and health benefits. E-marketing using mass emailing was also piloted. A mass email advert was designed and sent out to about 25,000 potential consumers, with information on the product, outlets where it could be found, and contacts for accessing additional information, via the website or telephone. An interactive website, with information and a counter to monitor visits to the website was set up and used to monitor effectiveness of the above methods, besides being a direct marketing tool. A counter on the Nutreal website keeps track of client interest. Nutreal produces weekly and monthly sales reports to show trends.

Farmers are being prepared to be suppliers through collective marketing, by teaching them post-harvest techniques to maintain the quality of their beans. Farmers groups are also being strengthened by VEDCO, both for production of grain and seed. Progress has been made regarding production of seed, which is sold to community members. Availability of good quality seed is expected to lead to increased bean production. When farmers' groups have adequate volumes, quantities of beans supplied for processing will be recorded and monitored.

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

Farmers in Kamuli own and cultivate an average 1½-3½ acres, and one-half borrow or rent land (averaging 1 acre) for their agricultural activities. Most were growing maize and beans, but initially few (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.

Project households have increased the area planted in beans by approximately 50% to the current size of ½-¾ acre. They have increased market participation in beans, with 50% more smallholder farm households now producing beans in sufficient quantities to earn income by selling some (currently 65% of farm households). Improved crop management practices and technologies have stimulated market participation, as they have effectively increased the quantity available for sale (median sale 50 kg). Basic value addition activities such as proper drying, sorting, grading, storage that minimizes insect infestation and damage, have helped improve quality, demand, and price. Our results to date demonstrate the importance of reliable access to market information that is timely, strengthening farmer groups, and establishing associations that can effectively engage in collective marketing with various types of buyers, including the food processing industry.

The project in Uganda has sought to strengthen the collective marketing capability of farmer groups. As farmers begin to think and act as business persons, they demonstrate improved understanding of market price variations, skills to obtain higher prices resulting from improved post-harvest grain handling, better coordination of grain bulking and storage at the community level, and negotiation skills. In addition, the project provided assistance to farmer groups to develop business plans, to improve record keeping and analysis, to promote gender equity and better functional group dynamics, and to create opportunities for farmers to visit and learn from successful farmers and seed production groups. With selected groups, local community based production and sale of quality seed has been promoted to improve widespread smallholder farmer access to improved varieties and other yield enhancing inputs.

A multi-stakeholder bean value chain forum (farmer marketing groups and associations, government agencies, non-governmental organizations, private sector traders, transporters, distributors, and processors) has been established to enable participants to identify key constraints and solutions for broad-based successful market participation. As a result of the stakeholder forum held in May in Jinja (already described in detail under Objective 1 above), the bean farmers have established stronger links with traders. Further, input traders have started to extend their services to farming communities, and are willing to provide some advisory services. Tulemereko Agro-Input Dealers, a subscriber to Uganda National Agro-Input Dealers Association (UNADA), is willing to establish demonstrations within the community to promote its inputs, especially seed, pesticides and fungicides. Through VEDCO's partnership with

AGRINET, bean farmers are now accessing information on market prices of beans from the different regional markets, as well as the bean varieties that are on high market demand. These markets range from the local markets in Kamuli to those in the city center and at diffuse Kenyan border points of Malaba and Busia.

Participating in the CRSP project has enhanced farmers' assets and capabilities, both individually and collectively. Their social capital has been enhanced through strengthening their groups and the connections made with other groups locally 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 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. Our efforts to support development through the bean value chain stakeholder forum has already enabled project farmers to establish contacts with organizations that provide microfinance services.

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

Project researchers have mentored students' research and report writing and guided integration of student research projects within the broader set of research and development activities. At the Master's level, Catherine Ndagire, M.Sc. student in Human Nutrition at Makerere University, has completed her research. She pilot tested the extension materials in Kamuli District that were developed through her work. She submitted her thesis, which is currently under examination by internal and external examiners, after which she will schedule the defense. George Jjagwe, M.Sc. student in Agricultural Extension and Innovation Studies, completed data analysis and has prepared a complete draft of his thesis which is currently under review by his advisory committee. Marie Grace Nkundabombi, M.Sc. student in Food Technology (from KIST in Rwanda) has completed her first year of coursework at Makerere University. Her research concept has been approved and she is writing the full proposal; a source of funds to support her research during the second year has not yet been identified. Aisha Nakitto Musaazi, M.Sc. student in Applied Human Nutrition at Makerere University, passed her thesis defense, and submitted the final thesis; she will graduate in January 2013. Simon Okiror, Agricultural Economics, successfully defended his thesis and graduated. A manuscript from his thesis is being prepared for journal publication.

At the Ph.D. level, Martin Mutambuka, Ph.D. student from Uganda in Food Science and Human Nutrition at Iowa State University, defended his dissertation in May 2012, and is finalizing revisions. Dissertation title: "Iron bioavailability and consumer acceptability of extruded common bean (*Phaseolus vulgaris*) flour." Gerald Sebuwufu, Ph.D. student from Uganda in Crop Physiology and Sustainable Agriculture at Iowa State University, plans to defend his dissertation in December 2012 and graduate during Spring 2013. Dissertation title: "Physiology of Genotype x Soil Fertility Effects on Yield and Accumulation of Seed Iron and Zinc in Common Bean (*Phaseolus vulgaris* L.)."

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

- Mazur R (2012) "Improving Production, Nutrition, Marketing and Livelihoods – Bean Value Chain R&D in Uganda." The Role of Agricultural and Food Systems Research in Combating Chronic Disease for Development.2nd Annual LCIRAH Agri-Health Workshop. School of Oriental and African Studies, University of London. London. July 2-3.
- Mazur R (2012) "Integrating Agricultural Production, Nutrition and Marketing for Sustainable Livelihoods and Well-Being in Africa." Sustaining Health in a Changing Environment: Creating a Resilient Future. Nutrition and Wellness Research Center Symposium. Iowa State University, Ames, Iowa. May 16-18.
- Mazur R (2011) "Value Chains - How Can They Achieve Food and Nutrition Security Goals?" West Africa CAADP Nutrition Program Development Workshop. Dakar, Senegal. November 9-12.
- Nakimbugwe D (2012) "Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda (April 2008 – Sept. 2012). Project Overview, Key Achievements and Way Forward." Presented at the In-Country CRSP Projects Meeting.School of Food Technology & Nutrition Conference Hall, Makerere University, Uganda. April 25.
- Nakimbugwe D (2012) "Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda (April 2008 – Sept. 2012). Project Overview, Key Achievements and Way Forward." Presented to the Dry Grain Pulses CRSP External Evaluation Team. School of Food Technology & Nutrition Conference Hall, Makerere University, Uganda. June 29.
- VasanthakaalamH (2012) "Enhancing Nutritional Value and Marketing of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda." Project report presented at the Kigali Institute of Science and Technology, Kigali, Rwanda, August 17.
- Habnshuti P, Bagirishya A, Vasanthakaalam H, Karayire A, Nyagahungu I, Mazur R,& D Nakimbugwe (2012) "Development of Nutrient Dense Bean Based Composite Flour for Soup." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. February 13–17.
- Mazur R, Ugen M, Bwambale N, Sebuwufu G, & D Nakimbugwe (2012) "Disseminating Improved Bean Production Management Practices and Technologies and Strengthening Marketing Capabilities." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. Feb. 13–17.

- Sebuwufu G, Mazur R, Westgate M, & M Ugen (2012) "Improving the Yield and Quality of Common Beans in Uganda." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. February 13–17.
- Mutambuka M, Hendrich S, Murphy PA, & MB Reddy (2012) "White Common Beans (Phaseolus vulgaris) have Higher In vitro Iron Bioavailability than Colored Seed Coat Varieties." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. February 13–17.
- Ndagire CT, Nakimbugwe D, Muyonga JH, Reddy MB, Hendrichs S, &P Murphy (2012) "Nutrient Density and Acceptability of Bean-Based Composite Flour Porridge in Rural Uganda." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. February 13–17.
- Mulinda NV, Nyagahungu I, Vasanthakaalam H, Sinha A, Jeyakumar R, Uwamariya D& R Mazur(2012) "Effect of Thermal Processing on Functional Properties of Bean Flour." Poster presented at Global Pulse Researchers Meeting. Kigali, Rwanda. February 13–17.

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: December 2012
Training Status during Fiscal Year 2012: full-time student
Type of CRSP Support (full, partial or indirect): Partial

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

Trainee #3
First and given names: Catherine Tamale
Last name: Ndagire
Citizenship: Ugandan
Gender: Female
Degree: M.Sc.
Discipline: Food Science & Technology
Host Country Institution to benefit: Makerere University, Uganda
Training Location: Makerere University and Iowa State University
Supervising CRSP PI: Dorothy Nakimbugwe
Start date: August 2009
Project completion date: December 2012
Training Status during Fiscal Year 2012: full-time student
Type of CRSP Support (full, partial or indirect): Partial

Trainee #4
First and given names: George
Last name: Jjagwe
Citizenship: Ugandan
Gender: Male
Degree: M.Sc.
Discipline: Agricultural Extension & Education
Host Country Institution to benefit: Makerere University, Uganda
Training Location: Makerere University
Supervising CRSP PI: Dorothy Nakimbugwe (Co-PI Paul Kibwika)
Start date: August 2010
Project completion date: December 2012
Training Status during Fiscal Year 2012: 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 2013
Training Status during Fiscal Year 2012: full-time student
Type of CRSP Support (full, partial or indirect): Partial

Explanation of Changes
Not Applicable

Networking and Linkages with Stakeholders
NaCRRI has been multiplying more than 200 bean lines high in iron, zinc and protein that it received from the University of Nairobi through CIAT. Through the Material Transfer Agreement (MTA) 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 have been very useful in understanding the physiology of seed nutrient composition, the research work of Ph.D. student Gerald Sebuwufu. In addition, NaCRRI researchers Michael Otim (entomologist) and Pamela 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 have guided 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 bean value chain stakeholder workshop for Kamuli in Jinja in May 2012, involving participants from various 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 corresponds to VEDCO's commitment to continue playing a facilitative role.

Visits to ISU by Co-PIs from Makerere University (Uganda) and KIST (Rwanda) 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.

KIST's research has led to collaboration with HarvestPlus to determine the iron, zinc and phytic acid content of beans cultivated in Rwanda. It has also led to partnership with the Chemistry Dept. at KIST and the training of KIST staff by North Dakota State University in use of HPLC (high-performance liquid chromatography) to determine these nutrients.

Two Uganda-based organizations that participated in our Bean Value Chain Stakeholder Forum in Jinja in May 2012 and our Project Dissemination workshop in Kampala in July, AgriNet and Farm Radio Africa/Uganda, are current and prospective partners, respectively. AgriNet monitors markets for agricultural commodities, collects and disseminates market information to farmers. AgriNet already supplies market demand and price information to VEDCO, which shares this information with the farmer groups that it supports. Farm Radio Africa/Uganda organizes participatory campaigns that utilize radio and other communication technologies to disseminate information about relevant agricultural management practices and technologies, and is currently initiating collaboration with VEDCO.

A noteworthy outgrowth of this project's successful collaboration is a proposal recently submitted to USAID-Uganda for a five-year value chain project which targets more than 20,000 households in production and marketing of maize, beans, soybeans, and coffee. "Strengthening

Agriculture and Rural Transformation through Value Chain Development (START-VC) involves these partnering organizations: CARANA, CNFA, VEDCO, Uganda Coffee Academy, and Grameen Foundation.

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

Mutambuka M, Murphy PA, Hendrich S, Reddy MB (2012). "White common beans (*Phaseolus vulgaris*) have higher in vitro iron bioavailability than colored seed coat varieties." Paper being prepared for submission to *Journal of Agricultural and Food Chemistry.*

Mutambuka M, Hendrich S, Reddy MB, Lamsal PB, Hui W, Murphy PA (2012). "Optimization of white common beans (*Phaseolus vulgaris*) extrusion cooking process." Paper being prepared for submission to *Journal of Agricultural and Food Chemistry.*

Sebuwufu G, Mazur R, Westgate M, and Ugen M (2012) "Genotype and Soil Fertility Interactions on Yields of Common Beans (*Phaseolus vulgaris* L.) Grown by Smallholder Farmers on Nutrient Depleted Soils in Southeastern Uganda." Paper being prepared for submission to *Field Crops Research* or *Agronomy Journal.*

Sebuwufu G, Mazur R, Westgate M, and Ugen M (2012) "Response of mono and intercropped common bean (*Phaseolus vulgaris* L.) to phosphorus intensification on low nutrient soils in Uganda." Paper being prepared for submission to *Field Crops Research* or *Agronomy Journal.*

Sebuwufu, Gerald et al. (2012) "Photo-assimilate supply per seed affects the accumulation of Fe and Zn in common bean (*Phaseolus vulgaris* L) seeds." Paper being prepared for submission to *Crop Science Journal.*

Nakitto, Aisha Musaazi (2012) "Development and Evaluation of Nutritious Fast-Cooking Bean Flours." Final M.Sc. Applied Human Nutrition Thesis. Department of Food Technology & Nutrition, Makerere University.Paper being prepared for submission to *Journal of Nutrition and Food Sciences.*

Ndagire Tamale, Catherine (2012) "Optimized Formulation and Processing Protocol for a Bean-based Composite Flour." Final M.Sc. Applied Human Nutrition Thesis. Department of Food Technology & Nutrition, Makerere University.Paper being prepared for submission to *Journal of Nutrition and Food Sciences.*

Jjagwe, George (2012) "Constraints and Opportunities for Smallholder Farmers' Access to Lucrative Markets: Analysis of the Bean Value Chain in Kamuli District." Draft M.Sc. thesis. Department of Agricultural Extension and Innovation Studies, Makerere University.

Nkundabombi Marie Grace (2012) "Characterization of Local and Improved Beans Varieties and Their Products." M.Sc. Research project proposal, Applied Human Nutrition. Department of Food Technology & Nutrition, Makerere University.

Kisekka, Rashid and TimothyMukalazi Mubiru (2012) "Preventing Post-Harvest losses of Beans and Maize through Solarization and Triple-Bagging." Final B.Sc. Report. Department of Food Technology & Nutrition, Makerere University.

Nassozi, Adrian and Margaret Mbaziira (2012) "Culinary, Sensory and Nutritional Properties of Local and Improved Bean Varieties." Final B.Sc. Report. Department of Food Technology & Nutrition, Makerere University.

Mushabe Wilson, Ndahabwa Manasseh, Ndayisaba Emmy (2012) "Culinary Properties of 16 Bean Varieties Newly Released by ISAR in Rwanda." Project report for B.S. degree. Department of Food Science and Technology. Kigali, Rwanda: Kigali Institute of Science and Technology.

Mazur, Robert (2012) "Improving Production, Nutrition, Marketing and Livelihoods – Bean Value Chain Research and Development in Uganda." Paper being prepared for submission to *Food Policy*.

Literature Cited

AOAC (2012). Total Solids in Cordials and Liqueurs. Association of Official Analytical Chemists. Method no. 940.09.

Proulx AK&MB Reddy (2006) Iron bioavailability of hemoglobin from soy root nodules using Caco-2 cell culture model. *Journal of Agricultural and Food Chemistry* 54:1518-1522.

Turner BL, Richardson AE& EJ Mullaney (2007) *Inositol Phosphates: Linking Agriculture and the Environment*. Wallingford, UK: CAB International.

Contribution of Project to Target USAID Performance Indicators

Our project has a strong record of achieving performance indicators/targets. Cumulatively, we have been mentoring 27 students for degree training, seven at graduate level (of whom three are female) and 20 at B.S. level (of whom ten 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 FY12, bean crop management practices and technologies have been disseminated to an additional 642 farmers (70% women). We monitored the process and impacts to identify any barriers and most effective strategies. At least 954 households have benefitted directly from CRSP project interventions, 104 more than anticipated. We have progressed well in terms of the number of technologies and management practices that are under research (4), and under field testing (4), and ready to be made available for transfer (12), as anticipated. The number of additional hectares under improved technologies or management practices (381) exceeds what was originally anticipated (350).

Farmers marketing associations in two sub-counties are directly benefitting from project activities. We are providing technical assistance directly to 82 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. Discussions between the Department of Food Science and Technology at Kigali Institute of Science & Technology in Rwanda, and Africare and World Vision in Rwanda may lead to effective collaboration.

Contribution to Gender Equity Goal

Among the core team of 12 research scientists and professional practitioners, 50% are women. As noted above, we have been mentoring three female graduate students and ten female undergraduate students; comparable data for males are four and ten, respectively. Of the 30 farmers participating directly in the field experiments, 80% are women; similarly, 87% of the 67 farmers who received extensive project training sessions are women. Approximately 70% of the additional 642 farmers receiving training and improved bean seeds during FY12 are women. Of the 954 households that have benefitted directly from CRSP project interventions, 15% are female headed.

Progress Report on Activities Funded Through Supplemental Funds

Supplemental funds received for FY12 supported training, technology dissemination, and research. The project team developed new training materials and media (print, video) for improved management practices and technologies that was utilized in training more than 800 farmers in 60 demonstration sites. Topics covered by print and posters included germination testing; plant spacing; soil nutrient amendments (manure application); pest and disease management; harvesting, threshing, drying, and moisture testing; solarization and triple bagging; sorting and seed selection; and processing and preparation of food products from beans. Three different training methods/media, all followed by field demonstrations, were used in training on planting and triple bagging: (1) interactive training, (2) animated video, and (3) farmer acted video. The animated video on triple bagging was produced by Dr. Barry Pittendrigh and colleagues at the University of Illinois.

A small battery-powered projector (3M MPRO 150 Pocket Projector) with supplemental Speaker Case (Insignia) was used to present the video at farmers’ training facilities. Trainers on foot or bicycle can easily carry these portable devices to places where farmers live and work. The visual and audio qualities were adequate, depending on the size of group. Groups with less than 10 participants exhibited a relatively low level of interaction and few group discussions among farmers during the training. However, when the size of the training group was more than 40, training became messy, and farmers sitting at the back had problem in hearing and watching the videos.

Research by an ISU-based graduate student in communication and sustainable agriculture (Ms. Tian Cai) explored the effectiveness of video to complement or replace existing lecture/demonstration training for small farmer groups in rural Uganda. Her master's thesis supervisor, Dr. Eric Abbott, is a development communications specialist. The study was conducted in four parishes in Butansi sub-county of Kamuli district during February-March, 2012. A total of 325 project farmers participated in the study in which quantitative and qualitative data were gathered through an experiment including a pre-test and a post-test with a control group design. Results showed that video could effectively complement or, in some circumstances, replace conventional lecture/demonstration training methods in knowledge improvement, attitude and intention to adopt improved management practices and technologies. Combining video, lecture and demonstration is especially effective for groups with little or no prior knowledge of a topic. Moreover, video alone or video plus lecture/demonstration can be as effective as conventional training in decreasing gaps in knowledge of training topic among subjects of both genders and varying education levels and scale of bean planting.

Consistent capacity building activities in Kamuli were guided by Dr. Haroon Sseguya, Makerere University faculty member from the Department of Agricultural Extension and Innovation. VEDCO's staff and Community Based Trainers (CBTs) learned advanced methods of farmer learning facilitation, and numerous farmers learned improved practices. The supplemental funding also strengthened collaboration among VEDCO, Makerere University and Iowa State University faculty and students. It helped scale up innovative management practices and technologies to wider populations in Uganda.

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 reponses analyzed	O			O			O			O			O		
1a. Biological & agronomic controls for pests & diseases initiated	O			O			O			O			O		
1a. Variety perform. fertility repons. Bio & agron. Controls analyze	X			O			X	√		O			O		
1a. Best performing bean varieties reported to breeders	X			O			X	√		X			O		
1a. Seeds provided for post harvest storage studies	O			O			X	√		X			O		
1b. Training in group dynamics & mgmt. practices for quality seed	O			O			O			O			O		
1b. Exchange visits to established seed production programs	O			O			O			O			O		
1b. Extension guide for bean CBSP initiated and tested	O			O			O			O			O		
1b. Linkages establ. for breeders, seed processors, marketers	O			O			X	√		X			O		
1b. Seed storage facilities established	O			O			X	√		X			O		
1c. Effects of solarization on germination and storage evaluated	O			O			O			O			O		
1C. Farmers trained in effective use of solarization technique	O			O			O			O			O		
1c. Polyethylene for solarization distributed to farmers groups	O			O			O			O			O		
1c. Barriers to adoption of solarization identified and reselved	O			O			O			O			O		
1c. Storage techniques evaluated for pest control and germination	X			O			X	√		X			O		
1c. Farmers trained in new solar techniques	O			O			X	√		X			O		
1c. Storage materials produced and distributed to famers	O			O			X	√		X			O		
1c. Training in mananging bulking facilities completed	O			O			X			X			O		
1d. Exchange visits of other farmer groups conducted	O			O			O			O			O		
1d. Contacts establ. w/districts to scale technologies & practices	O			O			X	√		X			O		
1d. Stakeholder workshop to review bean prod. Training materials	X			O			X	√		X			O		
1d. Extension materials translated and published	O			O			X	√		X			O		
Objective 2	**Enhance the Nutritional Value and Appeal of Beans**														
2a. Cold extruded bean products & process developed at KIST	O			O			O			O			O		
2a. Bean-based weaning foods developed for Uganda & Rwanda	X			X			O			O			X		
2a. Extension approaches indentifed and content developed	X			X			O			X			X		
2a. Farmers trained in bean cold extrusion processing	O			O			O			O			X		
2a. Baseline nutritional status established for feeding studies	X			X			O			O			X		
2b. Analysis protocol for culinary properties obtained	O			O			O			O			O		
2b. Analysis of desirable culinary traits of current varities initiated	O			O			O			O			O		
2b. Culinary traits & sensory charg of current varieties documente	X			X			O			O			X		
2b. Analysis of culinary trits & sensory char of improv var initiated	O			X			O			O			X		
2c. Tech incubation & transfer models identified and modifed	O			X			O			O			O		
2c. Local & int'l industries as potential markets for beans identifed	O			X			O			O			O		
2c. Private industry interest/conditions to adopt bean tech. evaluated	O			X			O			O			O		
2c. Links establ btw farmers' assoc & private industries	O			X			X			X			O		
2c. Protocols for value-addition w/private sector partners initiated	O			X			O			O			O		
Objective 3	**Increase Marketing and Consumption of Beans and Bean Products**														
3a. Farmer groups' composition, roles, assets, capabilites identified	O			O			O			O			O		
3a. Farmer groups' needs determined and prioritized	X			O			O			X			O		
3b. Farmers trained in group/assoc dynamics and gender equity	O			O			O			O			O		
3b. Partner meetings held in two sub-counties	O			O			O			O			O		
3b. Participatory market research groups formed	O			O			O			O			O		
3b. Market chain analysis for bean enterprises conducted	X			X			O			X			O		
3b. Market information sources assessed	X			X			O			X			O		
Objective 4	**Incr. Capacity, Effectiveness & Sustainability of Ag. Research Institut.**														
4. Training M.S. (FST and AgEcon) at MAK on-going	O			O			O			O			O		
4. Training M.S. student if FST from Rwanda on-going	O			O			O			O			O		
4. Training M.S. student at Makerere University Completed	O			X			O			O			X		
4. Training PhD students at Iowa State University on-going	X			O			O			O			O		
4. Inter-organizational learning fostered	X			X			X			X			X		
4. Prelim. Results disseminated (con. 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 Vassanthakaalam		
Name of the U.S. Lead PI submitting this Report to the MO	Kathleen Brown														

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, 2011 -- September 30, 2012)

FY 2011 PERFORMANCE INDICATORS
for Feed the Future

Project Title: Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Stakeholders in Uganda and Rwanda
Lead U.S. PI and University: Robert Mazur, Iowa State University
Host Country(s): Uganda, Rwanda

	2012 Target	**2012 Actual**
Output Indicators	**(October 1, 2011-Sept 28, 2012)**	
Degree Training: Number of individuals enrolled in degree training		
Number of women	3	3
Number of men	3	3
Short-term Training: Number of individuals who received short-term training		
Number of women	300	449
Number of men	100	193
Technologies and Policies		
Number of technologies and management practices under research	5	2
Number of technologies and management practices under field testing	5	6
Number of technologies and management practices made available for transfer	10	12
Number of policy studies undertaken	1	1
Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	130	143
Number of rural households benefiting directl from CRSP interventions - Male Headed households	720	811
Number of agricultural-related firms benefiting from CRSP supported interventions	5	5
Number of producer and/or community-based organizations receiving technical assistance	3	3
Number of trade and business organizations receiving technical assistance	3	3
Number of community-based organizations receiving technical assistance	80	82
Number of women organizations receiving CRSP technical assistance	80	82
Number of public-private partnerships formed as a result of CRSP assistance	2	2
Number of of HC partner organizations/institutions benefiting	4	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices as a result of CRSP technical assistance	350	384

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 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 three new bean varieties in three market classes in 2012. These included a new high-yielding upright, full-season pinto bean variety, Eldorado, upright pink bean variety Rosetta and an early season white kidney bean variety Snowdon. Eldorado has outstanding yield potential, erect architecture, white mold tolerance, and good canning quality. Rosetta possesses virus resistance, erect architecture, has good seed color, and does not exhibit the stem breakage observed in Sedona pink variety. Snowdon is high yielding variety that matures seven days earlier than Beluga variety and produces a larger brighter white kidney bean seed than Beluga. The widespread adoption of new upright black bean variety Zorro from MSU breeding program has provided growers with opportunity to direct harvest the crop and thus reduce production costs. 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 future breeding programs. In Ecuador a new bean variety is being released to farmers in the northern valleys. INIAP 484 Centenario is a large-seeded red-mottled type and is the first to possess resistance to three important foliar diseases (rust, anthracnose and angular leaf spot-ALS) and to the root disease Fusarium wilt. The variety was bred exclusively by the INIAP research team and was released through the process of evaluation and participatory selection with members of the CIALs in the provinces of Carchi, and Imbabura. Over 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 program expanded the crossing program and successfully produced over 50 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. Thirteen new climbing bean varieties for high altitude zones, including five Fe biofortified varieties were officially released in 2012. Farmers who evaluated the lines during participatory variety selection field days preferred them because of their high yield, resistance to major diseases and pests, and seed that met urban market preferences. Two doctoral students concluded field research in Rwanda in 2012; 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. Beans occupy 20-31 % of cultivated land area in Rwanda and are grown by almost 95% of farmers in all major regions of the country. The country has the highest per capita bean consumption in the world, exceeding 40 kg. Climbing beans have been adopted by households across a range of different farm sizes, gender and economic classes. Drought tolerant climbing bean varieties have been released recently in Eastern province and contribute to increased productivity of beans in this drought prone area. The yields are about 3 to 4 tons per hectare for climbers and 1.5 to 2 tons for bush beans. In highland areas where climbing beans are the most popular, the production has increased significantly due to the fact that the crop benefits from mineral fertilizer residues from crop rotation with maize. Fertilizer for maize is subsided at 50% by the government through its land consolidation and crop intensification programs. Beans are produced by resource-poor farmers in Rwanda and Ecuador and more vulnerable to attack by diseases and insects, and abiotic stresses including drought, heat and low soil fertility. The important diseases of beans are angular leaf spot (*Phaeoisariopsis griseola*), anthracnose (*Colletotrichum lindemuthianum*), ascochyta blight (*Ascochyta phaseolorum*); and root rot caused by complex of soil pathogens, particularly *Pythium, Fusarium* and *Rhizoctonia* species. Breeding for disease resistance is a key element in the successful boost of the bean productivity in both countries. 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

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

Approaches and Methods

1. Continue to select parental breeding materials for crossing in Ecuador, Rwanda and U.S.

2. 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 three new varieties, Eldorado pinto, Rosetta pink and Snowdon white kidney released by the MSU breeding program in 2012, were produced in the western US. Eldorado has outstanding yield potential, erect architecture, full-season maturity, white mold tolerance, and good canning quality. Rosetta possesses virus resistance, erect architecture, has good seed color, and does not exhibit the stem breakage observed in Sedona pink variety. Snowdon is high yielding variety that matures seven days earlier than Beluga variety and produces a larger brighter white kidney bean seed than Beluga. The widespread adoption of the high-yielding, upright black bean variety Zorro, released by the MSU breeding program in 2009, has provided growers in Michigan with opportunity to direct harvest the crop and thus reduce production costs.
- A total of 3,900 plots were harvested for yield and 1,977 single plant selections were made in the early generation nurseries as part of the MSU breeding program activities in 2012. A new great northern line is under consideration for release in 2013, based on continued high performance and improved seed quality over Matterhorn variety. Sources of common bacterial blight (CBB) resistance were identified in advanced kidney and cranberry bean lines. A group of high-yielding bush cranberry breeding lines with CBB resistance will be sent to Uganda and Zambia for testing in 2013. Rust is becoming an increasing threat to navy, black and small red bean producers in Michigan, and resistance to the emerging race 22:2 has been identified in new navy, black and small red bean lines.
- Genotyping of the SEA5xCAL96 RIL population continued at MSU. An additional 22 simple sequence repeat (SSR) and 12 Insertion deletion (InDel) markers were added. A genetic map for this population consisting of 1031 cM and representing 86% of the bean

genetic map was constructed. A quantitative trait loci (QTL) analysis identified 41 QTL associated with drought tolerance related traits studied in the field in Rwanda and in Colombia. One of these QTL that accounted for 37% of the phenotypic variation for yield was mapped to chromosome Pv11.

- An article detailing efforts to develop a stable transformation system for common bean was published. Progress was modest and since the program was unsuccessful in securing new funding sources the research will not be continued.
- The bean breeding program in the Rwanda Agriculture Board (RAB) substantially increased the number of crosses in 2012. More than 200 single and backcrosses were made during the two cropping seasons (2012a & b) to incorporates multiple resistance to anthracnose, ALS, bean common mosaic virus into elite lines with yield potential or high levels of micro-nutrients, Fe and Zn. Continued selection in BC_1 from F_1 progeny from multiple parents will be conducted this coming season in disease hot spots.
- Selection for micronutrient rich lines from advanced populations (F4 to F8) that were introduced from CIAT in 2012 has continued. All together 550 advanced lines were selected in the three mid or high altitude stations of Rubona, Rwerere and Musanze. From this group genetically stable lines will be introduced in the preliminary yield trial (PYT) while individual plant selections will continue among the remaining segregating populations in 2013A. An evaluation of 14 bush and 23 climbing advanced high iron bean lines introduced from CIAT last year was conducted in an advanced yield trial (AYT). The best lines will be tested in multiple sites across all agro-ecological zones before distributing seed for national performance trials (NPT).
- Fourteen bush been varieties (SCR 9, SCN 1, NUA 425, NUA 377, NUA 397, NUA 379, NUA 567, NUA 541, NUA 474, SCR 18, SCR 16, SCR 8, SCB 790, NUA 566) were selected from among 104 biofortified bush bean lines introduced from CIAT evaluated in PYT at Rubona. Another observation nursery of 182 biofortified climbing beans from CIAT was evaluated in Rubona and Rwerere. Twenty-three lines from MNC group were selected and planted in 2012a and repeated in 2012b seasons. The data from the two seasons was unreliable due to heavy rains, so these trials will be repeated in 2013a season.
- An adaptability test trial was planted at three sites in Rwerere and Bukonya. Four bean varieties were tested and their performance will be compared to popular climbing bean in the region (G2333, known as Mamesa), and local mixture. Compared to the two checks, RWV2527 and RWV2875 were the best candidate lines for future release. Further tests are needed to confirm their potential across the northern region of Rwanda.
- The breeding program in Ecuador participated in the prerelease of red-mottled disease resistant variety INIAP 484, Centenario with local bean farmers, CIAL members of the Chota, Mira and Salinas valleys, technicians from public and private institutions, and CRSP scientists from MSU and Cornell, near the town of La Concepción (Carchi) in May 2012. Centenario is a large red mottled bean with resistance to ALS, anthracnose, rust and Fusarium wilt. Centenario was derived from cross between AMPR5, breeding line with red mottled seed and resistance to rust and anthracnose, and CAL 143 with resistance to ALS. Ten red mottled lines with rust, anthracnose and ALS resistance were selected and coded as FMR (Beans with Multiple Resistance). The line FMR 3 generated from this cross had a red mottled seed, type I growth habit and was advanced through plant-row selection to F6 generation in 2009. The reaction of FMR3 to anthracnose and ALS was evaluated under greenhouse conditions using artificial inoculation with virulent races and representative of

the production areas. In all evaluations FMR3 line showed high levels of resistance to both pathogens rated on the 1-9 CIAT scale. The Concepción check was susceptibility to both pathogens, while Portilla was resistant to anthracnose and susceptible to ALS. Similarly FMR3 line was evaluated in field in the presence of the soil borne pathogen *Fusarium oxysporum*, causal organism for Fusarium wilt root rot, and was shown to be resistance to this pathogen. Promising FMR lines were planted and evaluated in participation with the CIAL de la Concepción located at 1400 meters altitude in 2010-2011. The FMR3 line was selected by farmers, based mainly on plant health (resistance to rust, anthracnose and angular leaf spot), yield, pod load, and seed quality In the 2012a cycle, seed of FMR3 line was increased with the seed growers in CIALs La Concepción (Carchi) and Pablo Arenas (Urcuquí-Imbabura) and in the same cycle FMR3 line was pre released as a improved and bush bean variety INIAP 484 Centenario, in homage to the all time best Ecuadorian General Eloy Alfaro Delgado, 100 years after his death.

- Centenario was evaluated as breeding line FMR 3 for four years (2009- 2012) over six growing seasons in research plots and in participatory trials with CIALs in the Mira and Salinas valleys. Performance data of FMR3 and checks were also collected under foliar and root disease pressure in poor soils expressing low fertility for two cycles. The highest yield obtained in fertile soils was 2413 kg/ha compared to 1208 kg/ha for Portilla check. Performance in low soil fertility was 1182 kg/ha compared to 949 kg/ha for the control. In 2011, FMR3 line yielded 1554 kg/ha compared to Portilla check at 647 kg/ha in a trial that had a severe leafhopper (*Empoasca kraemeri*) attack, suggesting that Centenario may carry levels of tolerance to this pest. The overall performance of Centenario in experimental trials was 1723 kg/ha compared to 1238 kg /ha for the Portillo check where it displayed an overall 485 kg/ha yield improvement.
- The breeding program in Ecuador continues to combine resistance to rust, anthracnose, ALS and Fusarium wilt in a range of seed types, 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. In the Experimental Farm at Tumbaco in the 2011b cycle, seven simple and backcrosses were made to incorporate resistance to ALS into different seed color classes: white, purple mottled and yellow (canary). Tumbaco is an excellent site to select for combination for resistance to drought and Fusarium wilt. F_1 seeds were sown in these populations and self-seeded in the next cycle (2012a), to produce F_2 seeds. In this same cycle other combinations were made to incorporate resistance to angular leaf spot, anthracnose and rust into red mottled and white seed coat colors. In the 2011b planting cycle, 11 F_2 populations resulting from single, triple and double crosses, for different seed colors were planted and evaluated. At harvest, individual plants were selected in the top six populations. In the next cycle F3 seed from individual F_2 plants were planted as plant rows. The top 30 rows selected for rust resistance, plant vigor and seed quality were harvested in bulk. The F_3 populations derived from double crosses were planted and evaluated. At harvest the best individual plants selected primarily for rust resistance, plant architecture and good seed and pod quality were harvested. F_4 seed from individual F_3 plants were planted, and the best 14 rows or progenies were selected for good adaptation, rust resistance and seed quality.
- In cycle 2011b six F_3 populations of solid red beans, 20 populations of red mottled seed types and seven populations of Uribe seed types (pink stipple) were planting and evaluated. At

harvest the best 20 red mottled seed progenies were selected. In the next cycle 2012a the selected individuals were planted in two replicates and data were taken on reaction to anthracnose under greenhouse and field reaction to rust, plant vigor, pod load and yield. Six lines showed resistance to anthracnose, the others were still segregated for susceptible and resistance. All lines with values of 1 and 2 in rust reaction between 2-4 in plant vigor and pod load on the CIAT 1-9 scale. Anthracnose resistant lines will be evaluated in the next cycle.

- In cycle 2011b at Tumbaco five promising black bean lines were evaluated for high performance pod load and adaptation. Line (G21212/*Condor) -1 and 9-10 black from Honduras were selected. In the next round (2012a) the two selected lines plus the Afroandino control were seeded for seed increase in 100 m^2 plots. The best performance was obtained with the rust resistant 9-10 black line from Honduras with 13 kg, and the line (G21212 /* Condor)-1F2 produced 12 kg while the Afroandino check only produced 10 kg. The two lines will be evaluated by CIAL in the next growing cycle.
- In 2012a, nine promising F_7 solid red seeded lines plus two checks were evaluated. Based on plant vigor pod load, rust and anthracnose (in greenhouse) resistance lines (Portilla x I-402)-5-3, and -5 (Portilla x Campeon)-1-9 were selected. These two lines yielded the highest with 2051 and 2144 kg/ha, respectively. These lines will be evaluated again along with others in the next cycle.
- Promising lines with type II growth habit were assessed in two growing cycles. In the first trial (2011b), (JE.MA./AND 1005- 5F3, and JE.MA. /AND 1005) - 1F3, outscored the check JE.MA for yield, vigor and pod load. In the next cycle (2012b), these and other lines were evaluated for resistance to anthracnose in greenhouses, rust and performance. Only (Portillo/TP6)-5F_2, was selected for resistance to rust, anthracnose and performance. All lines were highly resistant to rust compared to the Paragachi Andino check so in the next cycles crosses will be made to introduce resistance to anthracnose and ALS into the susceptible lines.
- In cycle 2011b, 12 promising red mottled bush bean lines and three checks were evaluated at Tumbaco. Based on vigor, pod load and number and yield, all lines outperformed Intag (658 kg/ha) and Concepcion (447 kg/ha) checks. The line (Concepcion/3/ PJ1/NSL// Concepcion/SEA11)-4 produced the highest yield at 1251 kg/ha. In the next cycle, 10 promising lines with multiple disease resistance (rust, anthracnose and angular leaf spot) were evaluated. These lines were evaluated and selected from the year 2008 and in this cycle were coded as FMR lines. In field rust reaction, vigor, pod load and performance; greenhouse reaction to anthracnose and ALS were evaluated. All were resistant to the three diseases. The line (AMPR5/CAL143)-4F_2-1F_4 that gave rise to the Centenario produced the highest yield at 1014 kg/ha compared to other lines and controls. Similarly FMR3 line (Centenario) was superior in performance, rust resistance and adaptation to the Portilla control.

<u>Objective 2:</u> 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.

<u>Approaches and Methods</u>

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

- Evaluation of SEA5xCAL96 recombinant inbred line (RIL) population for drought resistance was conducted over multiple seasons in Rwanda and in Colombia. In Rwanda, 125 $F_{5:7}$ RIL tested under the RSA code, parents, and local checks SER13, SER14, SER16, RWR2545, and RWR1668 were evaluated for the third season. Every genotype was grown in a plot consisting of two rows of 1.5m and 0.5cm between rows. Plots were organized in a 12x11 lattice. Overhead sprinklers were used to irrigate both RF and RFS plots to ensure good plant establishment and early growth as needed until the early pod filling. Thereafter, irrigation was discontinued in RF plots while the irrigated plots continued to receive supplemental irrigation twice a week. Experiments consisted of two replications in each water regime. In Karama, drought caused a percentage yield reduction of 14%. Drought did not affect days to flowering, maturity, harvest index, pod harvest index, and 100-seed weight. The average number of day to flowering was 39 while the average maturity was 79 days. Harvest index was 40 and 42% respectively in stress and no stress conditions, while pod harvest indices were 65 and 64 % respectively in stress and no stress conditions. The number of pod per plant under rain-fed conditions ranged from 5 to 17 with an average of 8 while they varied from 5 to 17 with an average of 10 pods/plant under irrigation. The same trend was observed for the number of seed/pod where they were reduced to one under drought. Seed yield was significantly affected by drought. Under rain-fed condition, yield varied from 99 to 222g/m^2 with an average of 138.6 g/m^2. Under irrigation conditions, mean yield was 161g/m2 ranging from 6 to 347g/m^2. Some genotypes such as RSA118, RSA 109, RAS120, and RSA129 performed well under both water conditions and possessed average seed size that is preferred in Rwanda.
- The same experiment was conducted at CIAT research station in Palmira, Colombia. A subsample of 97 lines, SEA5 and CAL96 parents, and a local check ICA Quimbaya were evaluated in 10x10 lattice experimental design with three replications. Experimental units consisted of blocks of 2 rows of 3.72m long and 0.6m wide. To ensure good stand establishments, two gravity irrigations were applied six days before planting and a second at 12 days after emergence. In both locations recommended agronomic procedures were followed. All experiments were hand planted, weeded and harvested. In Colombia, all lines matured earlier than in Rwanda. This was applicable to all phenology variables where days to flowering varied from 28 to 36 with an average of 32 days; the number of days to maturity varied from 59 to 71 days with an average of 69 days. The average number of pods per plant and seed per pod were 9 and 3 respectively with ranges of 4 to 15 and 1 to 5. Partitioning

indices, harvest index and pod harvest index varied from 13 to 59% and 38 to 70%. The average seed yield was 60 g/m^2. Genotypes that performed well under Palmira conditions with yield comparable to that of CAL96 include RSA142, RSA60, RSA118, RSA129, and RSA54. For 100-seed weight, the average of the population at Palmira was 29.8 g/100-seed weight ranging from 17.5 to 47 g/100-seed.

- The RAB651/* Concepcion inbred backcross line (IBL) population, developed in Ecuador, was evaluated for drought resistance in Rwanda. The evaluation was conducted in Karama dryland station under rain-fed and irrigated conditions. The plots consisted of two rows of 1.5 m long and 0.50m wide were organized in 9x9 lattice and replicated two times in each water regime. Seventy two IBL tested under 10T code, RAB651, and eight local checks SER12, SER13, SER14, RWR2245, RWR2154, SER16, SER30, and RWR1668 were tested. Overhead sprinklers were used to irrigate both RF and RFS plots to ensure good plant establishment and early growth as needed until the early pod filling. Thereafter, irrigation was discontinued in RF plots while the irrigated plots continued to receive supplemental irrigation twice a week. Variables days to flower, days to maturity, number of pod/plant, number of seed/pod, yield, and 100-seed weight were evaluated. In contrast to SEA5xCAL96 population where the loss of seed size and color of CAL96 was observed, RAB651 and Concepcion combined very well. All the seed had either red or red mottled color and some IBLs had large seed size comparable to that of Calima bean type. Under rain-fed conditions, there was no significant reduction of seed size. The average seed size was 34.5g/100-seed which varied from 19.1 to 61 g under irrigation. Under rain-fed, the seed size varied from 20.5 to 48.5 g with an average of 35.7g/100-seeds. There were no significant differences for number of days to flower and number of day to maturity between water regimes. The average number of days to flower was around 37 days in both water treatments while the number of days to maturity was around 76 days. However, yield was significantly reduced by drought stress. There was a 21% yield reduction in rain-fed plots as compared to plots that were irrigated. Under rain-fed conditions, the average yield was 99g/m^2 ranging from 33.2 to 203g. In irrigated plots, yield varied from 42 to 326g/m^2 with an average yield of 125g/m^2. Certain genotypes such as 10T8074, 10T8024, 10T8024, and 10T8056 were among high yielding RILs regardless of water treatment. Number of pods per plant and the number of seed per pods were as well reduced by drought. Seed is available in Puerto Rico and in Rwanda for further evaluations under drought stress.
- Field evaluation of bean breeding lines and germplasm for root rot resistance in New York: A total of 27 bean lines and varieties provided by MSU, Tim Porch (USDA/PR), and Don Halseth (CU) were evaluated in the root rot field at the Vegetable research Farm, Cornell University, Geneva, NY. Root rot severity ratings exhibited by the tested materials varied significantly and ranged from 3.2 (Medalist) to 5.8 (Pink Panther) on a scale of 1 (no disease symptoms, healthy) to 9 (>75% of root and stem tissues affected and at late stages of decay). All other promising breeding lines tested exhibited significantly lower root rot severity ratings than the susceptible checks. In addition, the yield of the selected materials harvested differed significantly and correlated rather well to their root rot ratings. Selected materials were returned to programs for use in future breeding efforts for root rot.
- Cover crops for managing root diseases of beans and other agronomic crops: The third and final year evaluation of the replicated 9 cover crop treatments (rye grain + Vetch, oat, sudex, forage radish, red clover, rapeseed, buckwheat, wheat, and a fallow check) was completed in 2012. Three strips of each cover crop (15 x 200 ft.) were established in each of 4

experimental fields with different management histories (conventional, organic, present-IPM and Future-IPM), thus they varied significantly in their root health and soil quality levels. The future-IPM field had the healthiest roots and the highest soil quality, whereas the conventionally managed field had the poorest root and soil health levels. The final analysis of the accumulated data is still on-going, but overall snap yield continues to be highest in the field with the highest soil quality and healthiest roots (Future-IPM managed field), whereas the lowest average yield is that of the plots in the conventionally managed field. However, the cover crops also impacted snap bean yield within each field. For example in the field with the highest root and soil health levels, highest snap bean yield was realized in plots previously planted to Rye grain + vetch, wheat or oat cover crops. Also, root rot severity was highest on roots of bean planted after a fallow check or a cover crop of buckwheat.

- 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 2012. The effect of zone vs. plow tillage practices on yield and root rot severity of CLRK was conducted in replicated plots (4 acres) at the Vegetable Research Farm, Cornell University, Geneva, New York. The zone-till plots were prepared in the fall of 2011, whereas the plow-till plots were prepared in spring 2012, 2 weeks before planting. All other production practices were according to commercial guidelines for dry bean production in New York. Emergence, stand establishment, root rot severity ratings, and seed weight of beans did not differ significantly among the two tillage systems. The latter is in contrast to previous evaluations when zone-tilled plots were prepared in the spring (shortly before planting) that resulted in lower stand establishment and lower yield. Thus, preparing zone-till plots in the fall will reduce inputs in land preparation and contribute to improved soil quality without adversely impacting yield stand establishment and bean yield.
- 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 2012, the reaction of 40 pea varieties (commercial and promising new selections) were evaluated in naturally infested soil (primarily with *Fusarium solani* f. sp. *pisi*) in greenhouse test and also in production field where 2 or more varieties are planted in the same field. Root rot severity ratings ranged from3.0 to 8.3 – 8.5 across varieties.
- Nine promising lines and three red mottled bush bean checks were evaluated for resistance to *F. oxysporum* at Tumbaco. The lines (PORTILLA x RMC20) -7, (PORTILLA x RMC27) -2, (PORTILLA x TP6)-5 and (P. ANDINO x TP6)-11 were superior in vigor, pod load and performance. These lines were selected to be evaluated in the next cycle for anthracnose resistance under greenhouse, rust reaction, vigor, pod load and performance in the field. All lines produced higher yields better than the control Portilla. Under these selection parameters lines CONCEP///PJ1/NSL//CONCEP/SEA 11)4F2, (PORTILLA/RMC20) -7 and (AMPR5/CAL143) 4F2-1F_4 (b) were selected for advance.
- In the 2012a cycle at Tumbaco, 14 sources of resistance to *F. oxysporum*, 12 for rust, 10 for anthracnose, 8 for ALS and 6 for CBB were planted and evaluated. Morphological data were taken (flower color) and agronomic (days to flowering, vigor, pod load, days to harvest and

rust resistance). Under strong natural rust pressure, all resistance materials reactions were 1-4 on the 1-9 CIAT scale. The moisture and temperature conditions were unsuitable for the development of other pathogens. Many of these sources will be used in future crossing. In both cycles crosses were performed to incorporate resistance to rust, ALS and anthracnose in commercial red mottled, white and yellow seed colors used as parents with promising lines and varieties.

- In the 2012a planting cycle at Tumbaco elite bush bean lines developed in different commercial seed types were planting and evaluated under drought stress. Each line was planted in 100 m^2 plots. Morphological, agronomic and rust resistance data were taken. Of the mottled red lines tolerant to drought stress, line (S23 /3/ YUNG // S23/DOR466) 2F2 was selected for rust resistance and yield performance. Among black beans, line 9-10 from Honduras, was selected for rust resistance, adaptation and performance over the control Afroandino. Large seeded yellow line (C.CHOTA x TB2)-6F_2, was selected for its resistance to rust, good growth vigor, superior performance and pod load compared to INIAP-Chota. The large white seeded FMR line-7 (FABE ARG x TB2)-1F_2-4F_4, was better than the control INIAP Fanesquero in rust resistance, vigor, yield pod. All the selected lines will be evaluated in CIALs over the next growing cycles.

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

Approaches and Methods

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:

- Rust was collected again from bean fields in Michigan, and the strain is similar to that collected over the last five 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. Resistance appears to be associated with the Ur-5 locus on chromosome Pv04 but further testing is needed to confirm this observation. 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.

- Twenty-three isolates of anthracnose from Ecuador have been characterized and 17 races were identified, the most virulent races being 423, 429 and 813. In regard to the effectiveness of resistance genes, the *Co-3* gene from Mexico 222 and the *Co-4*^{2}, *Co-5*^{2}, *Co-7* genes from G2333 were the only ones that showed full resistance to all isolates characterized. The remaining resistance genes exhibit compatibility with either one or more of the isolates characterized.
- In order to characterize isolates of ALS, the program has adopted a system of inoculating detached trifoliate leaves of the 12 differential varieties in a Petri dish with a moistened absorbent paper. The inoculum concentration used was 30,000 conidia/ml and the petri dishes were placed under greenhouse benches to protect them from direct sunlight. Six samples of ALS collected in the villages of Tumbaco (Pichincha), Tena (Napo), Pablo Arenas, Urcuquí and Intag (Imbabura) were characterized on the differentials and three races: 62:0, 30:0 and 31:3 were identified. Among the isolates of ALS that have been characterized to date, race 31:3 is the most virulent and race 62:0 is the most common. An additional six monosporic isolates will be characterized in the coming weeks. This work is critical to provide information to the breeders making decisions on which resistance sources to use to control ALS in the different production areas of northern Ecuador.
- Five new races of rust: 9:0, 12:0, 28:0, 61:0 and 60:0 were identified from five samples collected in the villages of Tumbaco (Pichincha), Carpuela, Cotacachi and Intag (Imbabura). These results indicate the large variability of rust in the country and indicate that races are highly Andean in origin. Concern exists that many of the resistance sources have been defeated. The *Ur 3*$^+$ gene from Mexico 235 was the only gene that showed full resistance to all isolates characterized to date. The *Ur-11* gene from PI181996 was attacked by a single isolate identified as race 53:63. Other genes have shown compatibility with either three or more rust isolates characterized.
- Surveys to diagnose major root diseases in Rwanda and collect isolates of root pathogens for additional characterization were initiated this year. Root rot samples and diseased leaf samples of angular leaf spot, bean rust and anthracnose will be collected from affected bean plants. Characterization of the isolates will be done in collaboration with all partners in the new NIFA project. Last season (2012B), many field visits were visited to assess the status of disease in the country where farmers use low inputs. Losses due to root rot disease were high. Field trials and greenhouse screening will be conducted to identify root rot resistance sources for our breeding program. A complete survey to collect root rot samples infected with *Pythium, Fusarium wilt, Rhizotonia* and *Macrophomina*, and foliar disease samples has started and will continue until December 2012. Screening of promising resistant germplasm in Rwanda will follow the disease characterization when isolates will be ready for artificial inoculation.

<u>Objective 4:</u> 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. 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.
8. 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. The second round of climbing bean and maize GxE trials were planted in September, 2011, monitored, and harvested in February 2012. Five climbing bean genotypes, a farmer bean mixture unique to each site, and a single maize genotype were planted in a randomized complete block design with 14 plots in three treatments: a sole crop (beans or maize only), bean intercrop with maize, and a bean mixture with maize broadcast (MBT). Trials were planted and replicated 4 times at two research stations (mother trials) and single replicates were planted on farm in 8 communities (baby trials). Data on yield, leaf area index, and multiple plant traits were collected.
- In the community sites, activities included farmer trainings on crop monitoring and rain data collection, and participatory genotype selection (PVS). Approximately 80 farmers participated in these activities.
- At the start of the season, farmers chose two bean genotypes from the trials to plant in their own modified experiments on-farm (grandbaby trials). The goal was to learn more about farmer experimentation and allow farmers to compare genotypes qualitatively.

Approximately 80 farmers participated and planted 3 plots each; a monocrop, an intercrop, and a control plot of the farmer's mixture in a monocrop.

- In order to compare advanced line selection by breeders and farmers, farmers in each location evaluated the cropping systems, the best genotypes for a monocrop, and the best genotypes for an intercrop with maize. Data was collected on their preferences and following voting, discussions were carried out and recorded to understand why farmers chose these genotypes for each system.
- In February and March, visits to farmer's grandbaby trials, surveys and semi-structured interviews were conducted in each community with approximately 60 farmers. Surveys gathered basic demographic information, how farmers experimented with the genotypes and cropping systems, farmer genotype preferences, and the impact of monoculture policies on farmers' livelihoods.
- A portion of this work was presented as a poster 'Genotype by cropping system interactions in northern Rwanda' Isaacs, K., S. Snapp, and J. Kelly at the ASA meetings, Cincinnati OH Oct 21-25. 2012.
- Increased grower awareness and knowledge of participatory breeding methods, plant nutrition, root and soil health issues have further improved bean productivity and acceptability. Land management through bean crop intensification and its place in land consolidation program has boosted the production of beans. Environmental risks due to climate change challenge these governments' initiatives. Sustainability of bean production as for other crops will be possible when insurance companies working with famers on agricultural investment risks becomes a reality. Last year the bean research program continued with farmer participatory approaches to identify appropriate and cost-effective innovations and enhance the adoption of new climbing bean varieties. Participatory variety selection (PVS) was conducted in Muhanga with farmer participation in four sites including RAB Muhanga station. Among the biofortified climbing beans evaluated (MAC 72, MBC 71, MBC 32, MBC 71), the farmer choice was for MBC 71. In another PVS trial conducted in July during the season 2012 B in Karama with the same lines, the farmer choice was made for MAC72 due its potential to better yield under drought condition.
- Demonstration plots have been established in Karama (Eastern province) to promote the five new drought tolerant bush bean varieties (SER 12, SER 13, SER 14, SER 16 and SER 30). An evaluation was conducted with farmers in July due to late planting (lack of rain at the beginning of the season). Different drought tolerant bean varieties were under seed increase for production of breeder seed in different RAB research stations. A total of 1096 kg of different varieties including the five bush beans and four climbing beans (MAC 44, MAC 49, MAC 9 and MAC 42) was produced and distributed to seed producers for production of foundation seed. 6,595 kg of basic seeds of drought tolerant and drought tolerant biofortified bean varieties were produced at Rubona, Nyagatare and Karama stations for 2012 A and 2012 B seasons.
- Thirteen new climbing and snap bean varieties in 2012 included 5 high yielding biofortified beans were officially released in 2012. The new iron-rich bean varieties were bred through conventional breeding methods. They included MAC42, RWV 3317, RWV3316, RWV3006 and RWV2887. Farmers who evaluated these beans during participatory variety selection field days preferred them because of high yield, resistant to major diseases and pests, and the seed met urban market preferences.
- Improved seed growers income and stability of bean production will contribute to better

nutrition and health of farm families and enhance the availability and use of quality seeds.

- Seed multiplication of the two bean varieties MAC 44 and RWV 1129 on 9 ha in Rubona produced 26 tons. Significant seed increases were conducted in Nyagatare both on-station with two bean varieties RWR 2245 and MAC 44 (1.7 Ha) and the production was estimated at 4 tons. Production of the two varieties (MAC 44 and RWR 2245) with farmer partners on land area of 10 Ha was estimated at more than 20 tons. Small seed increases were conducted in different research stations including Ntendezi, Rwerere, Karama, Ngoma, Muhanga; Gakuta, and Musanze.
- Evaluation and participatory selection of bush bean germplasm with local CIALs continued in Ecuador. In the town of La Concepción, three elite lines selected in the previous cycle plus a control variety were planted in large plots (200 m^2) at two locations. Two replicates were evaluated using the evaluation form (pod load, vigor, earliness and overall plant health), as criteria for each of the reviewers. A logistic regression of the results showed that line 3 had the highest probability (over 98%) of being selected by farmers in the CIAL. The line FRM3 (AMPR5/CAL143)-4F_2-1F_4, yielded 1874 kg/ha over the other two lines and the control (Concepción) at 1434 kg/ha. The CIAL de la Concepción selected FMR3 as the future variety Centenario mainly based on its high performance, overall health and seed quality and the produced 855kg of seed for the next cycle.
- In the town of Pablo Arenas (Imbabura) FRM3 line (Centenario) were planted at two fertile sites by the CIAL and participatory data were taken on plant growth, vigor and yield. In both locations the vigor of FMR3 line was superior to other materials. FMR3 produced the best average performance at 3299 kg/ha compared to 2207 and 1957 kg / ha of promising line (Y/POA 10)-3 and Intag, respectively. Farmers from the Pablo Arenas CIAL selected FMR3 as the future choice and they produced 855 kg of seed for the next growing cycle.
- A total of 8,865 kg of seed of varieties Portilla, Conception, Afroandino and breeding line (Y/ POA10)-3 was produced by four seed growers in the La Concepción, Pablo Arenas and Tumbatú CIALs in the 2011b growing season. Seed growers from La Concepción and Pablo Arenas CIALs multiplied an additional 1,855 kg of seed of the new Centenario variety. This seed will be planted in the next growing cycle for its official release as a variety.
- Nine lines and varieties with black, red and yellow seed types selected by agribusiness as suitable for canning were evaluated in three locations: La Concepción, Pablo Arenas and Tumbaco. Rust and ALS were particularly severe in Pablo Arenas, and only Negro San Luis (NSL) and Afroandino showed intermediate resistance to ALS, as the other lines were susceptible. All lines were resistant to rust, except Afroandino which showed an intermediate reaction. Yields were higher for NSL (2722 kg/ha) and Afroandino (2303 kg/ha) black varieties. The solid red seeded lines, BRB195 and BRB194 yielded 2022 and 1918 kg/ha respectively, where the canary yellow variety Rocha yielded 1839 kg/ha and the Colombian variety ICA Quimbaya only yielded 945 kg/ha.
- Seed of Afroandino and Rocha was also sent to be tested under precision farming systems (drip irrigation and fertilization) in Santa Elena (20masl) against the interest of commercial soybean producers in the region. Information to date suggested good adaptation of black bean Afroandino and poor adaption of yellow bean Rocha. The bean team plan to travel to Santa Elena to assess the trial later this year.
- Seven lines and two improved varieties of climbing beans with red, red mottled and yellow (canary) seed types were evaluated near the town of Chillanes Bolivar province, as part of senior thesis directed by Carlos Monar, Professor at Bolivar State University. According to

preliminary results the large solid red Creole line "bombolín" was the best for quality, pod load and overall health, followed by the yellow bean Siete Colinas.

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 concluded field trials in Rwanda in two seasons 2010-2011 and CIAT, Colombia. She was supported by a Borlaug LEAP fellowship for travel to conduct additional research work at CIAT and in Rwanda in 2011-2012. Final dissertation defense is scheduled for Nov 19, 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 was 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 concluded two field seasons in March 2012 and will graduate later in 2013.
- Sara Jablonski graduated with a Master's degree in CARRS- Major Professor – Kim Chung. She 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." Her findings are listed below:
- Across Latin America, CIALs have been highly successful at creating forums in which farmers and researchers jointly diagnose problems and collaborate on applied agricultural research. Collaborating with local farmers is expected to improve the relevance of agricultural research for local communities, increase farmer capacity for research, and increase the potential for technology adoption. However, implementing the CIAL methodology requires a high level of commitment to facilitative and participatory processes. This document reports on a case study that explores how Ecuador's national bean breeding program has implemented the CIAL methodology. It offers results and recommends how the breeding program can better achieve its research objectives by committing to a higher level of engagement with CIAL communities. This study found that:
- Improved bean varieties and complementary practices were partially adopted in study communities.
- There was a strong focus on doing technical work with few farmers and less attention paid to facilitating wider community engagement.
- Information did not flow readily between CIALs and their communities.
- Farmer interest in the CIALs was on the decline.
- To improve functioning of the CIALs, the author suggests:
- Focusing on fewer CIALs,
- Improve communication amongst scientists and farmers outside of the CIAL by committing to a process of farmer engagement and partnering with other institutions, and/or In the absence of developing a vibrant and functioning CIAL, working with traditional extension services to diffuse promoted technologies

Non degree Training – Extension Activities

- Two posters and a booklet that provide a description of bean varieties released were developed, printed and presented during the official release of new improved bean varieties at a ceremony in Musanze district. Printed copies were distributed to partners and individual farmers. This activity was a collaboration with other partners including Harvest-Plus and ECABREN. The bean research program participated in Mulindi Agriculture show organized by Ministry of Agriculture and Animal husbandry (MINAGRI). Small packs of bean seed of new bean varieties were disseminated to participants along with other technologies.
- Training of trainers (extension, research technicians, NGO staff, expert farmers, seed company technicians) was organized in partnership with Win-Win Seed Company and Agro dealer. The training was organized on seed and farming systems, and how to work with progressive farmers in Rwanda.
- A workshop on Participatory Research Methods Workshop: Client-Oriented Plant Breeding and Agronomy was held for 33 participants - largely from RAB and NGOs working in Northern Rwanda on Feb 18, 2012 the RAB Research Station, Musanze. The workshop was led by Dr. Snapp with assistance from Krista Isaacs, Gerardine Mukeshimana, Karen Cichy and Jim Kelly. Participants gained an understanding of theory, and new methodologies in participatory breeding and agronomy for improved bean-based farming systems. Focus areas will include: Trial designs, participatory educational approaches as well as participatory plant breeding case studies from Malawi and Ecuador and practical tools for field research and support of sustainable livelihoods.
- A molecular breeding workshop was conducted in the biotechnology lab at Musanze, Feb 28-29, 2012. Fifteen participants including 13 from the bean research program (Researchers and Technicians) of RAB and 2 students from Umutara Polytechnic doing their research work under CRSP project in Nyagatare attended the course. The first day was reserved to theory on molecular plant breeding and its application while the second day was reserved to the hands on sessions. Various topics including theories on importance and steps of marker-assisted selection (MAS), QTL analysis, DNA extraction, PCR, and DNA electrophoresis were covered. Participants learned the use of DNA markers that are tightly-linked to the target loci as a substitute to assist phenotypic screening through MAS to speed-up breeding and selection for different traits. Geraldine Mukeshimana and Louis Butare were the trainers during this workshop.
- Drs. J. Kelly and G. Abawi travelled to Rwanda during Feb 12-20, 2012 to attend the Global PULSE CRSP meeting and present oral and poster presentations of research work being conducted in Ecuador, Rwanda, Cornell and MSU.
- Drs. J. Kelly and G. Abawi travelled to Ecuador during May 13-19, 2012 to meet with collaborators at INIAP, review research activities, visit field research sites around the country and participate in the prerelease of new Centenario variety to farmers and extension staff from the town of Concepcion.

Contribution of Project to Target USAID Performance Indicators: Completed

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)
Mission staff in Rwanda attended the PULSE CRSP Global meeting held in Kigali in Feb 12-18, 2012. 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 Activities 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.
- A bean stakeholder meeting was organized in RAB eastern zone and plans to have similar meetings in Southern, Northern and Western Zones were made to initiate platforms for main actors in bean production chains.
- International NGOs including AFRICARE, ADRA, CARITAS Rwanda, and Catholic Relief Services were among key partners this year 2012. Local NGOs such as DERN, INGABO, CSC, and IMBARAGA (an umbrella group of farmer organizations) and individual farmers have contributed effectively in the dissemination of new bean technologies. National University of Rwanda (UNR), Umutara Polytechnic University, Kigali Institute of Technology (KIST), Higher Training Institute of Agriculture and Livestock (ISAE) and Bean Food Processing Industry in Butare (Huye) were among the major collaborators to research on beans in 2012.
- 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 in Rwanda, funding was secured from Harvest-

Plus, Bio-Innovate, AGRA – Alliance for a Green Revolution in Africa, ASARECA and PABRA network. Future funding prospects may be coming from Kirkhouse Trust and NIFA projects. 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.

Scholarly Activities and Accomplishments

List of Publications

Kelly, J.D., G.V. Varner, K.A. Cichy, and E.M. Wright. 2012. Registration of 'Rosetta' pink bean. J. Plant Registrations 6: 229-232. doi: 10.3198/jpr2012.03.0142crc.

Kelly, J.D., G.V. Varner, W. Mkwaila, K.A. Cichy, and E.M. Wright. 2012. Registration of 'Eldorado' pinto bean. J. Plant Registrations 6: 233-237. doi: 10.3198/jpr2012.02.0140crc.

Kelly, J.D., G.V. Varner, K.A. Cichy, and E.M. Wright. 2012. Registration of 'Snowdon' white kidney bean. J. Plant Registrations 6: 239-242. doi: 10.3198/jpr2012.03.0146crc.

Heilig, J.A., and J.D. Kelly. 2012. Performance of dry bean genotypes grown under organic and conventional production systems in Michigan. Agron. J.104:1485-1492.

Mukeshimana, G., Y. Ma, A. E. Walworth, G-q. Song, and J. D. Kelly. 2012. Factors influencing regeneration and *Agrobacterium tumefaciens*-mediated transformation of common bean *(Phaseolus vulgaris L.*). Plant Biotechnol. Rep. doi:10.1007/s11816-012-0237-0.

Book Chapters

Kelly, J.D. and K.A. Cichy. 2012. Dry Bean Breeding and Production Technologies, pp. 23-54. In: Common Beans and Pulses: Production, Processing, and Nutrition. Editors: M.A. Uebersax, M. Siddiq, K.D. Dolan John-Wiley Publishing Co.

Roman-Avilés, B., J.M. Lewis and J.D. Kelly. 2012. *Fusarium* Genetic Control: A Long Term Strategy, pp. 65-108. In: Control of *Fusarium* Diseases, Editors: Fernando M. Alves-Santos, Julio J. Diez, Research Signpost 37/661, Kerala, India. ISBN: 978-81-308-0470-5.

Nonrefereed Publications

Acosta-Gallegos, J., and J.D. Kelly. 2012. Strategies to improve adaptation of common bean to drought. Ann. Rept. Bean Improv. Coop. 55:7-8.

Brisco, E.I., T. Porch, and J.D. Kelly. 2012. Influence of leaf color in a dry bean mapping population on Empoasca sp. populations and host plant resistance. Ann. Rept. Bean Improv. Coop. 55:83-84.

Heilig, J. and J.D. Kelly. 2012. Utilizing growth pouches to screen black and navy dry bean breeding lines for early nodulation. Ann. Rept. Bean Improv. Coop. 55:67-68.

Miklas, P.N., J.D. Kelly, J.R. Steadman and S.McCoy. 2012. Release of partial white mold resistant pinto USPT-WM-12. Ann. Rept. Bean Improv. Coop. 55:291-292.

Mkwaila, W. and J.D. Kelly. 2012. Identification and validation of QTL for resistance to white mold in two pinto bean RIL populations. Ann. Rept. Bean Improv. Coop. 55:157-158.

Mukeshimana, G., L. Butare, S. Beebe, M.W. Blair and J.D. Kelly. 2012. Phenotypic evaluation of dry bean RIL populations for drought resistance in Rwanda. Ann. Rept. Bean Improv. Coop. 55:111-112.

Osorno, J.M., M.R. Miles, J. Weyers, J. Prendergast, J.D. Kelly, G. Varner, M. Siddiq, C.A. Urrea, K. Cichy and A.M. Linares. 2012. Genetic and environmental effects on canning quality of pinto and navy bean cultivars commonly grown in central US. Ann. Rept. Bean Improv. Coop. 55:77-78.

Sousa, L.L., M.C. Goncalves-Vidigal, A.S. Cruz, P.S. Vidigal Filho, V.A. Vallejo and J.D. Kelly. 2012. Genetic mapping of the Co-5^2 allele for resistance to *Colletotrichum lindemuthianum* in MSU 7-1 line. Ann. Rept. Bean Improv. Coop. 55:109-110.

Professional Recognition, Awards and Accomplishments

At the World Food Prize Conference in October 2012, Gerardine Mukeshimana was awarded the 2012 BIFAD Student Award for scientific excellence by a student working in a USAID CRSP project.

Dry Grain Pulses CRSP

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

(For the Period: September 1, 2011 – March 31, 2012)

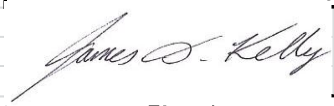
This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

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	04/1/12	Y	N*	04/1/12	Y	N*	04/1/12	Y	N*	04/1/12	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					x	x				
Nursery evaluation							x	x		x	x	
crossing	x	x					x	x		x	x	
Marker assisted selection	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		
Variety Release	x	x					x	x		x	x	
Objective 2												
Advanced Population development	x	x					x	x			x	
Test Populations in Rwanda										x	x	
Other population development	x	x					x	x		x	x	
Characterize CIAT resistance sources										x	x	
Increase, characterize local germplasm							x		x	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		
Root Pathogen x germplasm interaction				x		x	x	x				
Collect foliar pathogens in Rwanda	x	x								x	x	
Race characterization	x		x	x		x	x	x		x		

Objective 4												
Visit of Rwandan scientists to Ecuador							x	x		x	x	
Workshop Participatory in Rwanda										x	x	
Evaluation of elite lines in CIALs							x	x		x	x	
Variety releases in Ecuador							x	x				
Farmer vs. Breeder Selection										x	x	
Evaluation of climbing beans							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		

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



5-Oct-12

Signature **Date**

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

MSU

Root rot characterization of MSU lines was conducted at Cornell University, No race characterizations conducted on root pathogens at MSU

1. Not working on molecular markers due to lack of personnel at INIAP.
2. No work was doneon biofortification due to a lack of response of CIAT to perform analysis offered two years ago.
3. No new germplasm has been collected in country for the last two years

RWANDA

Marker assisted lab was not fully functioning at RAB

Bean samples were provided to KIST for nutritional and canning analysis - no data received

No characterization of root rot pathogens collected in Rwanda.. Conducted later

Expanded work was conducted on breeding population and germplasm for drought and root rot

Cornell

Discussed needed methodologies and protocols during recents visits and encouraged in-country work, due to difficulty in bringing isolates to the US.

Dry Grain Pulses CRSP		
PERFORMANCE INDICATORS/TARGETS for FY 12		
(October 1, 2011 -- September 30, 2012) Ecuador		
	PI-MSU-1	
	2012 Target	**2012 Actual**
Output Indicators	**(Oct 1 2011-Sept 30, 2012)**	
Degree Training: Number of individuals who have received degree training		
Number of women		
Number of men		
Short-term Training: Number of individuals who have received short-term training		
Number of women		
Number of men		
Technologies and Policies		
Number of technologies and management practices under research	10	10
Number of technologies and management practices under field testing	7	7
Number of technologies and management practices made available for transfer	6	6
Number of policy studies undertaken		

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	**2500**	2700
Number of rural households benefiting directly from CRSP interventions - Male Headed households	**2500**	2700
Number of agriculture-related firms benefitting from CRSP supported interventions	17	18
Number of producer organizations receiving technical assistance	**19**	20
Number of trade and business associations receiving technical assistance	**2**	3
Number of community-based organizations receiving technical assistance	**22**	23
Number of women organizations receiving CRSP technical assistance		
Number of public-private partnerships formed as a result of CRSP assistance	0	
Number of HC partner organizations/institutions benefiting		
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	9000	

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

Principal Investigator
Richard H, Bernsten, Michigan State University, USA
Cynthia Donovan, Michigan State University, USA
Eric Crawford, Michigan State University, USA

Collaborating Scientists
David Kiala, University Jose Eduardo dos Santos (formerly known as University Agostinho Neto), Angola
Feliciano Mazuze, Mozambican Institute for Agricultural Research (IIAM), Mozambique
Juan Carlos Rosas, Escuela Agricola Panamericana (Zamorano, EAP), Honduras

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Abstract of Research Achievements and Impacts
Research achievements have focused on diagnostics for the bean and cowpea markets in Angola and Mozambique. Cowpeas are now included in both countries and found to have different market structures than the common beans, as well as different production zones. Quality issues remain in both countries for marketing, with varietal mixing in sales (stemming from producer level) and off-season problems of pests in the stored commodity. In both Mozambique and Angola, market opportunities could be improved by strengthening agricultural research into varieties and cropping cycles with market opportunities, by improving storage options and technologies to avoid damage during storage, and by improving farmer and trader knowledge of trade through market information.

In Mozambique, there are clear differences on the consumption budget allocated for common beans and cowpeas. Urban households allocate a larger proportion of their budget on common beans than in cowpeas, whereas, rural households allocate the same amount for the two crops. Analyses reveal that in terms of production, cowpea is a female crop, whereas common beans are produced by both, males and females. For both, cowpeas and common beans, price variability can be high, both seasonally and between seasons due to weather variability and policy considerations in Mozambique and neighboring countries. In Mozambique cowpeas were generally more of a food security crop, with low per household sales, while common beans have previously been found to be highly marketed in the more concentrated production zones. This suggests that there are more developed marketing channels for the common beans. Women are active traders in the common beans wholesale markets of Mozambique. In Mozambique, common beans value chain is relatively short and do not take advantage of regional/ export opportunities.

The most visible impact in Angola will continue to be the training on value chains, policy, and price analysis. For CESE/IIAM, value chain training as well as training on investment and cost benefit analysis has contributed to development of research that can better address the issues farmers and traders face.

Project Problem Statement and Justification

Angola

The development of the common bean and cowpeas value chains in Angola depends heavily on understanding producer constraints on production and marketing, as well as identifying leverage points within the value chain in which cost savings and better coordination can be achieved. Prior to this project, very little was known about the marketing channels for these beans or how farmers engaged with the markets. The initial objectives of this project included collaboration to ensure a market information system (MIS), however due to lack of political will for MIS, the project has focused on farmer and trader surveys to help identify constraints and opportunities to then engage the stakeholders in discussions for change. In FY2012, field research on cowpeas was added to the earlier work on common beans. A key component of this project is the training of students and supervision of student theses and the utilization of value chain approaches in their thesis research.

Mozambique

In Mozambique, cowpea and common bean value chains are thought to be distinct but research and analysis was needed to understand the dynamics of farmers and traders to highlight opportunities for investment and better value chain coordination. A key research question is whether or not market traders can be more efficient or whether markets can function more efficiently overall. Price analysis was needed to understand the spatial relationships among the markets and the seasonal tendencies of market volumes and prices. One of the areas of research involves identifying opportunities for growth. Training with IIAM/CESE analysts will introduce concepts related to investment and cost benefit analysis to complement earlier partial budget analysis. This training will help analysts to evaluate opportunities with a view to profitability now and into the future for farmers and traders.

Results, Achievements and Outputs of Research

Objective 1: Angola

Identify efficiency in marketing channels of beans and cowpeas and leverage points to increase farmer profits and trader volumes

Kiala and Donovan worked with students to develop cowpea field research on marketing channels conducted in FY2012. The research team interviewed traders, consumers and a few producers in the rapid appraisal in Huambo province in late 2011. Later work by students visited selected areas in lower elevations. Strong seasonality was highlighted by the lack of large volumes in the off season, and the generally poor quality of cowpeas available in the market, due to presence of pests. In their market visits, the UCR team found similar results, with varietal mixing in the marketed quantities, although larger volumes were found in the lowland production areas. There was no evidence of any volume trading in the highland zones or of large private sector traders participating in cowpea markets.

Women are the principal participants in selling common beans and cowpeas in the highlands, with supporting roles played by youths in their families. Women traders from Huambo and other cities travel to purchase from producers in the rural areas. In general, women producers are responsible for selling common beans, and they often sell in small volumes to be able to meet household expenses. The producers do not travel from their farm or their local market to sell. It is the buyers who purchase from several or many sellers to accumulate sufficient volumes to transport to larger towns and cities. They then sell at wholesale and possibly retail levels in larger markets. These buyers are familiar with the best local markets to efficiently arrive, buy, and transport back within a day, to avoid having to seek local storage before transport. Although not unseen, it is less common for producers, whether as a group or as individuals, to bring together larger volumes to transport and sell themselves in the wholesale markets, as they are not as adept at arranging transport and knowing how to negotiate prices to minimize risk of losses. When this does occur, however, it is men conducting this volume trade of producers.

As a marketing channel, there are limited large scale traders dealing in wholesale markets who purchase common beans in the highlands to then transport in bulk to the major markets of Luanda and Benguela. In spite of improved transport systems in the past three years, there appear to have been no significant changes. Common beans are not seen as a key commodity by these traders, with few exceptions.

Paved primary roads facilitate transport between the key markets, however the lack of all-weather secondary and tertiary roads limits producer and trader transport within the production zones. The poor quality of these secondary and tertiary roads results in few transporters going off the paved roads; farmers and traders face major transport constraints due to the limited number of trucks in operation. The rehabilitated railway will provide new opportunities for commodity transport in the zone, as will the continued investments in secondary roads.

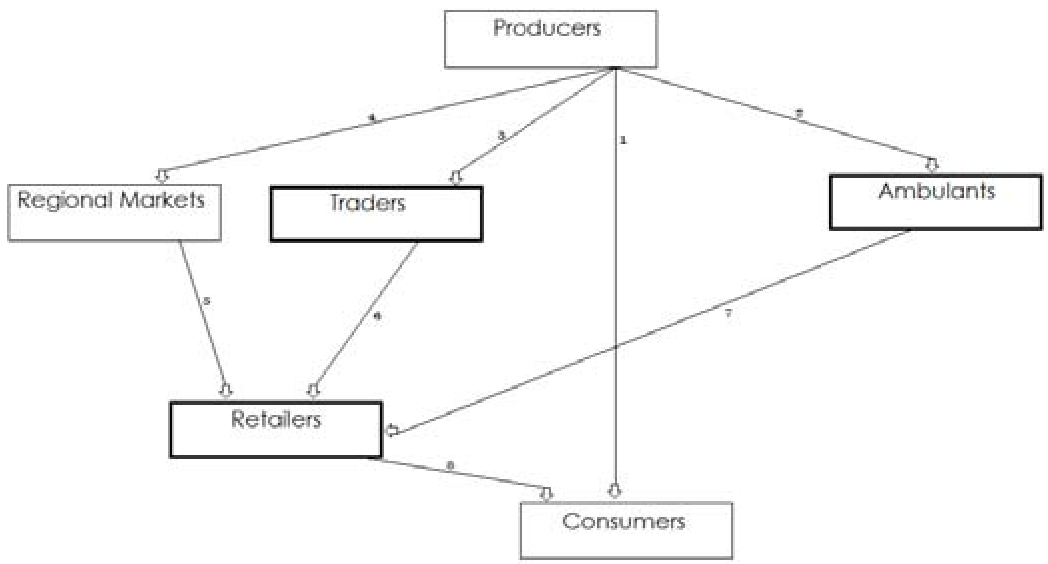
Producers of common beans and cowpeas face another constraint: lack of adequate storage facilities and technology. The constraint also affects the quality of grain available in the market and the traders' potential to use temporal arbitrage. Farmers want to sell commodity as soon as possible to avoid degradation, thus sell at low harvest time prices. Traders face the challenge of grain quality which deteriorates over time if stored without adequate means. In the market of Kamacupa, researchers saw degraded cowpeas that had been ground into a rough flour for sales.

Field research focused on both common beans and cowpeas in the two public markets in Huambo, the capital of Huambo Province. The traders in the main Alemanha market do not face high barriers to entry, as they simply pay a daily market fee to trade. However in the Municipal market in town, space is limited and traders obtained their licenses and space when the market was built and pay fees for their fixed locations. There is no longer space for new entrants in Municipal market. As a consequence, there are fewer legume vendors in the Municipal market than in Alemanha market and cowpeas are only sold as a side commodity by common beans sellers, with no specialization in cowpeas among the traders.

There are significant numbers of common bean traders in the Alemanha markets and many fewer cowpea traders; a few common bean traders also had small quantities of cowpeas for sale. When questioned, traders indicated that cowpeas were considered by consumers as an inferior good, sought by poor households that cannot afford to purchase common beans. The quantity sold per buyer were said to be much lower for cowpeas than for common beans. It should be noted that this may be directly related to consumption habits in the highland region and could be quite different in lower elevation, drier areas. Research in late 2011 indicated that markets in zones with higher production of cowpeas had major sales of cowpeas during the main harvest season, but quality issues, especially pest infestations, limited availability and sales in the off-season.

Overall, the market research shows little change in the market systems since 2009, with reliance on informal trading, limited numbers of agents, and few options to the informal sector traders. Research identified 4 main marketing channels (Txocanaie, 2011). For Channel 1, Farmers may sell directly to consumers in their local market, especially when markets have specific market days. In Channel 2, farmers may arrange transport to local town or city markets to sell at wholesale and retail levels. Channel 3 has farmers selling to itinerant women traders that arrive in local markets or at farm gate; these traders arrange transport to the larger towns and cities to sell to retailers, who in turn sell to consumers in urban markets. Channel 4 involves small groups of farmers arranging transport to Luanda or Benguela to sell beans, but this circuit is seen as highly risky due to difficulties in arranging transport, price uncertainty, and quality degradation in transport. Missing are the large-scale buyers who have the transport and storage capacity for spatial and temporal arbitrage.

Figure 1. Market Channel Map of Local Common Beans, Angola



World Vision continues to work on collecting market prices, and Donovan worked with their system coordinator, suggesting improvements to the data system, to deal with nonstandard units and to control for quality. They broadcast their information through a paper bulletin and radio broadcasts.

<u>Objective 2:</u> Mozambique

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

Isabel Cachomba, CESE analyst, came to MSU Aug 12-25 to continue work with Cynthia Donovan on the consolidated common bean and cowpea report, using price information as well as household survey results, combined with rapid market appraisals.

To determine whether consumption in urban areas was significant, nationally representative datasets from 2009/2010 were analyzed.

While conducting this analysis, it was clear that there are gaps in our knowledge of the cowpea value chain. Thus, Isabel Cachomba will lead the socioeconomists Amancio Nhantumbo and Cassamo Sumila in collecting data on the cowpea value chain including production gross margins in Niassa and Zambezia provinces. This fieldwork will be carried out in November-December 2012. This field research will include focus group interviews with farmers to evaluate their cowpea cropping to develop crop budgets, followed up with analysis of technology options with partial budgeting analysis.

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

Analysis by Cachomba and Donovan on TIA data indicates that farmers are increasing their ownership of cell phones; however SIMA has not moved forward on the development of the cell phone based system. This key objective remains unfulfilled. Only recently were funds allocated by MINAG/SIMA to hire consultants and obtain equipment for this effort, which is still at least three months in the making to institute. This objective remains unfulfilled.

Objective 3: Honduras

There was no work conducted in Honduras during FY2012. However, Bernsten and Rosas prepared a poster on the work conducted concerning Fair Trade efforts in Honduras. The poster Exporting Fair Trade Beans from Honduras to a U.S. Market demonstrated the key steps and costs in the process. The implications of the research are threefold, as stated in the poster. First, fair trade certification provides an opportunity for farmers to receive a premium price for their beans, but farmers are used to spot markets rather than the forward contracting needed here. When future prices are uncertain, this experience found that farmers preferred to wait and sell on the spot market. Second, the process for obtaining fair trade certification is extremely complex, such that farmers must have technical assistance to gain certification. Third, as obtaining fair trade certification is very expensive ($US 2,700/year), these costs account for a significant share of the final delivery price. Thus, the market is limited to upscale U.S. food retailers such as Whole Foods Market.

Objective 4: Institutional Capacity Building

Degree Training

First and Other Given Names: Ana Lidia
Last Name: Gungulo
Citizenship: Mozambican
Gender: F
Degree: MS
Discipline: Agricultural Economics
Host Country Institution to Benefit from Training: IIAM/CESE
Training Location: Pretoria, South Africa
Supervising CRSP PI: C. Donovan
Start Date of Degree Program: January 2009

Program Completion Date: December 2012
Training Status during Fiscal Year 2012: Thesis under revision
Type of CRSP Support (full, partial or indirect): Full support.

Short Term Training

Type of Training: Collection and Analysis of Market Prices training
Description of Training Activity: This training discussed the role of prices, price discovery and analytical challenges with prices as times series data, including a computer based session on price analysis. During the training, it was clear that analytical skills and computer skills were both lacking to be able to conduct thorough price analysis, but attendees were able to develop simple graphs and estimations of real prices as a result.
Status of this Activity as of September 30, 2012: Completed
When did the Short Term Training Activity occur? Dec 12-13, 2011
Location of Short Term Training: Faculdade de Ciencias Agrarias, Chianga, Huambo, Angola
Who benefitted from this Short Term Training Activity? A combination of students of FCA, NGO staff members for World Vision, ADRA and others, staff members from the Ministry of Commerce, Agricultural Research Institute, and Agricultural Development Agency
Number of Beneficiaries by Gender: Male –13
FeMale –8
Total – 21

Type of Training: Introductory Training on Investment and Cost Benefit Analysis
Description of Training Activity: This training presented the key concepts and research issues on investment analysis and cost benefit analysis, based on examples and exercises.

Status of this Activity as of September 30, 2012: Completed
When did the Short Term Training Activity occur? April 10-18, 2012
Location of Short Term Training: IIAM, Maputo, Mozambique
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Staff members of IIAM Center for Socio Economic Studies as well as two students from FCA, UJES, Angola
Number of Beneficiaries by Gender: Male –6
FeMale –0
Total – 6

Type of Training: English
Description of Training Activity: This training in South Africa is to provide intensive English in both classroom and living environment over six weeks
Status of this Activity as of September 30, 2012: Partially Completed
When did the Short Term Training Activity occur? One (1) trainee in March 2012, second to go in November 2012.
Location of Short Term Training: Capetown, South Africa
If Training was not completed as planned, provide a rationale: Second trainee was delayed and unavailable to travel until November; then, upon arrival at training in November, was informed that his daughter died and returned to Mozambique. Arrangements were made for him to attend training in January/Feb 2013.

Who benefitted from this Short Term Training Activity? Staff members of IIAM Center for Socio Economic Studies
Number of Beneficiaries by Gender: Male –2
FeMale –0
Total – 2 check numbers

Explanation of Changes
Key activities associated with Market Information System development in each country were not conducted due to lack of public sector resources and in the case of Angola, lack of public sector agency involvement. Estevao Chaves, the Pulse CRSP trainee who received his MS degree from University of Vicosa in Brazil, was recruited under a special program with the President's office and is advocating for public sector investments in MIS from that position, but progress is limited.

In Mozambique, Objective 3 was not accomplished. SIMA has been delayed by a combination of events and has not moved forward with the initiative. Recent survey evidence shows increasing farmer access to cell phones, and the investments may yet occur in late 2012. Our recommendation will be to ensure that there is an impact assessment study of the use of the phones.

Networking and Linkages with Stakeholders
USAID Mission was visited in Luanda in December 2011 and Mission staff members present included Scott Jackson and Gastao Lukanu. For all training activities, members of IIA are included; in the FY2012 markets and prices training, staff from various NGOS and government agencies were included in the training.

In Mozambique, the Mission has been kept up to date on the Pulse CRSP activities through informal interactions and brief meetings. USAID Agrifuturo continues to be engaged, although the stakeholder work has been delayed. Plans have been developed for a stakeholder meeting in December 2012, including private sector agents in trading and processing.

Leveraged Funds
Name of PI receiving leveraged funds**:** Cynthia Donovan
Description of leveraged Project: World Vision ProRenda project to increase smallholder income in selected crops, including common beans, in the Highlands of Angola. Under this project, we continue to sue the dataset collected as a baseline.
Dollar Amount: $10,000 (estimate includes shared cost of data collection and analysis)
Funding Source: WV, Gates

Name of PI receiving leveraged funds: Cynthia Donovan
Description of leveraged Project: Training program for policy analysis with IIAM socio-economists. Some training activities jointly funded with USAID/MSU Food Security Project
Dollar Amount: at least $5,000
Funding Source: MSU's Food Security Project (FSP) under USAID funding.

Scholarly Activities and Accomplishments
Bernsten, Rick and Juan Carlos Rosas. 2012. Exporting Fair Trade Beans from Honduras to a

U.S. Market. Poster presented at the Global Pulse Researchers Meeting in Kigali, Rwanda, 13-17 February, 2012.

Cachomba, Isabel and Cynthia Donovan. 2012. Value Chain Analysis of Common Beans in Mozambique. Poster presented at the Global Pulse Researchers Meeting in Kigali, Rwanda, 13-17 February, 2012.

Gungulo, Ana Lidia. Draft 2012. Expanding Pulse Production in Mozambique: Identifying Constraints and New Strategies. Johannesburg: University of Pretoria.

Txocanaie, R., A. Catuti, D. K. Kiala, and C. Donovan. Market Chain and Key Actors for Common Beans in Huambo, Angola. Poster presented at the Global Pulse Researchers Meeting in Kigali, Rwanda, 13-17 February, 2012.

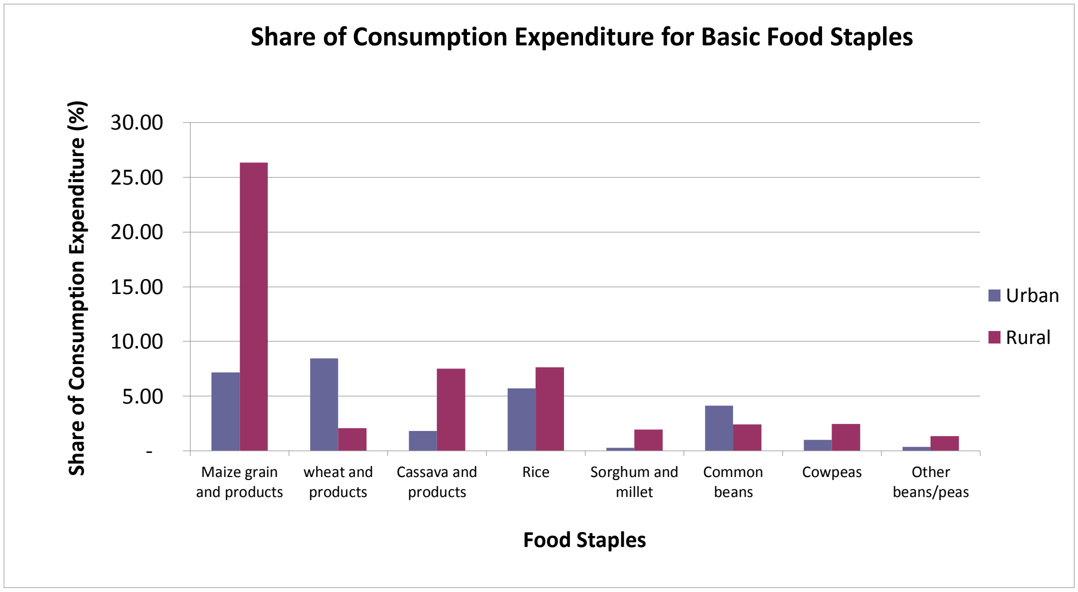
Tables/Figures

Table 1. Mozambique: Share of consumption expenditures for common beans and cowpeas (urban and rural areas), 2008/2009

Province	Expenditure on common beans (%)		Expenditure on cowpeas (%)	
	Urban	Rural	Urban	Rural
Niassa	6.0	3.4	0.8	1.2
Cabo Delgado	3.5	1.2	2.6	4.2
Nampula	3.1	0.7	2.2	3.7
Zambezia	4.1	3.3	1.1	1.8
Tete	6.5	4.0	0.8	1.2
Manica	4.0	2.3	0.6	1.0
Sofala	6.3	3.2	0.7	2.1
Inhambane	3.3	0.6	1.4	5.5
Gaza	3.9	1.7	0.7	2.2
Maputo Prov	5.2	4.6	1.1	1.9
Maputo City	2.9	-	0.7	-
Overall	4.1	2.4	1.0	2.4

Source: IOF, 2008/2009

Figure 2 Mozambique Consumption shares, Rural and Urban, 2008/2009



Source: Cachomba and Donovan, 2012 draft, based on IOF 2008/2009.

Table 2: Mozambique Production and Farming of Common Beans, 2008

Province	Farmers Cropping (%)	Annual quantity produced per farm household (Kg)		Total production (Kg)
		Mean	Median	
Niassa	29.4	330	155	22,500,000
Cabo Delgado	0.3	40	46	42,323
Nampula	1.3	85	36	820,940
Zambezia	6.2	131	53	6,664,316
Tete	32.9	130	89	15,900,000
Manica	11.8	123	71	3,977,422
Sofala	6.3	37	18	602,961
Inhambane	0.5	7	5	10,421
Gaza	22.6	28	10	1,597,221
Maputo	5.7	65	5	418,845
Overall	9.8	144	53	52,534,448

Source: TIA 2008

Table 3. Mozambique Aspects related to cowpea production

Province	Farmers Cropping (%)	Annual quantity produced per farm household		Total Quantity Produced (kg)	Total Quantity marketed (kg)	% of national production
		mean	median			
Niassa	32.2	86	59	6,416,267	690,845	10
Cabo Delgado	45.5	58	30	9,626,651	1,372,872	16
Nampula	38.8	43	18	12,500,000	2,905,246	20
Zambezia	37.2	33	17	9,982,596	1,867,329	16
Tete	59.0	40	18	8,730,754	1,367,726	14
Manica	33.5	32	15	2,902,043	611,630	5
Sofala	36.9	20	8	1,943,643	70,142	3
Inhambane	75.3	21	5	4,375,497	257,501	7
Gaza	63.7	28	11	4,401,041	134,412	7
Maputo	56.7	17	5	1,121,664	9,305	2
Overall	45.1	37	17	62,000,156	9,287,007	100

Source: TIA, 2008

Literature Cited

Cachomba, Isabel and Cynthia Donovan. 2012 Forthcoming. Common Beans and Cowpea Value Chains in Mozambique: Constraints and Opportunities for Agricultural Research and Policy Interventions. Maputo: Instituto de Investigacao Agraria (IIAM).

Catuti, Adolfo. 2011. Identificação de Oportunidades e Constrangimentos na Produção e Comercialização da Cultura de Feijão no Município do Bailundo Província do Huambo. Faculdade de Ciências Agrárias Universidade Jose Eduardo dos Santos, Chianga.

Txocanaie, Robertinho. 2010. Identificação de Canais de Comercialização do Feijão no Município do Londimbuali, Província do Huambo. 28 De Julho De 2010. Faculdade de Ciências Agrárias, Universidade Jose Eduardo dos Santos, Chianga

Contribution to Gender Equity Goal

Training continues for Ana Lidia Gungulo, a woman scientist from IIAM/CESE.

For the value chain analyses in both Angola and Mozambique, the main traders are women. In addition, women are often the household members responsible for cowpea cultivation, harvest and selling. Value chain improvements that can meet their needs will contribute to household income. Market information will help to improve the competitiveness of women farmers and traders. Combining market knowledge with technology, especially new varieties, will enhance the role that cowpeas play in livelihoods. Note that women participate with men in common bean production and marketing in Mozambique.

Progress Report on Activities Funded Through Supplemental Funds

While the funds were received earlier, the vehicle purchased for IIAM in northern Mozambique became available in FY 2012 and is currently being used to collect data on common beans and cowpeas value chain including production gross margins in the northern provinces of Niassa and Zambezia in November/December 2012.

In Angola, UJES's Guilherme continues to use the equipment and technology to record and later use educational presentations and classes based on MS Powerpoint and Camtasia software. In Mozambique, Sostino Mocumbi continues to use the technology as part of a set of innovations, including the use of the animated videos from the University of Illinois with the PII-UIUC Pulse CRSP Project and Scientific Animations without Borders (SAWBO).

Dry Grain Pulses CRSP
Report on the Achievement of "Semi-Annual Indicators of Progress"
(For the Period: October 1, 2011 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

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

	Abbreviated name of institutions																	
	MSU			UJES (UAN)			IIAM			0			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1: Angola																		
Rapid appraisal field research in common bean markets conducted with students	0			0			0			0			0			0		
Rapid appraisal field research in cowpea markets conducted with students	0			0			0			0			0			0		
Common bean market efficiency report drafted and distributed	0			x		x	0			0			0			0		
Outreach with farmer associations and local agencies	0			x		x	0			0			0			0		
Objective 2: Mozambique																		
Report on Rapid Appriasal Survey 2012 finalized and distributed	x	x		0			x	x		0			0			0		
Outreach on Rapid Appriasal Survey 2012 results with NGOs and farmer orgs	0			0			x		x	0			0			0		
Market efficiency report drafted and distributed	0			0			0			0			0			0		
Outreach to Bean Task Force on marketing efficiency preliminary results	0			0			x		x	0			0			0		
Cell phone system training for bean producer groups	0			0			0			0			0			0		
Preliminary assessment of use of cell phone system	x		x	0			0			0			0			0		
Objective 3: Honduras no activities																		
Objective 4: Capacity Building																		
Angola	0			0			0			0			0			0		
MS thesis finalized	0			0			0			0			0			0		
Outreach on MS thesis research	0			0			0			0			0			0		
Students trained on price and market analysis	0			0			0			0			0			0		
Students trained on partial budgeting analysis	0			0			0			0			0			0		
Mozambique																		
MS thesis finalized	0			0			0			0			0			0		
Outreach on MS thesis research	0			0			0			0			0			0		
CESE staff trained on survey research	0			0			0			0			0			0		
CESE staff trained on market efficiency analysis	x		x	0			0			0			0			0		
CESE staff trained on partial budgeting analysis	x	x		0			0			0			0			0		
CESE staff trained on Cost Benefit analysis	0			0			0			0			0			0		
CESE staff completes Intensive English course	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																		

Signature **Date**

Dry Grain Pulses CRSP		
PERFORMANCE INDICATORS/TARGETS for FY 12		
(October 1, 2011 -- September 30, 2012)		
	PII-MSU-2	
	2012 Target	**2012 Actual**
Output Indicators	**(Oct 1 2011-Sept 30, 2012)**	
Degree Training: Number of individuals who have received degree training		
Number of women	1	1
Number of men	1	0
Short-term Training: Number of individuals who have received short-term training		
Number of women	20	11
Number of men	30	17
Technologies and Policies		
Number of technologies and management practices under research	6	2
Number of technologies and management practices under field testing	3	0
Number of technologies and management practices made available for transfer	2	0
Number of policy studies undertaken	2	2

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	**10**	0
Number of rural households benefiting directly from CRSP interventions - Male Headed households	**40**	0
Number of agriculture-related firms benefitting from CRSP supported interventions	3	1
Number of producer organizations receiving technical assistance	5	2
Number of trade and business associations receiving technical assistance	1	0
Number of community-based organizations receiving technical assistance	1	0
Number of women organizations receiving CRSP technical assistance	2	1
Number of public-private partnerships formed as a result of CRSP assistance		1
Number of HC partner organizations/institutions benefiting		2
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	100	0

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

Principal Investigator
Jonathan Lynch, Pennsylvania State University, USA

Collaborating Scientists
Juan Carlos Rosas, EAP, Honduras
Magalhaes Miguel, IIAM, Mozambique
Kathleen Brown, Penn State, USA
Jill Findeis, Penn State, USA
Celestina Jochua, IIAM, Mozambique
Soares Almeida Xerinda, IIAM, Mozambique
Roland Chirwa, CIAT, Malawi

Abstract of Research Achievements and Impacts
This project has realized substantial progress for all objectives, including the development of new bean lines with greater tolerance to drought and low soil fertility in Central America and Mozambique, phenotypic profiling of many bean lines for root traits of value for bean breeding, discovery of new traits that can be used to select stress tolerant cultivars, discovery of genetic markers controlling these traits, characterization of several important agroecological benefits from bean lines with superior root traits, including reduced soil erosion, enhanced water utilization, and greater biological N fixation, comprehensive analysis of community preferences for bean lines and obstacles to seed dissemination, and training of bean researchers from Mozambique.

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 (e.g., QTL) would be useful.

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

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

<u>Objective 1:</u> Develop bean genotypes with improved tolerance to drought and low P.

<u>Approaches and Methods</u>

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

The selection process of inbred-backcross (IBC) lines having similar background of Amadeus 77, the most widely grown small red bean cultivar in Central America, but differing in several root traits, was continued during FY12 using drought and low P conditions on greenhouse and field trials. Selection was based on agronomic adaptation (plant architecture, disease resistance, maturity, vegetative and reproductive growth), yield and seed color (1-9 red seed color scale), shape (ovoid) and size (23-25g/100 seeds), similar to those from the recurrent parent Amadeus 77. 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 for their superior adaptation to drought or low fertility soil conditions and various contrasting root characteristics under these limiting stress factors.

During FY12, 30 IBC lines and the parental lines Amadeus 77 (recurrent), L88-13, L88-33 and L88-63 (donors) were evaluated during the summer season (January) of 2012 under irrigation. These lines were chosen from previous root phenotyping studies conducted under greenhouse and field conditions in PSU and Zamorano, using visual counts and observations of whorl number, basal roots number and angle, and measurements of root density, surface area, volume and length using the Winrhizo program. Seed yield among the 30 IBC lines varied from 720 to 1900 kg/ha. The best lines out yielded the recurrent parent Amadeus 77 (1,038 kg/ha) and their donor parents L88-13 (1,093 kg/ha), L88-33 (1,080 kg/ha) and L88-63 (870 kg/ha).

An additional field trial including 18 IBC lines and the parental checks Amadeus 77 and L88-13 were evaluated using fertilizer (130 kg/ha 18-46-0 at planting and 50 kg/ha Urea 46% before flowering) and without fertilizer treatments, during the second raining season (October 2011). Seed yields varied from 864 to 2,023 kg/ha with added fertilizer, and from 396 to 948 kg/ha without fertilizer treatments; the geometric mean (GM) varied from 724 to 1,420 kg/ha. Superior lines which performed well under with and without fertilizer treatments and higher GM were identified. Information of root characterization from previous studies was used to select the most low fertility tolerant lines from this group for further studies and on-farm validation trials.

Another field trial including six IBC lines and the checks Amadeus 77 and Seda (landrace), was conducted during the May 2012 season using fertilizer and no fertilizer treatments in a low soil fertility plot at Zamorano. The line BRT 103-182 has greater seed yield than the two checks under no fertilization and IBC lines; however, no differences were found on number and angle of basal roots, or on the number, diameter and density of adventitious roots and primary root diameter, to explain the yield superiority of this line. However, the cultivar Seda has the second greater seed yield, and have the highest shoot dry wt, nodulation score and number of adventitious roots. This work is being conducted as part of the research project for graduation of the Zamorano junior student Ms. Mariel Gallardo. On various studies, the cultivar Seda has been identified as being one of the best landrace under drought and low fertility conditions; and it is currently used as parent in crosses with the best tolerant small red and black lines for improving the adaptation to these limiting conditions in Central America.

A set of 18 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 during the October season of 2011 in a low N and P soil and using with and without soil fertilization treatments as in the previous trial 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. Seed yield under fertilization treatment varied from 898 to 2,944 kg/ha; and under no fertilization from 536 to 1,549 kg/ha. The same set of lines were evaluated again during the May season of 2012 and using the same fertilization (with and without) treatments. In this season, seed yield varied from 830 t0 1,265 kg/ha with fertilization and from 572 to 1,060 kg/ha without fertilization. The lines TLP19, VAX 3 and IBC 309-23 have the highest yields without fertilization; greater adventitious root density being the trait that differ the most between the line IBC 309-23 from the other two, as well as from the checks. Part of this work was conducted as the research project for graduation of Ms. Mariel Gallardo, a senior student from Zamorano. 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 traits as part of the research project for graduation of Ms. María Camalle, a junior student at Zamorano, conditions using the greenhouse soil cylinder technique and limited moisture and low soil fertility conditions.

Two field trials were conducted during FY12 in a low N, P and other soil nutrients plot at Zamorano to evaluate a set of 20 small red and black bean improved cultivars with (130 kg/ha 18-46-0 at planting and 32 kg/ha Urea 46% before flowering) and without fertilization treatments during the second (October 2011) and first (May 2012) raining seasons of the current FY12. 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. In the October 2011 trial, seed yields varied from 453 to 1,442 kg/ha with fertilization and from 336 to 829 kg/ha without fertilizer; and the GM varied from 398 to 1,094 kg/ha. Overall, the highest yields were observed in the cultivars ICTAZAM ML, Conan 33 and ICTA Sayaxché; however, the highest yields without fertilization were observed in Tío Canela 75, Don Cristóbal and Conan 33. At the May 2012 trial, seed yields varied from 810 to 1,372 kg/ha with fertilization and from 511 to 1,119 kg/ha without fertilizer; and the GM varied from 661 to 1,245 kg/ha. During the growth cycle at both trials, the cultivars were under moderate drought stress (<200 mm of rainfall), mainly at the reproductive stages. Root traits measured on these field trials included number and angle of coronary roots; number, diameter and density of adventitious roots; and diameter of primary roots. Although, significant variation was observed for most root traits under the fertilizer and unfertilized treatments, only some of the top yielding cultivars, such as MEN 2201-64 ML to be released in Haiti, were superior on number and density of adventitious roots, and this difference was observed mainly under no fertilization treatment. In collaboration with the UPR/Beaver DGPC Project, landrace cultivars and elite breeding lines have been using for developing improved small red and black bean cultivars with better adaptation to limiting soil fertility and rainfall conditions at Zamorano. Several advanced lines have been developed by inbred backcross and triple crosses using improved cultivars and breeding lines as donor parents. The line IBC 301-204, one of the most promising from this group, is expected to be released in 2012 as a cultivar for commercial production in the Atlantic tropical humid region of Nicaragua. This region is characterized predominantly by acid, low fertility soils; and most bean production is carry on during the “apante” (December) planting season under residual moisture. In drought experiments conducted during the summer season of 2012 at Zamorano, the line IBC 301-204 showed greater number of adventitious roots, shoot dry wt and seed yield than other promising lines and check cultivars. In a similar trial, including black bean promising breeding lines and check cultivars, the drought tolerant line SEN 96 from CIAT, also showed superiority in number of adventitious roots, shoot dry wt and seed yield.

Several other lines small red and black breeding lines are in an advanced testing stage in Honduras and other Central American countries, in collaboration with the national bean research programs members of the regional network and CIAT. In the other hand, lines developed under the project are included in regional trials (ERSAT) distributed by Zamorano, as part of the drought and heat tolerant trial for climatic change supported by the IDB and coordinated by the Red SICTA/IICA.

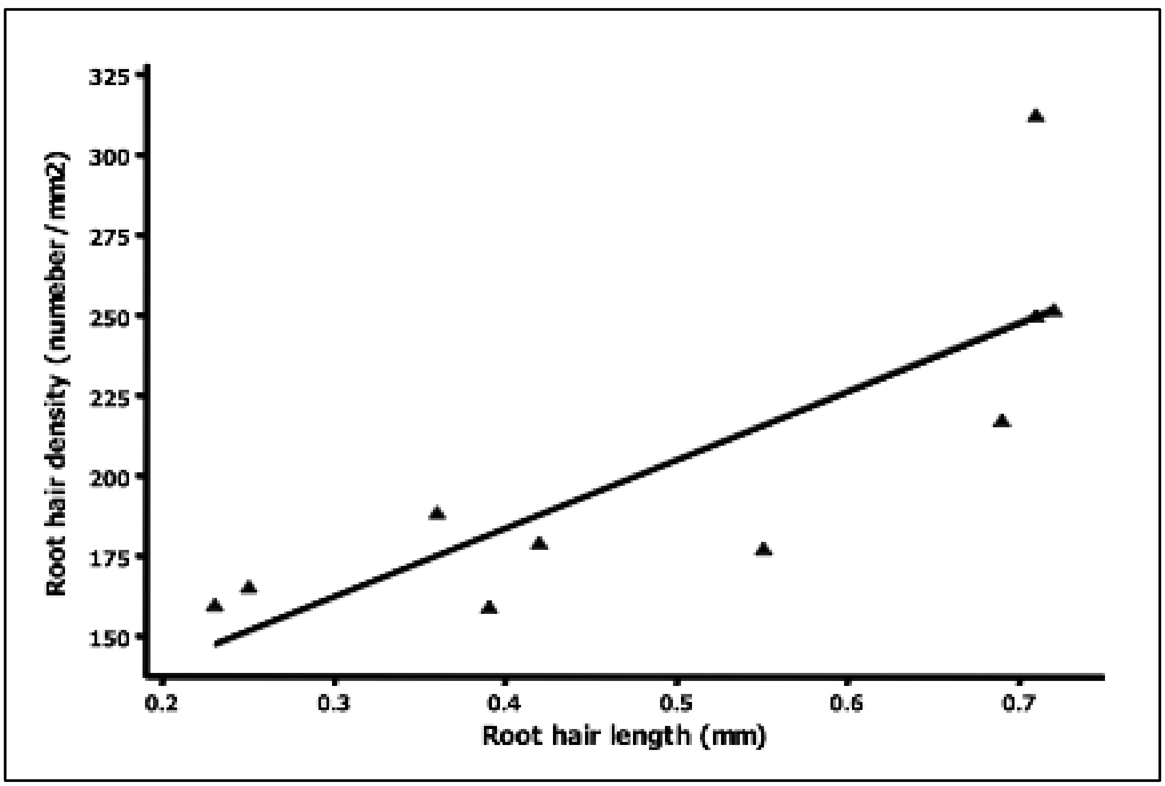
IIAM/Mozambique and PSU

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

1.2.1 Diversity of root phenes of common bean (Phaseolus vulgaris L.) from Andean and Mesoamerican gene pools

Low phosphorus availability and drought are major constraints to common bean *(Phaseolus vulgaris L.)* production in many developing countries. The root system is an important factor for plant productivity. Plants have evolved a wide range of adaptations to enhance phosphorus (P) and water acquisition from the soil. Variation in root traits has been reported in many crops. Information on diversity of root traits is crucial for development of genotypes adapted to a specific environment. To assess the diversity of root phenes in beans, 165 accessions from the bean core collection from CIAT were planted in the laboratory and field in 2010 in Pennsylvania, USA. Fifteen root phenes were evaluated from one root crown: adventitious root number, length, branching and diameter, basal root number, length, branching and diameter, basal root growth angle, primary root length, branching and diameter, basal root whorl number, number of nodules, and root rot infection. Substantial phenotypic variation in root traits among genotypes was found in adventitious, basal and primary root traits (Figure 1). Variation among genotypes within gene pools, and genotypes within country of origin were significant for all 15 root phenes. Accessions from the Andean gene pool had a greater number of whorls and basal roots, more lateral branches on basal and primary roots, and shallower basal roots than accessions from the Mesoamerican gene pool. Mesoamerican accessions had long and dense root hairs, many adventitious roots and deep basal roots. A positive correlation between root hair length and root hair density was also observed (Figure 2), indicating that genotypes with long root hairs also have many root hairs, traits that confer P efficiency acquisition in plants. Genotypes with root traits associated with adaptation to low P availability were found in both gene pools, and traits associated with adaptation to drought stress were mostly evident in the Mesoamerican gene pool, although some Andean genotypes expressed extensive lateral branches on basal and primary roots that may improve water acquisition from deeper soil horizons. Andean accessions have root traits that are suitable for regions with low P availability that is associated with volcanic soils of the Andes regions, while most of the Mesoamerican accessions were reported to be tolerant to drought stress and low soil fertility. Useful root traits for breeding for edaphic stresses were identified in both Andean and Mesoamerican gene pools, which have contrasting root architectural strategies for soil exploration. Breeding for multiple root phenes could enhance acquisition of multiple soil resources, particularly in developing countries.

Figure 1. Phenotypic variation of root traits in accessions from the Andean gene pool 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 (BRGA); Primary root length (PRL); Primary root branching (PRB); Primary root diameter (PRD); number of nodules per plant, and shoot dry weight in grams (SDW). Branching correspond to number of lateral roots in 2 cm root segment. ARN, BRWN and BRN are counts per plant. Root length and diameter are in cm and mm, respectively. The data are average of 4 replications.



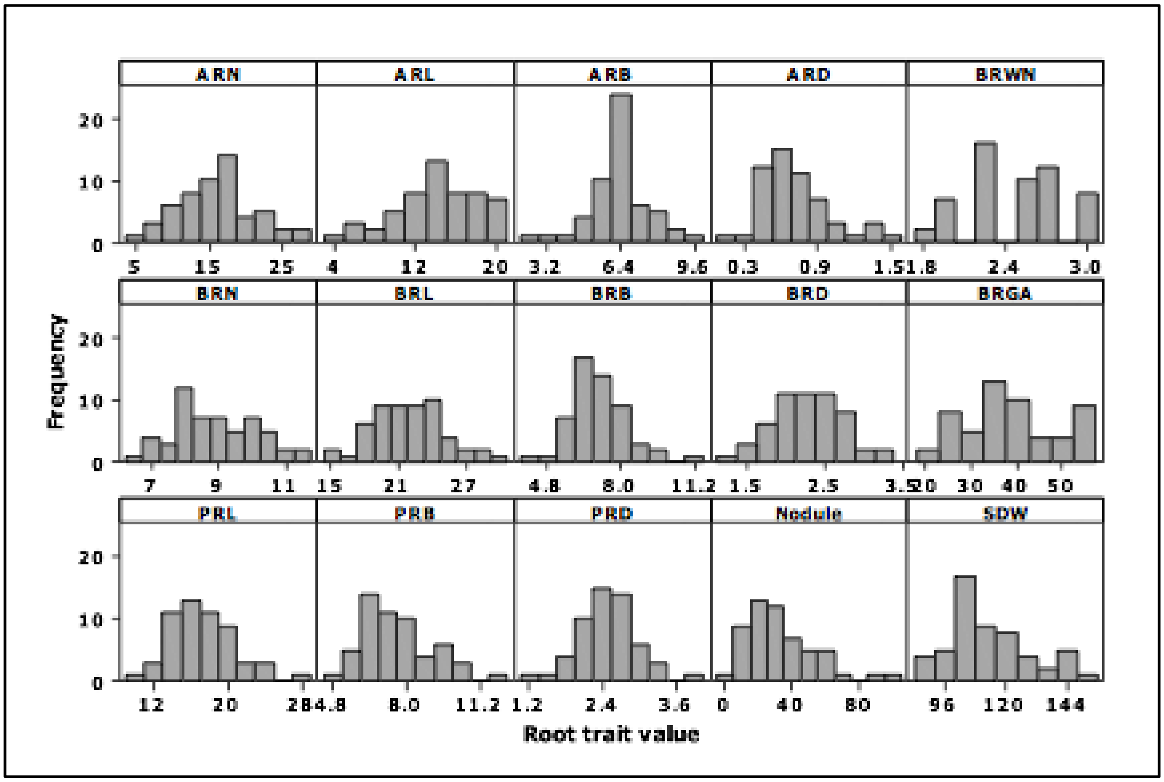
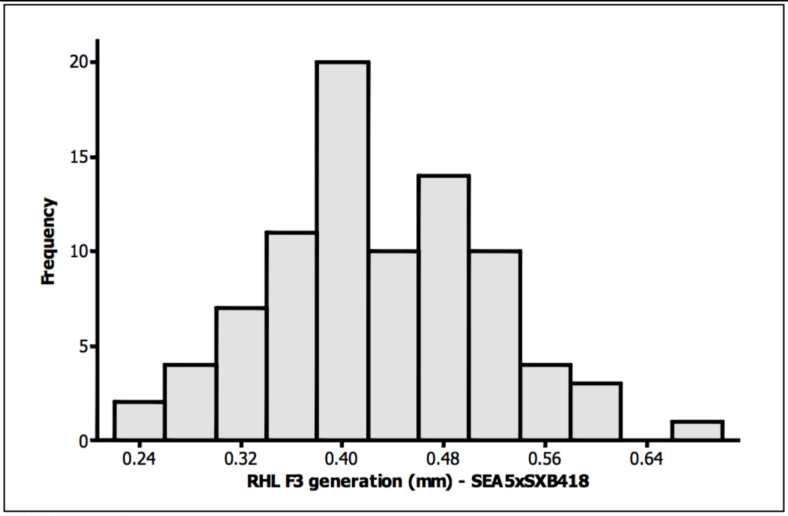


Figure 2. Positive correlation between root hair length and root length density measured in 8 day old common bean seedlings. Data are average of 4 replications. R2*** = 0.7. *** - significant at 0.01 probability level.

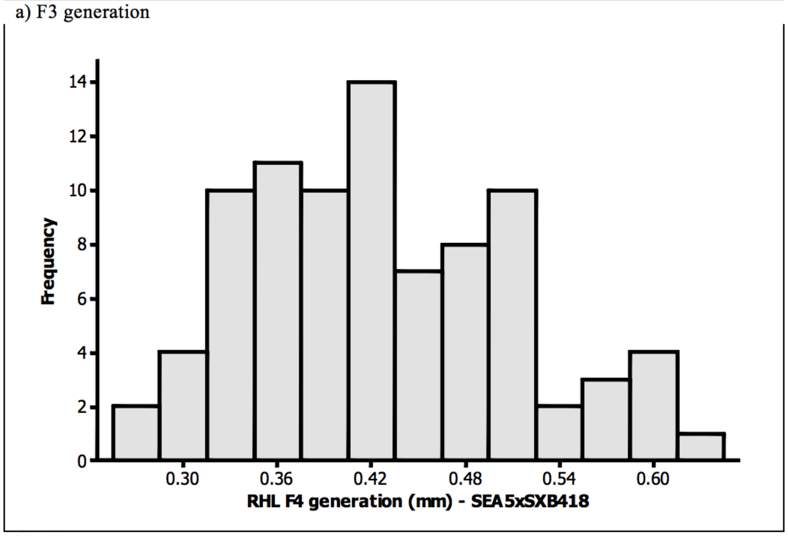
1.2.2 Heritability of root hair traits in common bean

Root hairs play an important role in phosphorus uptake. Information about the mechanisms of inheritance of root hair traits in common bean is lacking. The objectives of this study were to characterize root hair traits in two bean populations and to study the mechanisms of inheritance of root hair traits in common bean. Over 150 bean genotypes from CIAT were screened in the laboratory to identify parents contrasting for root hair traits. Five single crosses were performed and progenies of selfing after individual plant selection were advanced to F3 and F4 generation in Mozambique. Evaluations of F3 parents and F4 progenies were made on 8 day old seedlings in the laboratory in RCBD with 4 replications. To estimate heritability of root hair traits we used two populations, SEA 5 x SXB 418 and VAX 1 x SXB 418. SEA 5 is a genotype from the Mesoamerican gene pool, with long and dense root hairs. VAX 1 is also a genotype from the Mesoamerican gene pool with long and dense root hairs, while SXB 418 is also from Mesosamerican gene pool but with short and sparse root hairs. Parental-Offspring regression analyses were performed to estimate Narrow sense heritability (*b= h2*) of root hair length of F4 values (families means) on F3 values of the parents.

Results: Root hair length varied significantly among individuals within populations of both F3 and F4 generations. For the SEA5 x SXB 418 population, significant variation in root hair length was observed among F3 individuals and among F4 lines (Figure 3)



a) F3 generation



b) F4 progeny

Figure 3 – Variation of root hair length of 73 F3 (a) and 73 F4 progeny (b) from VAX 1 x SXB 418 measured in 8 day old bean seedlings. The data are average of 4 replications. The differences in root hair length among F3 individuals and among F4 lines were significant at $p = 0.01$. The average root hair length varied from 0.191 to 0.773 mm in the F3 generation and from 0.197 to 0.784 in the F4 generation. For the VAX 1 and SXB 418 populations, root hair length among individuals of F3 and F4 lines also varied (Figure 4), and significant differences in root hair length among lines within F3 and F4 generations in this population were detected at p value < 0.001. Root hair traits of the F3 Figure 4 – Distribution of root hair length of 86 F3 generation (a) and 86 F4 progeny (b) from SEA 5 x SXB 418 measured in 8 day old bean seedlings. The results are average of 4 replications.

Generation varied from 0.2 to 0.916 and similar results were obtained on F4 generation where root hair length varied from 0.187 to 0.843 mm. Although we used only two populations, our results indicate the existence of genetic variation in root hair traits within bean populations as previously reported, and these traits can be selected for genetic improvement and development of genotypes adapted to regions with low P adaptability. Preliminary regression analyses detected moderate heritability of root hair length measured on 8 day old bean seedlings under laboratory conditions in both populations. The estimated ($b = h2$) in the two populations were $h2$ = 0.51 (p-value<0.0001) for SEA 5 x SXB 418 population, and $h2$= 0.613 (p-value <0.0001) for VAX 1 x SXB 418 population. We have shown that root hair traits vary genetically and these traits can be targeted in breeding programs to genetically improvement bean cultivars.

1.2.3 Yield performance of F6 lines under low P stress

To develop bean varieties adapted to the agroecological conditions of Mozambique, five single crosses were performed using parents with root traits adapted to low P and drought, and generations of selfing were advanced to F6. In 2012, F6 lines developed from introgression of long and dense root hairs into lines with short root hairs were tested for yield performance in Sussundenga and Chokwe, Mozambique. The objective of the study was to evaluate yield performance of 22 bean lines derived from crosses of two Mesoamerican parents, VAX 1 x SEA5, under low P stress (Figure 5) and under normal P fertility in Chokwe. The experiment was planted in a RCBD with 3 replications and 22 treatments (bean lines). The trial was installed under low P stress (about 8 ppm available P) with application of 30 kg of N/ha and without application of P fertilizer. Seeds of each line were sown in three rows of 5 m, and the planting space was 0.6 m between rows and 0.15 between plants within a row. Weed and pest management and irrigation were applied as needed.

Significant differences for yield were detected among lines (p-value < 0.001). The trial was repeated in Chokwe where P levels were considered normal. The yield of the 22 lines from population VAX1 x SXB 418 evaluated in Sussundenga under low P stress varied from 750 to 1933 kg/ha, and local check had 750 kg/ha (Figure 6). Strong positive correlation between yield performance under low P stress and root hair length was observed in 14 bean lines (R2 = 0.706, significant at 1%) (Figure 7). The yield data in Chokwe were relatively higher and varied from

Figure 5. Better plant grows of new common bean lines under low P stress (left) compared to other varieties (right) in Sussudenga in 2012.

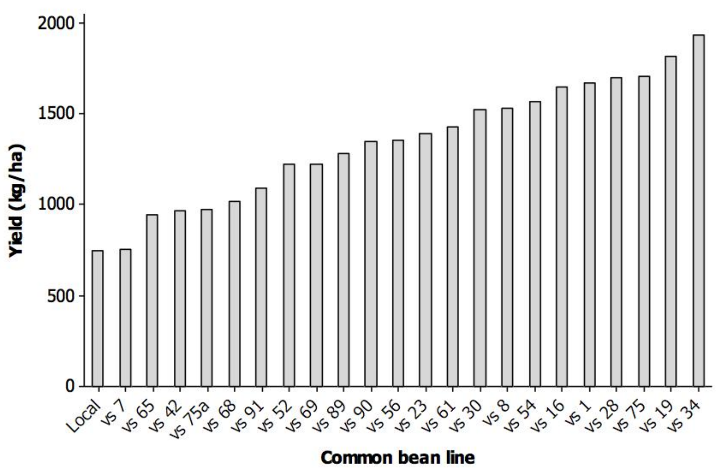


Figure 6. Yield performance of bean lines VAX 1 x SXB 418 population evaluated under low P stress in Sussundenga. The results are average of 3 replications.

1588 to 3256.8 Kg/ha. Our results indicate that the new lines had superior yields under low P stress, and long and dense root hairs influenced positively on yield increase under low P stress. Promising lines were selected for on-farm trials, and trials under drought stress.

1.2.4 Yield performance of 27 Andean bean lines

The objective of this study was to evaluate yield performance of 27 F6 bean lines derived from a cross of Andean bean genotypes (AFR 298 x PVA 773) under low P conditions. AFR 298 has long and dense root hairs, PVA 773 is a variety adapted and released in Mozambique but has short and sparse root hairs. The experiment was planted in a RCBD with 3 replications and 22 treatments (bean lines). The trial was installed under low P stress (about 8 ppm available P) with application of 30 kg of N/ha and without application of P fertilizer. Seeds of each line were sown in three rows of 5 m, and the planting space was 0.6 m between rows and 0.15 between plants within a row. The trial was repeated in Chokwe. Weed and pest management, and irrigation were applied as needed. Significant differences for yield were detected among lines (p-value < 0.0001). The average number of pods per plant varied from 24 to 14. The average yield among these lines under low P stress were superior to the local check and varied from 803 to 1975 Kg/ha (Figure 8). The local check line had the lowest yield (803 Kg/ha). These results indicate that our new lines have the potential of increasing bean productivity in regions with low P soils. On farm trials of selected F6 lines from all crosses are planned for the 2013 season in Gurue, Angonia. In addition, on-farm demonstration plots of promising lines were installed in Chokwe (Figure 9) and a field day was conducted to show farmers the promising lines at the late podding stage at the Chokwe Research Station (Figure 10).

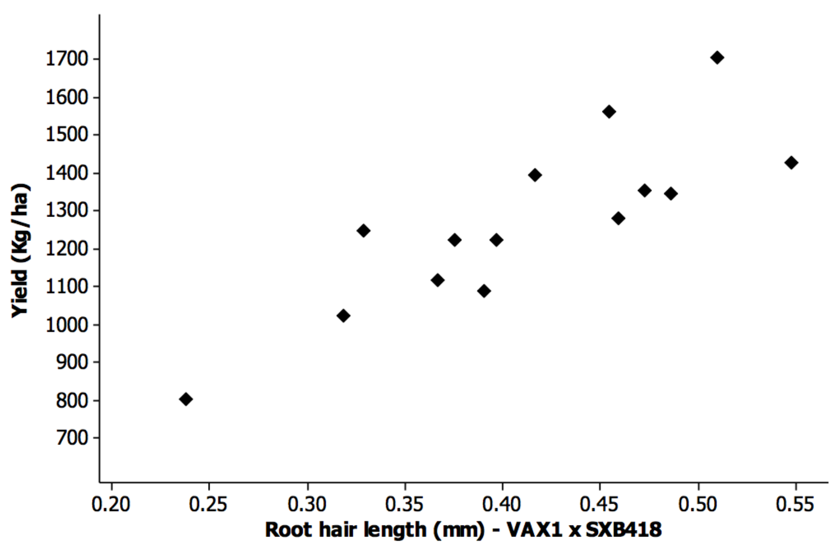


Figure 7. Scatterplot showing positive correlation between yield data and root hair length in 14 F6 lines evaluated from VAX1 x SXB 418 population in 2012.

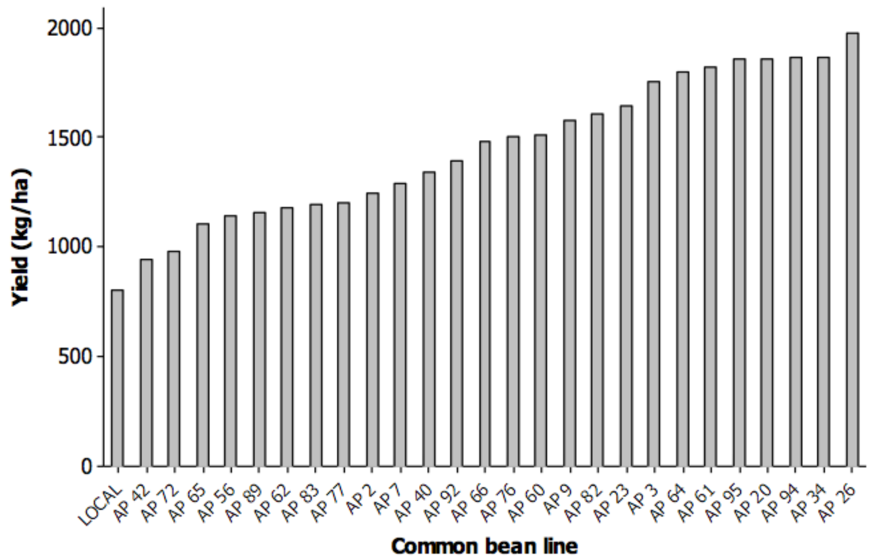


Figure 8. Yield performance of bean lines AFR 298 x PVA 773 population evaluated under low P stress in Sussundenga. The results are average of 3 replications.

1.2.5. Yield performance of six bean genotypes with contrasting root phenotypes

Six genotypes that were contrasting in basal root growth angle (BRGA), basal root whorl number (BRWN) and basal root number (BRN) were planted in Chokwe. The objective of the study was to assess yield performance of 6 genotypes with different root architecture under drought stress. The trial was planted in a RCBD with 4 replications. Root traits measured in the field included adventitious root number, length and branching, BWRN, BRN, BRGA, basal root branching, primary root length and branching, number of nodules and root rot infections. Root phenes were evaluated 45 days after planting. Significant differences in root phenes among genotypes were detected for adventitious root number, length and branching, BRGA, BRWN. BRN and basal root length, primary root branching and number of nodules ate 5 % level of significance. Bat 477, Tio Canela and SEQ 1003 had deeper BRGA than BRGA of Bonus, LIC-04-2-1 and LIC-04-3-1 lines. The number of BRWN varied from 2 to 4, and the number of BRN varied from 7 to 14 (Table 1). Variation in basal root branching and primary root length among genotypes was not significant at 5% level of significance.

Significant differences among genotypes were detected for yield (P value = 0.0004), indicating that the performance of the 6 genotypes were different. BAT 477 had the highest yield (1784 Kg/ha), followed by SEQ 1003 (1644 Kg/ha) (Table 1 and Figure 11). Even though the drought stress was not very strong for the purpose of the study the effect of deeper roots under drought stress, our results indicate that genotypes with deeper BRGA also had relatively higher yields. We also found a positive correlation between BRGA and yield.

Figure 9. Demonstration plots installed in farmer's field association in Chokwe 2012

Figure 10. Farmers evaluating common bean lines in Chokwe Research Station during the field day.

1.2.6 - Evaluation of common bean lines tolerant to drought stress

The objective of this 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 were evaluated in 2011 and 2012. Field trial was conducted at the IIAM Agricultural Research Station of Chokwe, Mozambique. Genotypes with 2 and 3 basal root whorls and deep versus shallow roots were included in the study. The experiment was planted in a RCBD with 4 replications in each year. Seeds of each genotype were sown in three rows of 5 m, and the planting space was 0.6 m between rows and 0.15 between plants in a row. Weed and pest management were applied as needed. Four replications were normally irrigated

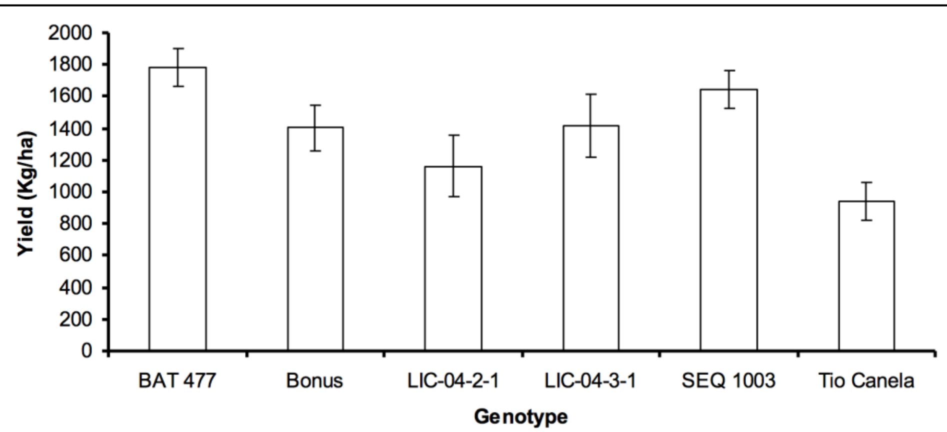


Figure 11: Yield performance of six bean genotypes evaluated in Chokwe. BAT 477 and SEQ 1003, known to be tolerant to drought, had superior yields compared to other 4 genotypes. Standard error of the mean are presented.

according to the plant needs, and the other four replications were irrigated up to flowering period. Collected data included number of pods per plant and yield performance.

Table 1. Characteristics of root traits of 6 bean genotypes evaluated in Chokwe, including yield performance. Evaluated root traits: Adventitious root number (ARN), adventitious root length (ARL), adventitious root branching (ARB), basal root length (BRL), basal root whorl number (BRWN), primary root length (PRL), and primary root branching (PRB). The root lengths were measured in cm, branching corresponds to the number of lateral roots in 2 cm of a representative root segment, and number of roots was actual counts. Data are average of 4 replications.

	Root trait									
Bean genotype	**ARN**	**ARL**	**ARB**	**BRL**	**BRWN**	**BRN**	**BRGA**	**PRL**	**PRB**	**Yield (Kg/ha)**
Bonus	8	8	7.25	21.75	3	10.25	37.5	18.5	10.75	1403.59
LIC-04-2-1	7.5	6	4.75	24.25	3	11	27.5	18	13.75	1161.67
LIC-04-3-1	12.5	13	10.75	18.25	4	14	26.25	14	9	1417.80
SEQ 1003	4.25	16.25	3.5	22	2.25	8.25	57.5	24.75	10.75	1644.61
BAT 477	5.5	11	6.75	17.25	2	7.25	67.5	20.5	13.75	1784.24
Tio Canela[1)]	6.5	18.25	8.25	22.25	2	7	62.5	24.25	9	-

[1)] Yield was not included because two plots were lost.

Results: Although we did not have strong drought stress due to the abnormal rainfall that occurred off season in Southern Mozambique, we found significant differences among genotypes in yield (P-value < 0.001) and number of pods per plant (P-value <0.001) in 2011. The yield varied from 2233 to 1017 Kg/ha. SEQ 1003 had the highest yield (2233 Kg/ha), followed by BAT 477 (2218 Kg/ha) and VTTT 924/2 (1999 Kg/ha. Doctor, a local variety had the lowest yield (1017 Kg/ha). In addition, the number of 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 32 pods per plant. Tio Canela and BAT 477 are drought tolerance genotypes and previous study showed that these genotypes have deeper basal roots, this aspect, probably influenced their good performance. The local check Bonus were among the genotypes that had relatively good yield (1762 Kg/ha), while SUG 131, another local variety had a yield of 1636 Kg/ha. The yield of G 19833 was 1432 Kg/ha. Over all, genotypes with deeper roots as SEQ 1003, BAT 477 and Tio Canela were among the best genotypes in terms of yield performance, confirming the importance of root architecture for water acquisition. Selected and promising genotypes will be used in advanced trials for yield performance and adaptability in both drought and low P conditions.

Results from the 2012 season did not show significant differences among genotypes in number of pods per plant and yield performance at the 1% level of significance in both stressed and non stressed treatments. Two sample T test of the mean yield of non stressed treatment and stressed treatments were significant at 10% level of significance. In fact the yield obtained in both treatments under water stress were relatively higher and varied from 1209 to 1959 Kg/ha, and the yield in normally irrigated treatment varied 1557 to 2363 kg/ha. Again, unexpected rains that occurred off season affected the yield performance of the trail. From our data, the following genotypes were had good yield performance due their good root traits for drought adaptation. We selected the following genotypes to be used as source of drought tolerance: Bat 477, Tio Canela, SEQ 1003. VTTT 924/2-4-2-1 and VTTT 925/7-6 can be directly tested in advanced trials to confirm or results. G 19833 is already known to have root traits adaptability for low P soils, that is used was parent.

1.2.7 - Planned crosses

We already have started and planned crosses for introgression of root traits into local genotypes or varieties to improve the existing varieties. Doctor, Kakhi are local varieties with good grain type but relatively low yield. Seed of other parents were increased and planned crosses for drought and low P adaptability will be performed next season. In the season we increased seed of about 290 LPA (low P Andinos lines) that resulted from crosses performed to improve root traits. The parents used in these crosses include G 19833, RAA 30, AFR 298, BRB 25 SEA 5 that are parent lines with root traits that confer P efficiency acquisition, crossed with PVA 733, SUG 47.

1.2.8 - Seed multiplication

Routine activities of seed increase and germplasm maintenance are conducted every season. Several bean lines collected in Mozambique and introduced from CIAT were increased in 2012 in Chokwe and Sussundenga. We also increased seed of 290 lines from Andes developed for low P environments. Part of the seed on these lines will be used in trials in 2013. Seed of local varieties were also increased.

1.2.9 - Phenotyping bean diversity panels

Several collections have been phenotyped to quantify variation for root architectural traits, identify sources of beneficial traits and understand the genetic control of root traits. A three hundred entry BeanCAP diversity panel representing North American common bean diversity was phenotyped for root traits for the second time in 2012. Once it has been phenotyped a third time data will be compiled and genetic analysis performed. We hope to identify QTL related to root traits and establish coefficients of relatedness, which will promote an understanding of how root traits are inherited.

Among a reference collection assembled by CIAT representing global genetic diversity we found substantial variation in adventitious root number and length, basal root number and length, and basal root whorl number (Figure 12). Most Mesoamerican genotypes had 2 basal root whorls with 7 to 8 basal roots, and these Mesoamerican genotypes had deeper roots that confer tolerance to drought stress. Andean genotypes had 2 to 3 basal root whorls, with several basal roots (7 to 11), and shallow basal roots compared to genotypes from Mesoamerican origin. Our results indicate that sources of tolerance to drought and low P stress can be found in both Andean and Mesoamerican gene pools. Bean breeders could use this information for development of varieties adapted to specific edaphic stress.

The 50 line IBC population developed at Zamorano by crossing the small red cultivar Amadeus 77 (recurrent parent) with lines L88-13, L88-43 and L88-63 was phenoptyed in the field for 8 architectural traits. This information was used to select genotypes with contrasting root systems to be used in intensive physiology studies evaluating the utility of root class dimorphism and multilines for combined water and phosphorus limitations.

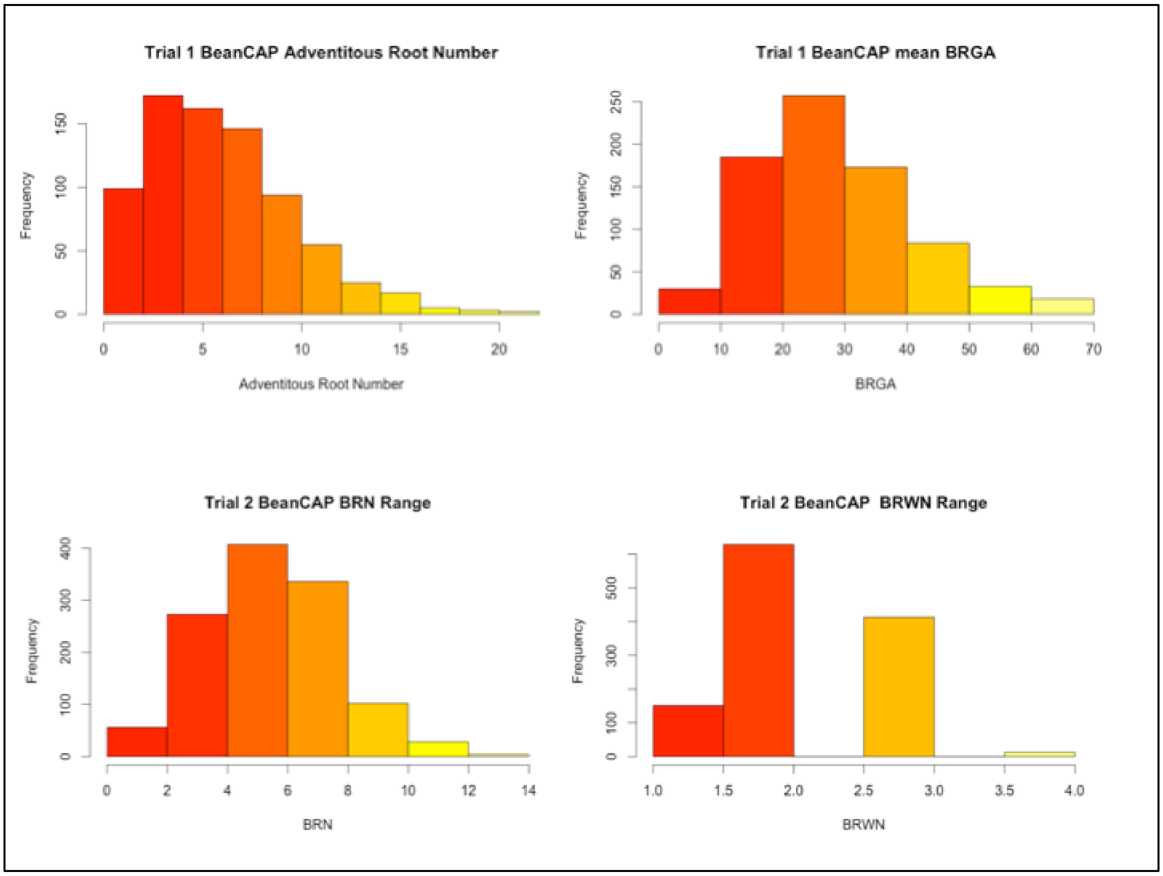


Figure 12: Basal root phenotyping of a North American bean diversity panel.

1.2.10 - Utility of Basal Root Whorl Number (BRWN) for water and P acquisition

Greater BRWN was associated with better growth under low P in a trial in Mozambique and a drought trial in Pennsylvania, indicating that BRWN could be a valuable trait for individual and combined stresses. The low P trial in Mozambique included three 2 whorl genotypes and three 3 whorl genotypes from the G2333 x G19839 population. The red oxisol typical of small-holder production zones in Africa had 6 ppm P (Olsen) in the low P plots and 19 ppm P (Olsen) in the medium P plots. Soil cores were used to determine root length by depth and three whorl genotypes had more shallow (0-15cm) than deep genotypes and more roots overall. Plant tissue was analyzed for P content and three whorl genotypes accumulated more P than 2 whorl genotypes (Figure 13). Shoot biomass collected at R5 showed no differences between whorl groups under medium P but under low P three whorl genotypes had significantly more biomass accumulation than 2 whorl genotypes. We conclude that greater BRWN increases shallow rooting, P acquisition and shoot biomass under low P.

To determine the utility of BRWN for water acquisition from drying soil, we evaluated genotypes with one, two and three whorls from the ALB and DOR364 x G19833 populations in rain-out shelters at Penn State. Soil moisture was monitored with TDR probes and soil cores. Plant water status was determined before final harvest with a Scholander pressure bomb. Root length distribution was determined with soil cores and two and three whorl genotypes had more root length in the 20-30 and 30-40 cm depth zones than one whorl genotypes. Harvests of shoot biomass at R5 demonstrated benefit of increased whorl number under drought. Under well-watered conditions genotypes with one, two and three whorls had statistically similar biomass. Under water stress three whorl genotypes had statistically more biomass accumulation than one-whorl genotypes (Figure 14). We conclude that greater BRWN is related to increased biomass accumulation under drought.

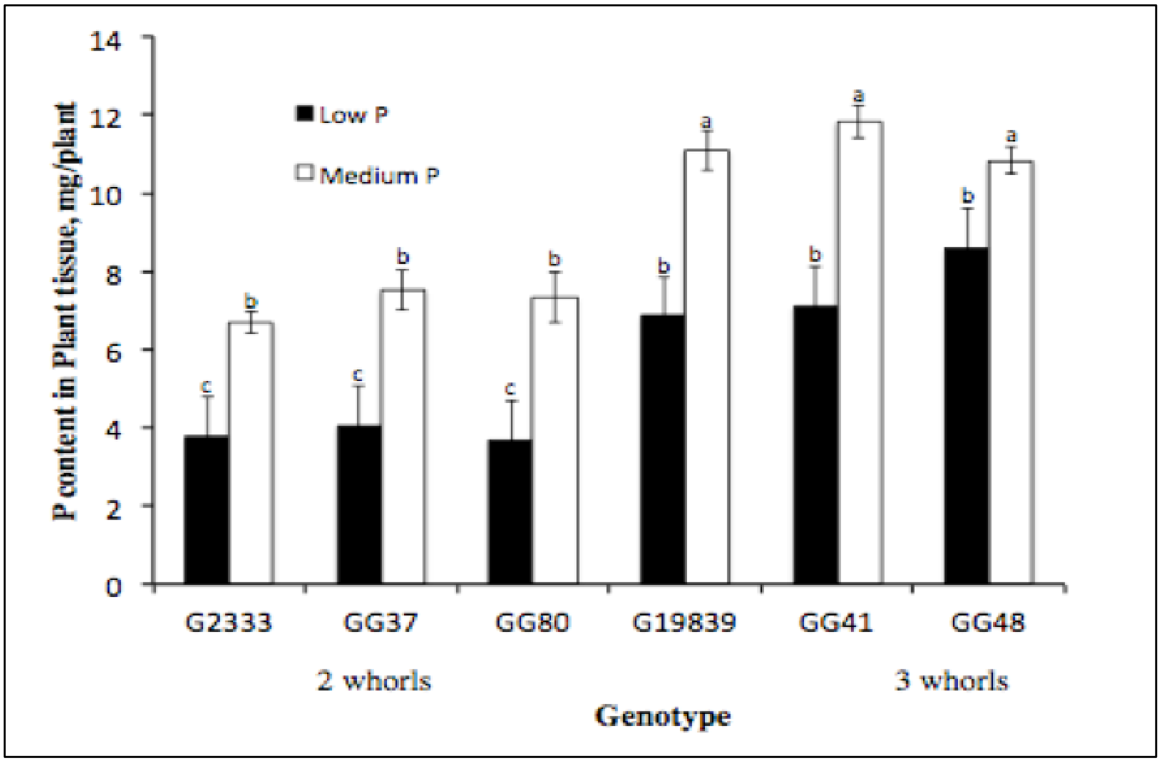


Figure 13. Phosphorus accumulation is greater in 3-whorl genotypes than in 2-whorl bean genotypes in the field in Mozambique.

A trial at Sussendenga sought to evaluate the utility of BRWN for combined water and phosphorus stress. The trial was complicated by excessive water stress and root rots but useful results were obtained. Six 2 whorl and six 3 whorl genotypes from the DOR364 x G19833 and G2333 x G19839 populations were evaluated. Soil water status was determined using soil cores and plant water status estimated used a Decagon leaf porometer. Stratified soil samples were collected (separated in to 10 cm segments) to determine soil P availability by depth. Leaf discs were collected to determine plant P status. An association between greater BRN and biomass at flowering as well as greater BRN and yield was found (Figure 15). Fitting the data to a linear mixed effect model indicates that each additional basal root adds 0.5g biomass at R5. We conclude that increased basal root number is associated with greater performance and that greater BRWN is a useful trait for combined P and water limitation.

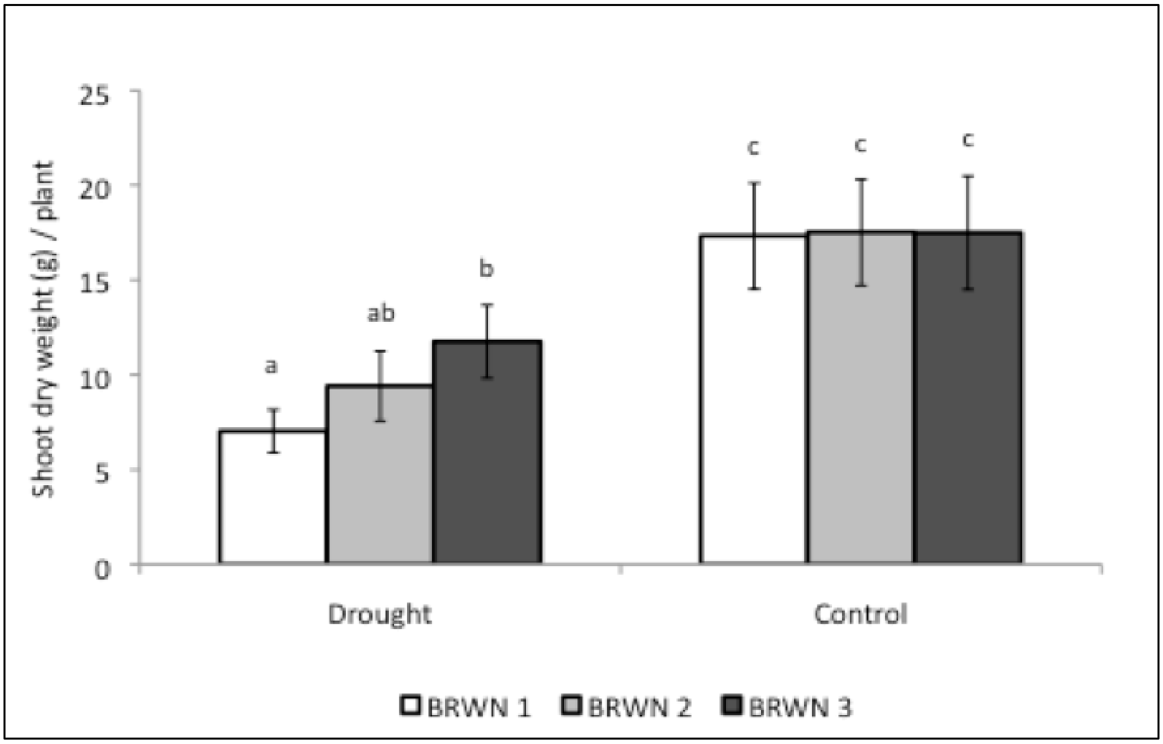


Figure 14. Increasing BRWN enhanced growth under drought in rainout shelters at Penn State.

SimRoot has been used to model effects of increased BRWN on P uptake and biomass under 5 different scenarios of phosphorus stratification. The model shows that increasing BRWN is associated with a 75% increase in P acquisition and greater biomass at 40 days after planting.

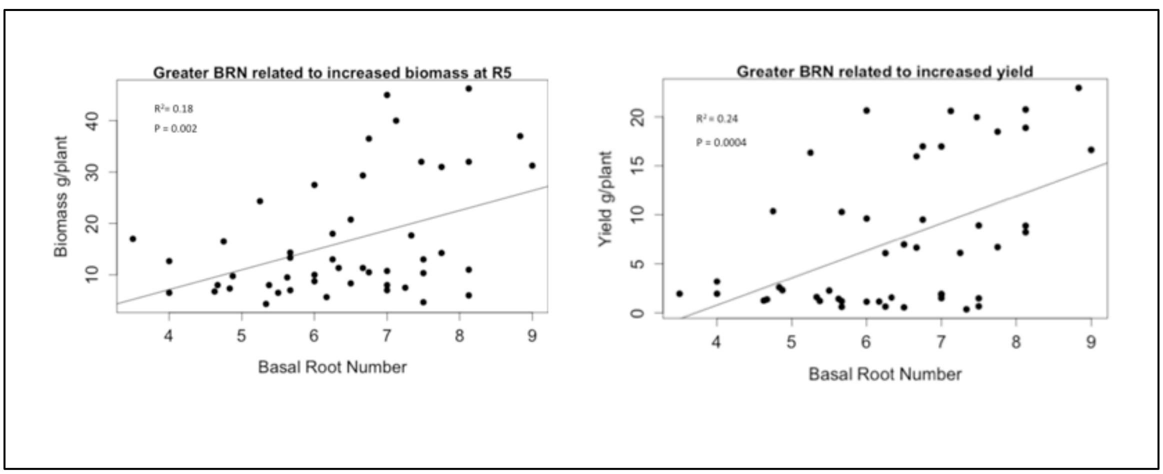


Figure 15: Basal root number is associated with greater growth and yield of bean lines under combined drought and P stress in the field in Mozambique.

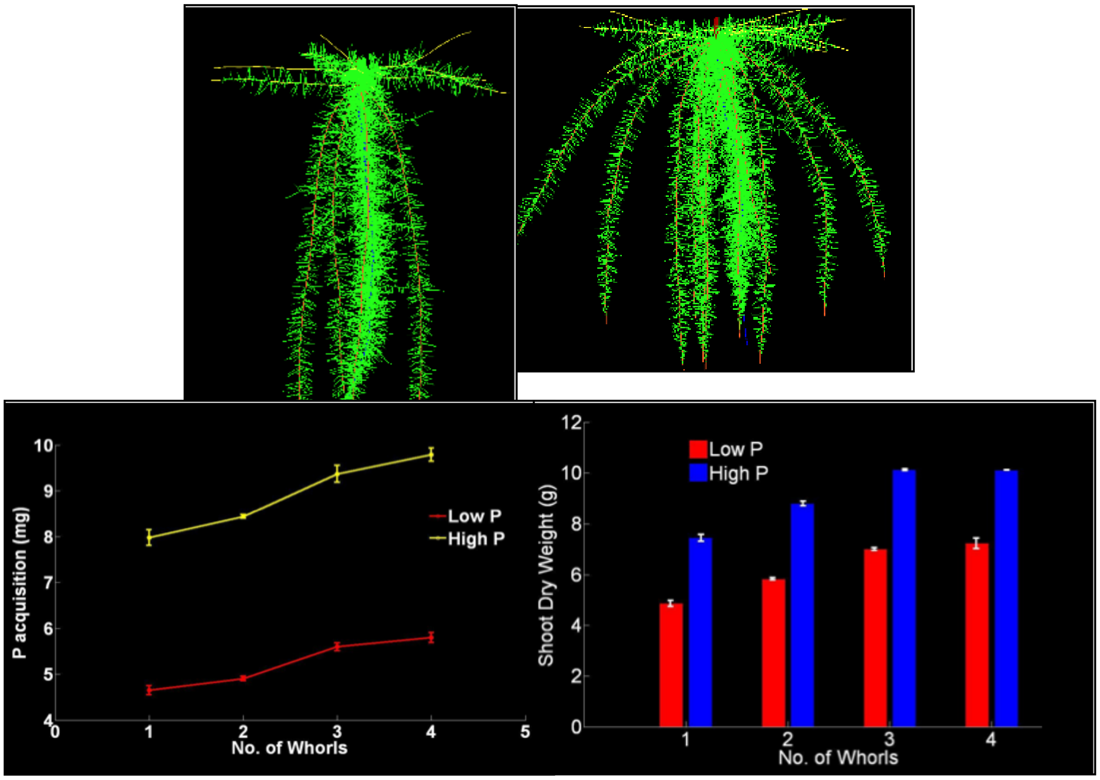


Figure 16: Functional-structural plant modeling showing effects of genetic variation in BRWN (top left one whorl vs. top right two whorls) on P acquisition and biomass accumulation.

A QTL map for BRWN and BRN has been generated using composite interval mapping. The objective of this study was to perform a quantitative trait loci (QTL) analysis for BRWN and BRN using two populations of recombinant inbred lines (RILs) developed from the crosses DOR364 x G19833 and G2333 x G19839. Phenotypic data on the number of basal root whorls and number of basal roots was measured on seedlings 3 days after imbibition. QTL analysis for basal root whorl number and total basal root number was performed using composite interval mapping in these two populations using four phenotypic datasets. We found a total of 23 QTL associated with BRWN and BRN in the two populations. In the DOR364 x G19833 RIL population, we found 3 QTL in the first dataset with one QTL controlling 14.6% of the variation. For the fourth dataset, we found 7 QTL with one QTL controlling 23.8% of the variation in BRWN. For BRN, we detected 3 QTL in the 2005 dataset with one QTL controlling 13.7% of the variation. In the fourth dataset, we found 7 QTL on 5 linkage groups. One of the QTL on linkage group B7 controlled 25.9% of all the variation for BRN in that population. Variability in BRWN in the G2333 x G19839 RIL population was controlled by only one locus on linkage group B3. For basal root number in the DOR364 x G19833 RIL population, we detected 4 QTL on B3, B6 and B7 in the first trial, and two QTL on B2 in the second trial. No QTL was found in the third trial. For the fourth dataset we found one QTL in linkage group B3 controlling 19.3% of the variation in BRWN. This proportion of variation explained by relatively few loci suggests that the potential for genetic manipulation of these traits via these locus is very good.

We believe the work demonstrating the utility of BRWN constitutes a major breakthrough that has the potential to have widespread and immediate impact. The trait is extremely easy to visually phenotype in laboratory grown seedlings 4 days after imbibition. Field and laboratory phenotyping was demonstrating in a 5 day workshop conducted at the Misamfu research station for 10 researchers of the Zambian National Agricultural Research Institute. Selection for greater BRWN is presently being using in breeding programs in Mozambique.

1.2.11 - Root class dimorphism and multilines

The combined drought and low phosphorus situation is complex since shallow soil generally has greater P availability and deep soil has more plant available water. This motivated the search for root phenes that can explore both deep and shallow soil zones, what we termed dimorphic root systems. Since bean root architecture can be defined by distinct root classes (adventitious, basal and tap), one way to explore multiple soil zones is to pair root class phenotypes (dimorphic root class pairings). Another approach is to pair genotypes with different root architectures but identical agronomic characteristics (multilines; Figure 16a).

Figure 16a. Representative multiline showing contrasting BRGA in alternating plants.

To evaluate the utility of dimorphic root class pairings we phenotyped genotypes from the DOR364 x BAT77 and from a set generated by backcrossing Amadeus 77 to 3 genotypes with superior root traits from the TLP19 x B98311 population. We grouped the genotypes into phenotypes, such as strong adventitious roots with deep basals, strong adventitious roots with a strong tap or shallow basals with a strong taproot. In several field trials with combined low P and water stress in South Africa and Mozambique, yield under water stress was reduced by 90%, which we consider too severe to indicate utility of root phenotypes. The best performing lines under control and phosphorus stress (L88 57 and BRT 17) both have shallow BRGA and many adventitious roots. BRT 17 and DB 48 yield similarly under control but BRT 17 produced more under phosphorus stress. Their root phenotypes are similar and both have shallow BRGA except that BRT 17 has many adventitious roots and DB 48 has few. L88 57 and L88 21 yield similarly under control but L88 57 produced more under phosphorus stress. Their root phenotypes are similar and both have many adventitious roots except that L88 57 has shallow BRGA and L88 21 has deep BRGA. These examples highlight the importance of surface exploration and indicates many adventitious roots paired with shallow BRGA is a useful mechanism for phosphorus acquisition.

We found a consistent benefit of bean architectural multilines compared to the average yield of the component lines under stressful conditions in on farm trials in Honduras (Figure 17). We repeated this study under combined P and water stress at URBC 2011 and 2012 and again found slight benefit of multilines under P stress. This type of trait differs from other single trait studies in that the benefit of multilines would become more obvious in large plot and field scale evaluation and when evaluated at a greater number of locations. We are continuing the evaluation of multilines with bean breeding colleagues in Central America.

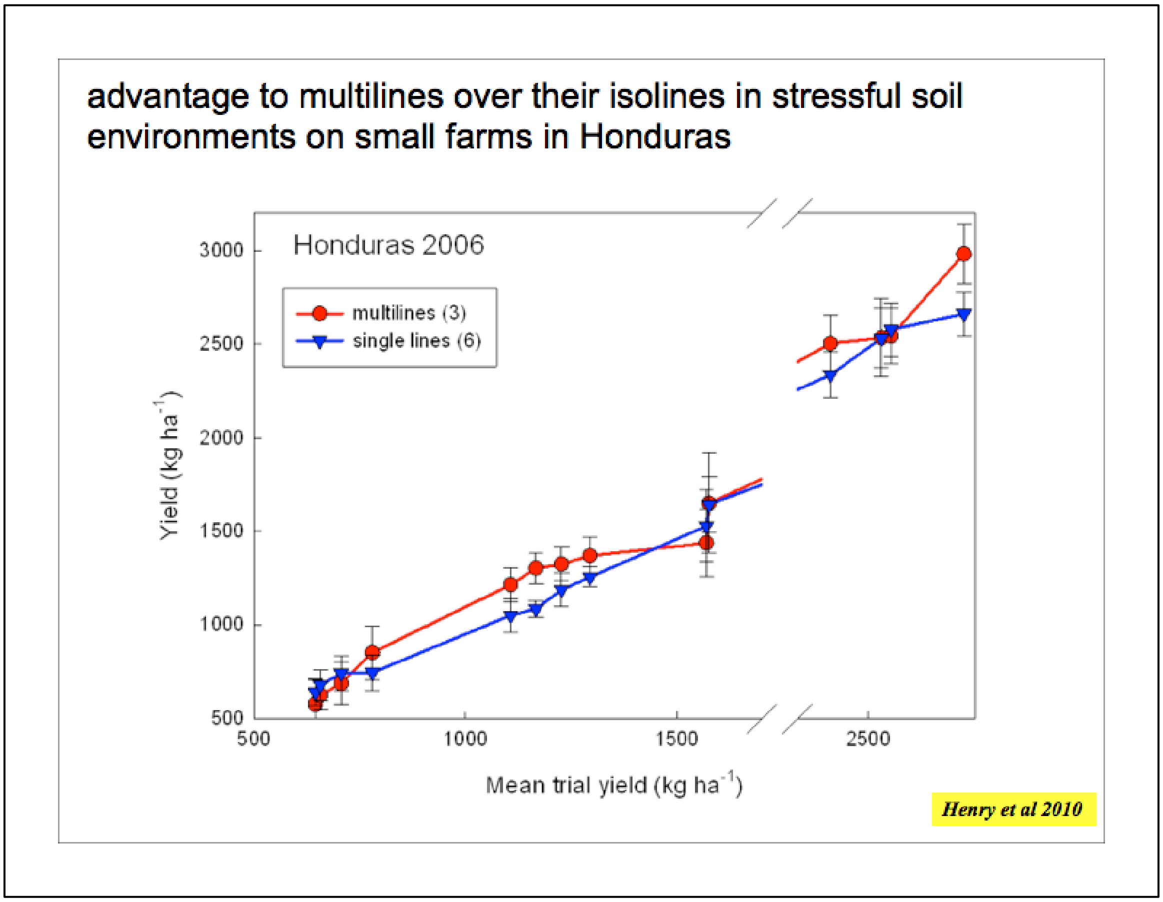


Figure 17: Root architectural multilines yield more than the average of component isolines in stressful conditions in on-farm trials in Honduras. From Henry et al. 2010 Field Crops Research 117:209-218.

1.2.13 - Root phene synergism for P acquisition

Shallow basal root growth angle (BRGA) increases phosphorus acquisition by enhancing topsoil foraging, since in most soils phosphorus is concentrated in the topsoil. Root hair length and density (RHL/D) increase phosphorus acquisition by expanding the soil volume subject to phosphorus depletion through diffusion. We hypothesized that shallow BRGA and large RHL/D are synergetic for phosphorus acquisition, meaning their combined effect is greater than the sum of their individual effects. To evaluate this hypothesis phosphorus acquisition in the field in Mozambique was compared among Recombinant Inbred Lines (RILs) of common bean having four distinct root phenotypes: long root hairs and shallow basal roots; long root hairs and deep basal roots; short root hairs and shallow basal roots; and short root hairs and deep basal roots. Results revealed substantial synergism between BRGA and RHL/D. Compared with short-haired, deep-rooted phenotypes, long root hairs increased shoot biomass under phosphorus stress by 89.3% while shallow roots increased shoot biomass by 57.7%. Genotypes with both long root hairs and shallow roots had 298% greater biomass accumulation than short-haired, deep-rooted phenotypes. The utility of shallow basal roots and long root hairs for phosphorus acquisition in combination is therefore twice as large as their additive effects. We conclude that the anatomical phene of long, dense root hairs and the architectural phene of shallower basal root growth are synergetic for phosphorus acquisition.

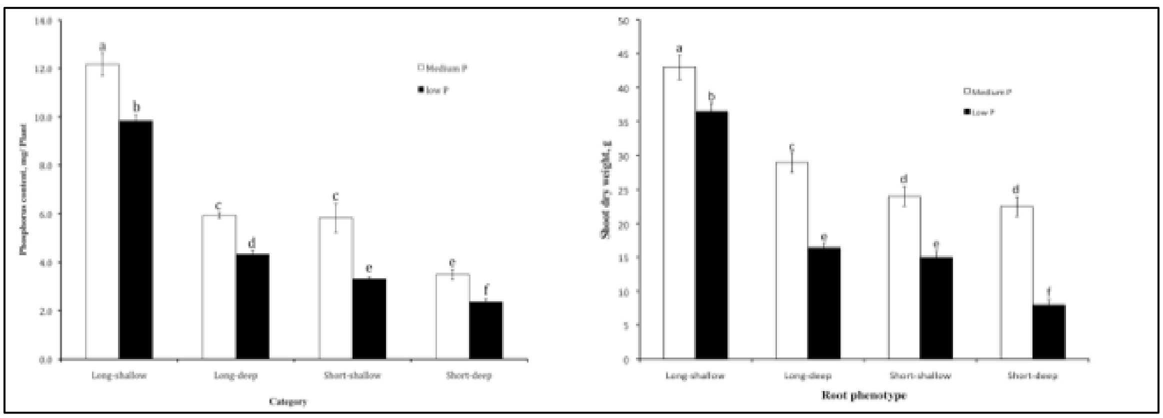


Figure 18. Genotypes with shallow BRGA and long root hairs accumulated more phosphorus and had greater shoot biomass at flowering in the field in Mozambique.

1.2.14 Utility of root cortical aerenchyma (RCA) for nutrient acquisition

The formation of root cortical aerenchyma (RCA) reduces root respiration and nutrient content by converting living tissue to air volume. It was hypothesized that RCA increases soil resource acquisition by reducing the metabolic and phosphorus cost of soil exploration. To test the quantitative logic of the hypothesis, *SimRoot*, a functional – structural plant model with emphasis on root architecture and nutrient acquisition, was employed. Sensitivity analyses for the effects of RCA on the initial 40 d of growth common bean were conducted in soils with varying degrees of phosphorus availability. With reference to future climates, the benefit of having RCA in high CO2 environments was simulated. The model shows that RCA may increase the growth of plants faced with suboptimal phosphorus availability up to 14 % for bean after 40 d of growth. Maximum increases were obtained at low phosphorus availability (3 mM). Remobilization of phosphorus from dying cells had a larger effect on plant growth than reduced root respiration.

The benefit of both these functions was additive and increased over time. Larger benefits may be expected for mature plants. Sensitivity analysis for light-use efficiency showed that the benefit of having RCA is relatively stable, suggesting that elevated CO2 in future climates will not significantly effect the benefits of having RCA. The results support the hypothesis that RCA is an adaptive trait for phosphorus acquisition by remobilizing phosphorus from the root cortex and reducing the metabolic costs of soil exploration (Postma and Lynch 2011 Annals of Botany 107: 829-841).

1.2.15 - Bean polycultures have greater nutrient acquisition than bean monocultures
Since ancient times in the Americas, maize, bean, and squash have been grown together in a polyculture known as the "three sisters." This polyculture, and its maize and bean intercropping variant have been shown to have greater yield over monocultures on a land equivalent basis (LER > 1). In this study we showed how below-ground niche complementarity may contribute to this yield advantage. During two seasons, we grew monocultures and polycultures of maize, bean and squash in field plots differing in nitrogen and phosphorus availability. The polycultures, comprised of either maize, bean and squash or only maize and bean, had greater yield and biomass production on a land equivalent basis than the monocultures (LER). The differences in root crown architectures, vertical root distribution and uptake of shallow and deep placed tracers among the components of the "three sisters" suggest that these species have different, possibly complementary, nutrient foraging strategies. Maize acquired the greatest fraction of nutrients from the topsoil by placing more roots in the topsoil than the subsoil. Common bean explored the vertical soil profile more equally, but squash's root placement depended mostly on phosphorus application. These differences in root placement may have reduced interspecies root competition, and increased total soil exploration, with consequent positive effects on plant growth and yield (Postma and Lynch 2012 Annals of Botany in press).

1.2.16 - Physiological evaluation of common bean genotypes for root traits associated to phosphorus acquisition efficiency in low P soils
During the 2010/11 growing season, we received both from Honduras and CIAT headquarters common bean genotypes for evaluation in Mozambique. These genotypes were planted for seed increase so that the seeds can be sufficient to establish an experiment with two P treatment levels with four replications and for destructive phenotyping in the field at Sussundenga Research Station. During this growing season these genotypes were planted and soon we will be conducting destructive phenotyping in the field, where root traits associated to P acquisition efficiency will be evaluated. In addition, an experiment with objective of testing the performance of genotypes contrasting for a number of root traits, grown under multiple stresses, including low P availability, drought and the combination of the two stresses.

1.2.16 - Seed increase of Andean and Mesoamerican materials for distribution to farmers
More than 200 genotypes were increased during the 2010/11 growing season (Figure 20). This activity was crucial for the implementation of socio-economic studies that would start by seed distribution to a larger number of farmers in 8 villages across the central and northern region of Mozambique. The seed increase plants were planted in two cycles. The first planting was done in February and the second was in August. Therefore, we were able to obtain enough seed to distribute to an average of 50 farmers in 8 villages, at same time ensuring the germplasm maintenance at Sussundenga Research station. In addition a number of on-farm demonstration

plots, where genotypes with root traits associated with P acquisition efficiency were established in four villages in Angonia, Gurue, Rotanda and Lichinga. These demonstrations enabled to disseminate part of the technologies to farmers.

Figure 19. Physiological evaluation of common bean genotypes for root traits associated with phosphorus acquisition efficiency in low P fields at Sussundenga Research Station.

1.2.17 - Field Evaluation of Mesoamerican and Andean genotypes for performance under low P availability

Five sets of experiments involving a total of 191 genotypes were established in the field in Sussundenga Research Station during 2011/12. The experiments included yield evaluation under low P availability of 49 Mesoamerican and 24 Andean materials received from CIAT in Colombia; evaluation of 46 Mesoamerican materials received from Honduras, 32 Andean materials from BILFA collection and 40 lines from bio-fortification project. Because of limited amount of seeds available, the biofortified materials were only increased under optimal P availability (fertilized plots) without assessment of their yields. All the other materials were planted under low P availability (6 ppm of P), with the spacing of 60 cm between the lines and 10 cm between the plants in the line. Yield data was recorded at harvest.

Data analysis of 49 Mesoamerican materials received from CIAT Colombia had field yields under low P availability varying from 0.16 (Meso 40) to 4.87 ton/ha (Meso 85), with an average of 1.75 ton/ha. Most of genotypes had yields of 1.5 ton/ha while 5 genotypes had less than a ton/ha. Fourteen genotypes out of 49 had yields of more than 2 ton/ha and only two had 3.72 and 4.87 ton/ha respectively (Figures 19, 21). Genotypes with more than 2 ton/ha under low P we consider to be P efficient. Next evaluations will determine the root traits associated with P acquisition efficiency among the outstanding genotypes.

Figure 20. Technology dissemination (P efficient varieties of bean) through the establishment of on-farm demonstration plots in Namiepe, Gurue.

Yield assessment of 46 Mesoamerican genotypes (small reds, blacks and whites) received from Honduras showed yield variation from 0.37 to 6.03 ton/ha, with average of 1.70 ton/ha, under low P. In this experiment, 12 out of 46 genotypes had yields of more than 2 ton/ha and we consider them as P-efficient genotypes (Figure 22).

Most BILFA materials are noted to be P-efficient materials when grown in low P soils. We evaluated a total of 32 materials in the field, where grain yield was recorded. The performance of the materials was not superior to other materials especially for Mesoamerican materials that were tested under same conditions. Grain yield varied from 0.16 to 2.68 ton/ha, with an average of 0.93 ton/ha (Figure 23). Only one genotype (MR 13456-12-3) had yield more than 2 ton/ha (2.68), and 9 genotypes had yield more than a ton, while the remaining 21 genotypes had yield less than a metric ton per hectare. These genotypes, although less P-efficient, they have very good color and large seeds, among other agronomic attributes that might be of preference to the farmers.

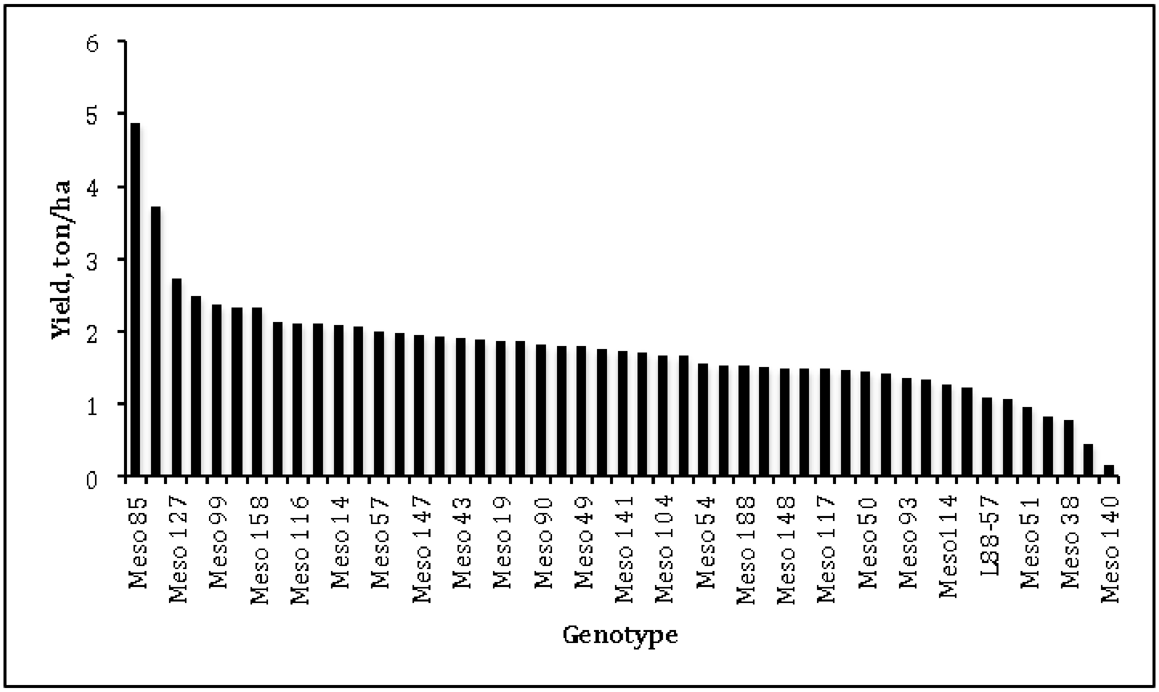
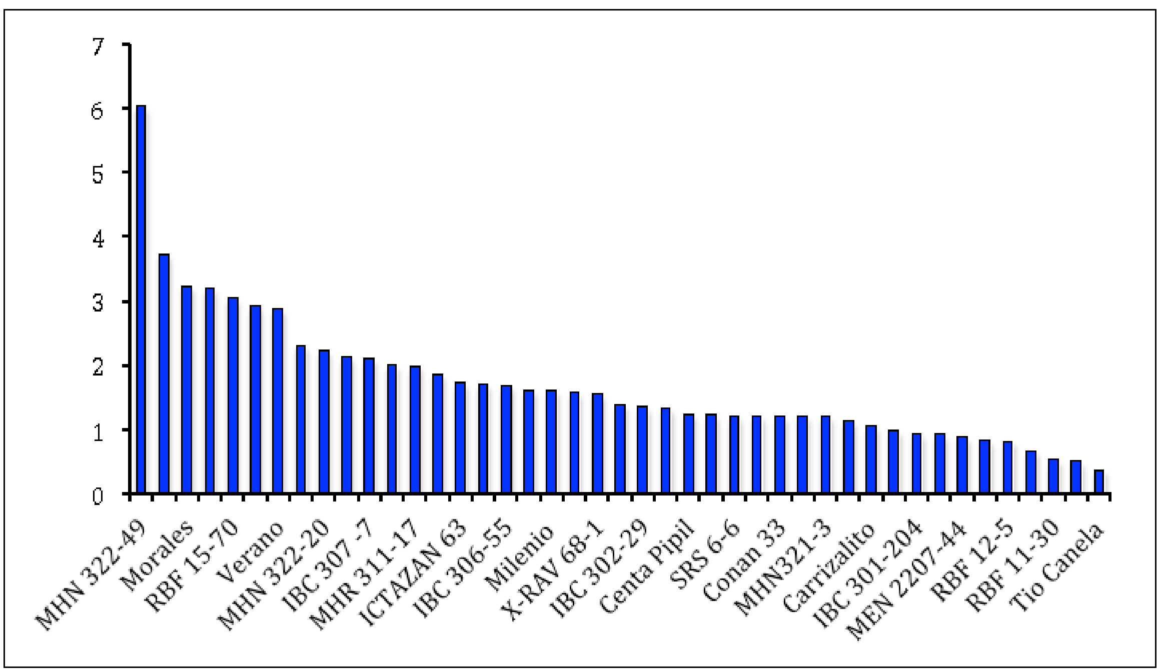


Figure 21. Yield data of 49 Mesoamerican bean materials planted under low P fields at Sussundenga Research Station during the 2011 growing season.



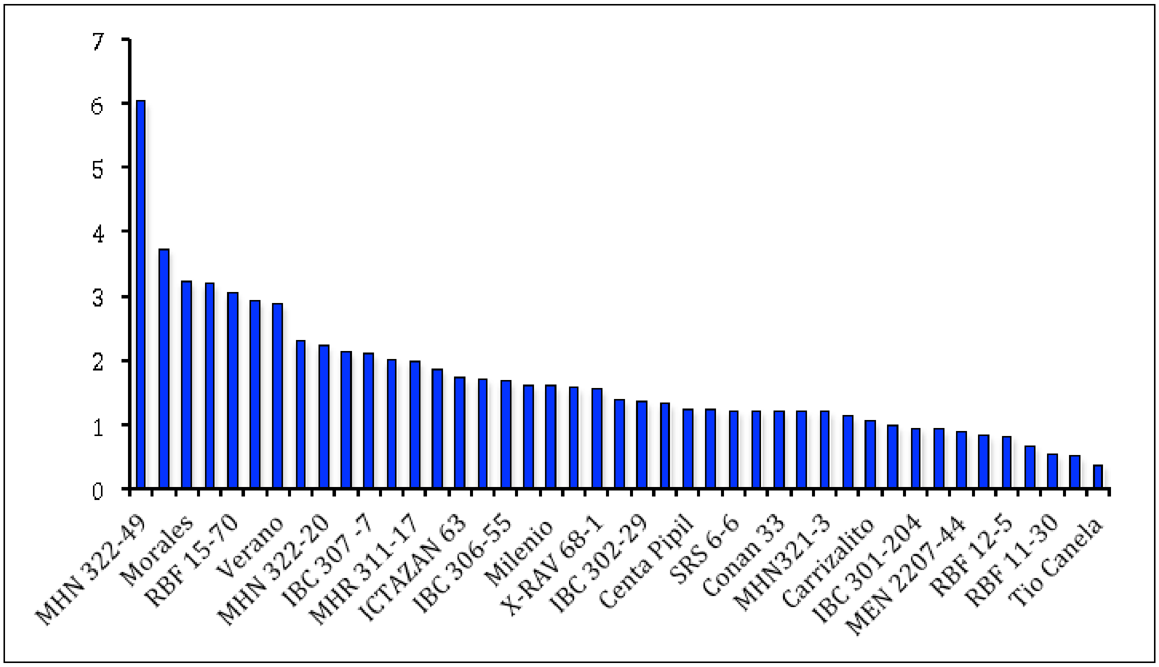


Figure 22. Mesoamerican bean materials received from Honduras in collaboration with Dr. Juan Carlos Rosas at EAP.

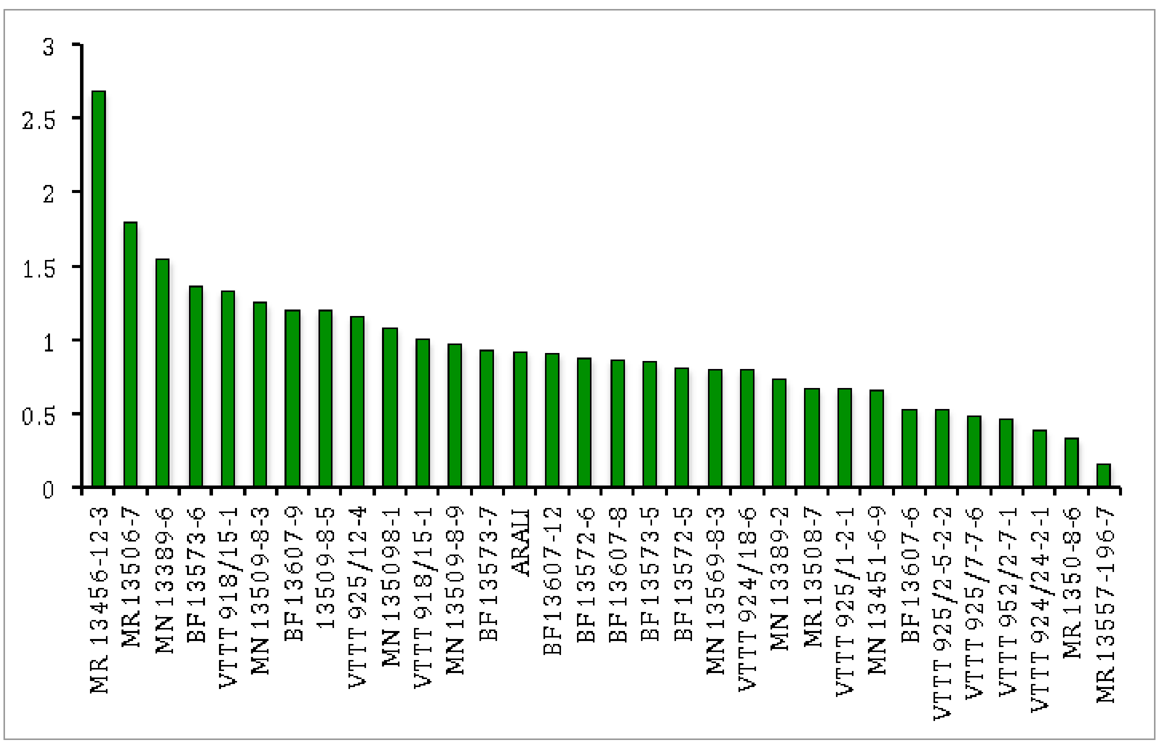


Figure 23. BILFA materials evaluated for grain yield under low P availability in red soils of Sussundenga Research Station, Mozambique.

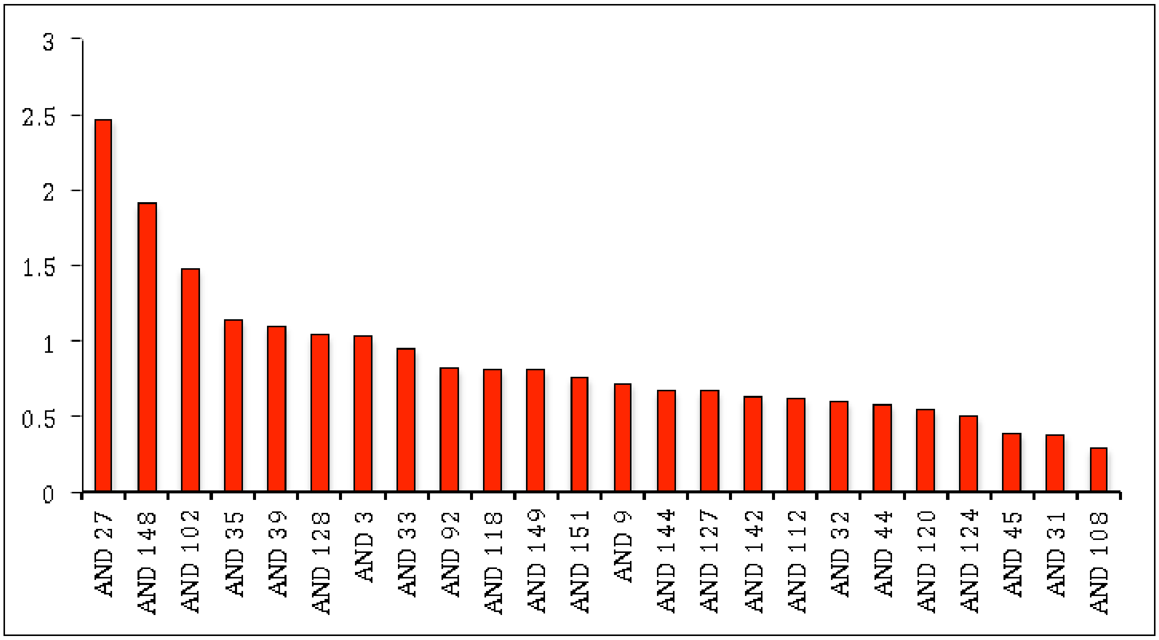


Figure 24. Field evaluation under of Andean materials from CIAT-Colombia .

Twenty-four common bean materials from Andean gene pool received from CIAT Colombia were evaluated under low phosphorus availability at Sussundenga Research Station. Grain yield varied from 0.29 ton/ha to 2.47 ton/ha, with average yield of 0.87 ton/ha (Figure 24). These genotypes although with superior characteristics in terms of coat color and seed size they are less P –efficient compared to other set of genotypes that have been evaluated under the same field conditions.

All the genotypes valuated during the last growing season have been planted again in the field in Sussundenga where they will be phenotyped for root traits and phenotypic data will be correlated to grain yield. In addition to root phenotyping, grain yield data will again be recorded for assessment of yield stability of the genotypes across seasons.

Other Activities

Utility of root hairs for K acquisition in low K soils
Root hairs have been repeatedly demonstrated to have a positive impact on phosphorus acquisition. Root hairs expand the nutrient depletion zone and permits transport of highly immobile phosphate ions across cell membranes. Potassium is nearly as immobile as phosphorus and we theorize that root hairs would have a similar positive impact in potassium uptake in low K soils. Trials are currently underway to determine if common bean genotypes with long and short root hairs differ in K uptake capacity. Preliminary results indicate a plastic response of root hair length with root hairs becoming longer under low K conditions.

Cowpea phenotyping and root trait evaluation
Shovelomics was performed on a two hundred entry cowpea collection representing worldwide diversity. Substantial variation was observed and genotypes with contrasting root architectures

were selected for future studies in order to establish the utility of root traits for limited water and phosphorus (P) conditions. Correlation exists between tap root diameters at different depths which indicates that only one measure of tap root diameter may be sufficient. Lack of correlation between tap root diameter and lateral branching density indicates that they are independently controlled and can likely be selected for singly. This independent segregation indicates that topsoil and subsoil exploration can be selected for and potentially combined in a single plant that would be tolerant to both low P and drought. Work will continue to establish the utility of specific root traits and to identify QTL for traits of interest.

Crosscutting Activities

During the implementation of the CRSP project we were able to:

- Establish a low P site at Sussundenga Research Station, where more than 200 genotypes of common bean (both Adean and Mesoamerican) were tested for tolerance to low phosphorus availability, and drought. Genotypes also were screened in order to identify and quantify root traits associated to phosphorus acquisition efficiency and drought. These traits included root hairs, basal root growth angle, basal root whorls and adventitious rooting.

- Seeds of 40 outstanding common bean genotypes (with 25 to 200% greater grain yields under low P availability compared to local checks) where distributed to about 200 selected farmers for field evaluation and technology dissemination, in collaboration with the McKnight P-Efficient project.

- A 3000 liter-container attached to a tractor trailor was acquired for back-up irrigation of the field trials at Sussundenga Research Station, when there is a shortage of electric power to run the main irrigation system.

- Two motor-pumps (one for Chokwe Research Station and one for Sussundenga Research Station) were acquied. The Chokwe motor pump is used for direct irrigation to the fields while the Sussundenga motor-pump is used to pump water from a source to the container, and then to the fields.

- A cold room facility was rehabilitated in Chokwe, to better preserve bean materials being evaluated and developed by the breeding component led by Celestina Jochua in Chokwe.

- 200 farmers benefited from the bean seeds in Angonia, under the collaboration of the AGRA project. These genotypes were selected from the CRSP evaluation trials and made available to the farmers participating in other projects in the region.

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

2.1 - Interaction of mulching on yield of P-efficient common bean productivity

A trial was conducted from June 30th to October 12th 2011 at Chókwe Research Station, Mozambique to evaluate the effects of mulching on the productivity of P-efficient (shallow rooted) and P-inefficient (deeper rooted) common bean genotypes (Figure 25). Table 2 shows the characteristics of the six (6) genotypes used for the study. The treatments included mulching with two levels (mulch applied, and no mulch applied) as the main plot, the 6 genotypes, [shallow rooted (Lic04-3-1, Lic04-2-1, and Lic04-7-2), and deep rooted (Seq1003, TioCanela, and BAT477)] were planted as sub-plots, and 2 fertilization treatments (Treatment 1: N=15 Kg Ha-1, and Treatment 2: N=15 kg Ha-1 + P=30 Kg Ha-1) were applied to each sub-plot. The experimental design is a split-split plot with randomization of application of treatments applied in main plots and subplots. Irrigation was always applied as signs of wilting showed up in mulched plots, using deep rooted genotypes for controlling the need for irrigation. Basal root whorl number (BRWN), Basal root growth angle (BRGA), and grain yield are the main components measured.

The shallow rooted genotypes had between 3 and 4 whorls, while the deeper rooted genotypes had 2 whorls, and very rarely 3 whorls. The growth angles of the shallow rooted genotypes were almost half of the growth angles of the deeper rooted genotypes (Table 2). This confirmed our selection of P-efficient and P-inefficient genotypes for this study. Therefore, in the analysis of grain yield we also grouped the treatments in 2 categories, the deep and shallow genotypes.

Table 2: Genotypes and trait characteristics measured in the field at Chokwe Research Station in 2011

Genotype	Shalloness	BRWN	BRGA
Lic04-3-1	Shallow	3	26
Lic04-2-1	Shallow	4	27
Lic04-7-2	Shallow	3	26
Seq1003	Deep	2.2	57
TioCanela	Deep	2	62
BAT477	Deep	2	67

The results show that under bare soil (no mulch applied) the grain yield was similar regardless of application of more P, but deeper rooted genotypes had about 28% higher yield than the shallow rooted genotypes due to better water use efficiency. The addition of P on mulched shallow rooted genotypes increased grain yield by 22%, while the yield increase on mulched deep rooted genotypes was only 1.8%. This result shows that the P-efficient genotypes use the added P better, and the benefit from mulching is greater when P is applied. However, as we can see in Table 3 the yield increase with P application is about 6% on "no mulch applied" treatments on P-efficient genotypes (Table 3).

Table 3: Grain yield (Ton Ha-1) of shallow rooted and deeper rooted genotypes trial conducted in Chokwe Research Station in 2011.

Mulching	Shallow		Deep	
	N	NP	N	NP
NoMulch	901.4	957.6	1153.6	1227.6
Mulch	986.1	1173.2	1099.6	1249.6

2.2 - Root shallowness of common bean: a trait that can contribute to increased productivity and reduce water erosion in low P tropical agroecosystems

Much common bean production in Latin America and Sub-Saharan Africa, where three quarters of the crop are grown, takes place on steep, erosion-prone slopes with low soil fertility. Bean genotypes with root traits enhancing topsoil exploration have greater phosphorus acquisition than conventional genotypes, but enhanced phosphorus extraction may be counteracted by reduced soil erosion from greater crop biomass and canopy cover. This study was conducted in a low phosphorus Ustox in Mozambique to evaluate the effect of shallow-rooted bean genotypes on alleviation of water erosion including reduction in runoff water, sediment and P in runoff water. We hypothesized that shallow-rooted genotypes would reduce interrill erosion more than deep-rooted genotypes. The treatments included two shallow-rooted genotypes and deep-rooted genotypes which are Recombinant Inbred Lines (RILs) from the same population, and bare soil. The four genotypes were planted in 1.6 m by 2.0 m runoff plots on a 6% slope. Treatments were replicated 4 times in 2008 and 5 times in 2009. Shallow-rooted genotypes had 81.2% more roots in the surface 15 cm soil than deep-rooted genotypes. Shallow-rooted genotypes had consistently less runoff water volume, sediment and dissolved P than deep-rooted genotypes. The shallow-rooted genotypes had 46% more shoot biomass, 15 to 28% more canopy cover, and 26 to 34.6% less runoff sediment than deep-rooted genotypes. Compared to bare soil, the runoff reduction was 27 to 39% for shallow-rooted genotypes and approximately 14.5% for deep-rooted genotypes. Root length density in the top 15 cm was well correlated with canopy cover (R2=0.98), runoff (R2=0.85), and shoot biomass (R2=0.89), and the volume of runoff was correlated with sediment suspended in water (R2=0.80). We conclude that bean genotypes with root traits permitting greater P acquisition attain better shoot growth, better canopy cover, and reduced soil P lost to water erosion in low P tropical soils. Introduction of genotypes with enhanced phosphorus acquisition may therefore help conserve soil fertility by reducing soil erosion.

2.3 - The effects of root traits enhancing P efficiency on biological N fixation

Low P availability is a primary constraint to the production of common bean in Africa and Latin America. Genetic variation for root traits that enhance topsoil foraging is being used to generate new Common bean (*Phaseolus vulgaris* L.) genotypes with greater P acquisition efficiency. A study was conducted at Lichinga (Mozambique) in 2008 and at Ukulima (South Africa) in 2010 to test the hypothesis that P-efficient common bean genotypes have better nodulation and better N2 fixation than conventional genotypes. Ten genotypes of two P-efficiency categories were grown with two phosphorus levels and inoculation/liming combinations. P-efficient genotypes had significantly greater nodulation efficacy than P-inefficient genotypes. Under low P, inoculation increased the nodule number of P-efficient genotypes by 34 to 71%. For P-inefficient genotypes, inoculation increased nodule number by between 20 to 46%. Nodule activity of P-efficient genotypes were consistent in both years and were between 50.6% and 92.5%, a rate at least 30% greater than for P-inefficient genotypes. For the P-inefficient genotypes the nodule activity varied between 27.5 and 33.4%. For liming and inoculation treatments the contrast of responses between the two categories of genotypes was much larger. Shoot dry weight was generally greater for P-efficient genotypes (13.5 to 9.1 g plant-1) compared to 9.5 to 7.5 g plant-1 for the P-inefficient genotypes under low P. For P-inefficient genotypes there was no significant difference between inoculated and non-inoculated treatments under low phosphorus in either year. Under low P inoculated treatment the genotype L88-57 fixed the equivalent of 39

Figure 25: Field trial of interaction of mulching and root architecture in Chokwe, Mozambique.

kg of urea ha-1 followed by G19833 and L88-14 fixing N equivalent to 32 kg of urea ha-1, and the smallest amount was fixed by the genotype DOR 364 with the equivalent of 1.6 Kg of urea (46%) ha-1. These results suggest that the introduction of P-efficient genotypes may greatly contribute to increased productivity and sustainability of low-input systems since a considerable amount of N is fixed by the symbiotic nitrogen fixation process with P-efficient lines and its cost is lower than the use of inorganic fertilizer by poor farmers.

Objective 3: Socioeconomics

The socioeconomic research undertaken for this project involved a major survey effort in four provinces of Mozambique, including three provinces located in the major bean-growing region of Mozambique. Provinces included Manica, Niassa, Zambezia, and Tete. The baseline involved 4 separate surveys, the results of which are summarized in this report. In addition, a follow-up survey is underway in Mozambique, following distribution of new selected P-efficient common bean seed at the village sites. Seed distribution was delayed to ensure thorough IIAM-directed testing of seed under local conditions; thus, the survey of experiences with the improved P-efficient seed was delayed to ensure sufficient testing.

The following document (prepared in collaboration with socioeconomic graduate students engaged in the project, and principally by Luis Sevilla) summarizes some of the findings to date. Objectives of the study include identifying and understanding barriers to the widespread adoption of new bean technologies, determining household constraints towards achieving full income and nutrition potential, and lastly to study the intra-household effects of the introduction of a new bean technology (Lynch et al 2008[1]).

[1] http://expeng.anr.msu.edu/uploads/files/167/PSU-1%20Tech%20Prog%20Rpt%20FY08%20Final.pdf)

3.1 – Background material

Mozambique has a population of 22,894,000 with an average annual population growth rate of 2.1%; the majority of the population lives in non-urban areas and with only 38.4% living in urban areas (United Nations 2011). In 2009, Mozambique had a gross national income (GNI) per capita of $440, significantly below the sub-Saharan Africa average for GNI per capita of $1,126. Nearly 55% of its population is living below the national poverty line (African Economic Outlook 2011; World Bank 2011a). The fertility rate equals 4.6 births, and the mortality rate is 76.9 per 1000; life expectancy at birth (2010-2015) is expected to be 49.4 years for females and 48.8 years for males (United Nations 2011). In 2010, Mozambique had a Human Development Index score of 0.317, dramatically below the sub-Saharan average HDI of 0.460 and the world average of 0.679 (UNDP 2011). Despite recent economic growth, Mozambique has failed to address important social issues and as a result, was 165th out of a total of 169 countries in HDI rankings[2].

In 2009, the agricultural sector employed nearly 80% of the economically-active population in Mozambique (FAO 2005) but only accounted for 31.5% of Mozambique's GDP (World Bank 2011b). Agriculture is dominated by smallholder families as well as small and medium enterprises. Approximately 3.2 million smallholder families account for 95% of the land under production (World Bank 2006). Smallholders farm in small rain-fed plots of approximately 1.8 hectares, with low inputs and low yields. Smallholders typically produce food crops such as maize, cassava, rice, and beans, and a small percentage (16%) also produce cash crops such as cotton and tobacco (World Bank 2006). On the other hand, small and medium-size private enterprises produce cash crops such as cotton, cashew, other nuts, sugar cane, tobacco, and tea. As a primary source of employment for a large segment of the population, agriculture is important to Mozambican livelihoods. Between 1996 and 2003, the rural poverty headcount decreased from 69% to 54% due to increases in the food and cash crop sectors (World Bank 2006).

3.2 - Study sites in bean-growing regions in northern Mozambique

The socioeconomic work was undertaken in three districts in the northern (bean-growing) region of Mozambique. Research was also conducted in Manica Province, at village sites near the Sussundenga IIAM Zonal Station near Chimoio. In each of the northern districts, paired research sites were selected, with one village site having linkages to IIAM and one not. Those linked to IIAM are proximate to where the field/lab research takes place. A second site was selected in each district as a paired site. Paired sites were selected on the basis of distance from the IIAM site and shared site characteristics (eg, village population size, etc.). The findings in this report are limited to data from the 3 bean-growing provinces in the north; pilot testing was done in Manica Province. A description of the three provinces in northern Mozambique is given below.

Tete. The two villages in Tete province are located in Angonia district in the northeastern part of Tete province. Angonia has a total land area of 3,277 square kms. and in 2010 had a population

2 The HDI measures the average achievements in a country in three basic dimensions of human development: (i) a long and healthy life measured with life expectancy at birth, (ii) knowledge measured through adult literacy rate and the combined primary, secondary and tertiary gross enrollment ratio, and (iii) standard of living measured through GDP per capita (UNDP 2011).

of roughly 360,000, yielding a population density of roughly 101.4 people per square km. Given the district's size, it is estimated that there are approximately 150,000 hectares of arable land available, with only 50,000 hectares currently used by agricultural households. The major crops grown in the district are maize, cassava, beans, peanuts, and sweet potatoes (Ministerio de Educao Estatal 2005a).

Zambezia. The first village site is located in Gurue district in northern Zambezia province. Gurue has a total land area of 5,688 square kms. and a population of roughly 265,000. Population density is again low, at 42.6 people per square km. Extensive tea plantations take up a large portion of the arable land, typically leaving small farmers to work on 1 hectare plots (39% of the cultivated area in the district). Major crops grown in the district include peanuts, sweet potatoes, beans, cassava, maize, rice, tobacco, sugar cane, and sunflowers (Ministerio de Educao Estatal 2005b).

The second research site is in Zambezia province, in the Alto Molocue district. Molocue covers a total area of 6,343 square kms. and had a population of roughly 250,000 (2010) with a population density of approximately 36.2 people per square km. It is estimated that of the total 637,000 hectares of land, approximately 400,000 hectares have arable land and only 60,000 hectares are being used by farm households. The major crops grown include maize, sorghum, peanuts, cassava, beans, cotton, and tobacco (Ministerio de Educao Estatal 2005c).

Niassa. The first village site in Niassa province is located in Lichinga district in the western part of Niassa. Lichinga covers 5,342 square kms. and in 2010 had a population of 100,000 with a population density of 16 people per square km. Farming takes place mainly in small plots, covering a total area of 22,947 hectares. The major crops are maize, beans, cassava, peanuts, sweet potatoes, and potatoes (Ministerio de Educao Estatal 2005d).

Lastly, the second village in Niassa is located in Mandimba district in southern Niassa province. Mandimba covers a total area of 4,699 square kilometers and in 2010 had a population of approximately 132,000. The population density equaled roughly 24.2 people per square km. With regards to agriculture, approximately 26,000 plots of land are being farmed and approximately 35% of these plots are less than half a hectare in size and nearly 50% are operated by women. Main crops grown include cassava, beans, maize, and rice (Ministerio de Educao Estatal 2005e).

3.3 – Methodology

Data gathering

A collaborative IIAM-Penn State baseline questionnaire was administered to Mozambican households in 2008-09. A total of 289 male and female participants participated in the study. Survey site selection was done in coordination with researchers from IIAM familiar with the country. Using geographic maps, two villages per province were selected as noted above, with one site serving as a control site and the other serving as an experimental site. Google maps were made of each village site, including both 'fullview' landscape and quadrant village maps. The quadrant maps (clearly) showed living quarters/compounds, roads and paths, shops, schools, clinics, fields and field edges (in many cases), degraded areas, streams and other sources of water, etc. While it typically was not possible to differentiate shops from schools from clinics from the maps, later 'ground truthing' in the villages allowed this differentiation. The village center was used to center the maps, with each quadrant map spanning approximately 2 km in each direction from the city center. The fullview maps showed the larger landscape. The fullview Google maps were developed to help villagers acclimate themselves to the village location, if needed.

Prior to any work in the villages, village leaders (both the traditional chief and municipal chief, if present) were consulted, to secure their permissions. After permissions were granted, drawn from a random sample of households across the village were interviewed using three survey instruments: PROFILE, PLOT, and TARGET surveys. The PROFILE and PLOT surveys were administered to only one member of the household to reduce survey fatigue; pilot testing in the Manica villages indicated that reducing the number of questions would be beneficial. The PROFILE survey was conducted with the female spouse or female head of household. The PROFILE survey included the household profile (individuals within the household) and questions related to crop sales. The PLOT survey was administered to the male spouse or male head of household. The PLOT survey also consisted of questions related to plots of land administered by the household, total agricultural production, and data to reflect asset holdings and socio-economic status. Lastly, the TARGET survey was administered to both male and female heads of household. The survey included questions related to:

- Income sources
- Bean production, consumption, and sales
- Decision-making structure of households
- Intra-household differences in preferences for specific bean varieties and attributes/traits
- Constraints to achieving income and nutrition potential relative to legumes
- Social and economic networks in place and ways in which existing networks can be utilized to enhance the probability of adoption of introduced improved cultivars
- Disease-food security interactions, with a particular focus on malaria

Interviews were conducted in a face-to-face format over multiple days during the dry season. Interviewers fluent in Portuguese and local languages helped guide respondents through the survey. All interviewers received training before data collection. Interviewers (one male and one female) approached each household and asked to speak to the male and female heads of the household; in some instances, only one member of the household was available and therefore the entire survey was administered to the individual available at that time. Appointments were made for individuals not a home. The collected surveys were checked by a supervisor each night to ensure completeness.

As part of the survey process, the Google quadrant maps were used with survey respondents to identify their social and economic networks. Because the network questions were included on the TARGET survey, network data were collected among females and males, allowing analysis of male and female networks separately. When both a male and female were present in the household, the network data could be used to create (denser) network maps for both together.

Survey data were coded from the paper version into a digital version using Excel 2007. The digital responses were then converted into a STATA data file. Using STATA, the data were checked for errors in the data entry process and analysis was conducted.

The baseline data set is very rich in content, allowing for comparison to future surveys to be conducted as new cultivars are developed and diffused. IIAM distributed thoroughly-tested cultivars for local assessment in early 2012, and a follow-up survey is now underway to assess specific constraints that households receiving the seed report facing. Households receiving the seed were identified by IIAM personnel to allow this follow-up. Households were provided choice among multiple seed varieties, and their choice(s) were recorded. Figure 26 below shows examples of the maps used, and high village interest.

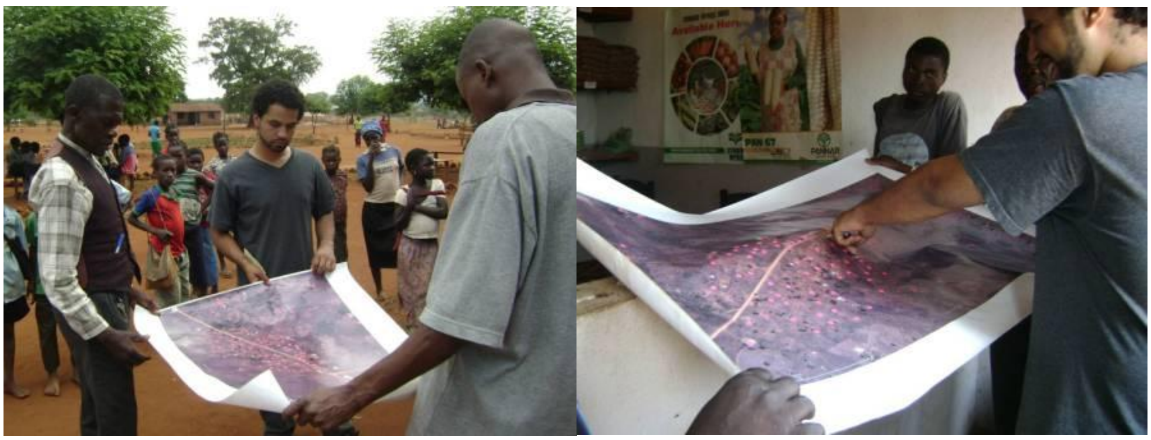


Figure 26. Village map demonstration in Munhinga, Manica Province, Mozambique.

3.4 - Summary of selected findings
A summary of selected findings for the socioeconomic study is included below.

1. Bean sales are found to be a very important source of income for the (vast) majority of farms in Mozambique's bean-growing regions. Over 80% of households surveyed in Niassa and Tete reported relying on bean sales as a source of income; in Zambezia, a smaller yet still large portion of the population (60%) reported relying on the sales of beans.

2. Income from bean sales averaged 4649.46 meticais in Niassa for households selling beans, and most Niassa households fail to consider bean profitability as a problem. Maize sales resulted in a lower 1586.86 meticais annually. In Zambezia, beans sales generated an average 2246.67 meticais annually, and in Tete, agricultural income was found to be significantly lower, with bean sales averaging (only) 569.28 meticais per year. The majority of farmers in Zambezia and Tete report profitability as being a problem.

3. Villages in Tete are observed to be very seriously food stressed. About 80% of respondent households – 4 of 5 -- reported that not having enough food to eat is a very serious issue for them. Almost all of the remaining households reported hunger as serious.

4. Hiring out household labor to other farms appears to be an important coping mechanism to combat food and income difficulties during the hunger season. A greater ability to grow

beans during this period on larger farms may represent a useful strategy for income generation.

5. Households reported strong interest (>70%) in producing soybeans, if guaranteed a buyer. This was also the case for black beans: over 80% of households in the three provinces reported a willingness to produce black beans, if a buyer was guaranteed. In Niassa and Tete, over 60% of households reported eating soybeans, whereas less than half of households in Zambezia ate them. Black beans generated less interest for home consumption.

6. Our experiences in the villages point to the importance of (shorter) cooking time as a preferred trait. As expected, drought resistance was viewed as a very important trait, particularly among males. Also important is the ability to enhance soil to benefit other plants. Respondents also preferred bean varieties with fewer plant diseases (50.0% very important for females; 55.6% males) and fewer insect pests (49.1% very important for females; 5.6% males). The possibility of intercropping with maize is also very attractive to roughly half of all respondents regardless of gender. Nearly 90% of respondents were interested in beans with the following characteristics: ability to improve soil, drought resistance, lower requirements for fertilizer, less labor, fewer insect diseases, and an ability to intercrop with maize.

7. Introducing new bean varieties that they could sell themselves to consumers in distant markets was less important, especially among women but also among almost 40% of men. But both men and women reported interest in having new bean varieties introduced that are demanded by traders coming to the farm or homestead.

8. The major constraint to the production of more and better common beans is the very serious lack of access to improved seed in Mozambique. Informal sharing mechanisms (relatives and friends) were reported by both men and women as the best means in place to obtain improved seed varieties. Study results provide evidence that formal channels such as seed stores, extension, NGOs, or farmer’s organizations are not driving the spread of improved seed varieties. Rather, informal channels such as friends and family in the same village or else more distant relatives help households obtain improved seeds that are otherwise difficult to access. Extension (whom the villagers trust for technical training) and also the NGOs are not considered a primary source of improved seed.

9. When asked if not having enough good bean seed available locally was a problem, 73% of households in Tete and Zambezia said that they considered not enough good bean seed available locally to be a large problem or problem for them. In contrast, in Niassa roughly 65% of the households didn’t find having enough bean seed a problem or small problem. Households in Niassa also reported more than double the income from bean sales, as compared to the other sites. In Niassa, bean income is higher and good seed more accessible. Bean seed sharing networks are found to be thinner (less dense) than anticipated.

10. A majority of respondents wanted security – both social and market – before adoption (Smith & Findeis 2012). That is, a majority of male and female respondents reported that they would not want to be first adopters, but rather would need to see others successfully grow a new

cultivar first. The majority of respondents also reported that they would have to be shown how to grow it before they would try it out. Thus, how improved seed are introduced into the villages becomes an important question.

11. There is substantial internal and external variation in social and economic networks in the villages (Smith & Findeis 2012). Those villagers identified as 'Participators' using latent class analysis were likely to participate in seed demonstrations, seed trials, etc. and tended to be quite active in the village. However, they differentiate from the 'Well-connected', an identified group with ties to external networks. Being linked to external networks is likely key to accessing input and output markets, as well as information.

These results emphasize the need for greatly improving access to new seed as a strategy to improve food security and relieve hunger. The serious lack of seed companies in Mozambique at this time represents a major constraint to improved seed access, as do slow cultivar release rates by Mozambique but also by a number of other countries in the East African region. Further, reliance on seed sharing has the disadvantage of slow diffusion, given that (seed) sharing networks are found to be more fragmented than expected in the majority of analyzed villages. Solving the seed access problem represents a major challenge in the East Africa region and its solution will undoubtedly serve to reduce binding constraints to higher bean yields in areas that have the potential for higher productivity in Mozambique.

Objective 4: Capacity Building

Bean breeder Virginia Chesale from Malawi defended her MSc thesis and returned to Malawi.
Samuel Camilo of IIAM passed the TOEFL and began his M.Sc. studies in May 2011.

Graduate students engaged in the socioeconomic studies include Maria da Luz Qienhentos of IIAM (M.S. studies) and Luis Sevilla (Ph.D. studies); neither student receives USAID funds but both have contributed to the data analyses reported here. Survey methods training was provided at IIAM-Sussundenga at a training workshop held August 13-15, 2012 for four IIAM staff: Maria Adelina, Domingas Avelino, Zefanias Fazenda and Elvis Nhantunbo.

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 (VIDAC and ECAR Trials). A similar group of lines were tested by farmer groups involved in the Participatory Plant Breeding Program for the Mesoamerican Region (PPB-MA) 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; three cultivars were released in El Salvador and one cultivar will be released by the end of 2012 in Nicaragua. These locally released cultivars are being disseminated thru the Bean Technology Dissemination Project from the DGPC/USAID and the PPB-MA Program in Central America. In addition, promising lines from the DGPC 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 research program. Some of these lines developed by the project were included in the set of 50 bean lines sent to IIAM in 2010. A new set of drought and low fertility tolerant lines will be sent to IIAM, after the visit of J.C. Rosas to Mozambique in January 2013 under the PSU- McKnight Project. It is expected that two technicians from IIAM will received training on breeding and selection, including PPB, seed production and *Rhizobium* technology at Zamorano facilities during the last quarter of 2012.

Leveraged Funds
P.I.s: JC Rosas
Title: Participatory plant breeding
Amount: $250,000 over 5 years (2010-14)
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.: JP 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: 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.: 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: Biotic and abiotic constraints to legume productivity in developing country workshop

P.I.s: JP Lynch
Duration: 3-1-11 to 12-31-11
Amount: $100,000

List of Publications

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Smith, RA, JL Findeis. 2012. Explaining audience segmentation: investigating adopter categories to diffuse an innovation to prevent famine in rural Mozambique. Journal of Health Communication: International Perspectives. DOI:10.1080/10810730.2012.688249.

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Dry Grain Pulses CRSP

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

(For the Period: October 1, 2011 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

Project Title: *Improving bean production in drought-prone, low fertility sopild of África and Latin America- An integrated approach.*

	Abbreviated name of institutions											
	EAP			IIAM			PSU			PSU		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	######	**Y**	**N***	#####	**Y**	**N***	#####	**Y**	**N***	#####	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)											
Objective 1:breeding												
Honduras												
Testing IB lines- Drought/low P	**x**	x		**0**			**0**			**0**		
Testing lines/cultivars- BNF	**x**	x		**0**			**0**			**0**		
Tolerant lines in regional trials	**x**	x		**0**			**0**			**0**		
Develop new improved lines	**x**	x		**0**			**0**			**0**		
Conduct on-farm trials	**x**	x		**0**			**0**			**0**		
Lines sent to IIA	**x**		x1*	**0**			**0**			**0**		
Mozambique												
evaluation and selection of bean geno	**0**			**x**	**x**		**0**			**0**		
development of bean genotypes and i	**0**			**x**	x		**0**			**0**		
introgression of root traits	**0**			**x**		x4*	**0**			**0**		
advance generations of populations c	**0**			**x**	x		**0**			**0**		
seed increase/multiplication	**0**			**x**	x		**0**			**0**		
Objective 2: Integrated Crop Management												
prepare local RP	**0**			**x**	x		**0**			**0**		
field study: moisture conservation/dro	**0**			**x**	**x**		**0**			**0**		
on farm demo of moisture conservatio	**0**			**x**		x6*	**0**			**0**		
pot evaluation of RP	**0**			**x**	x		**0**			**0**		
field evaluation of RP	**0**			**x**		x6*	**0**			**0**		
Objective 3: Socioeconomics												
conduct PVS	**0**			**x**		x5*	**0**			**0**		
farm household surveys	**0**			**0**			**0**			**x**	x2*	
code and clean ex post data	**0**			**0**			**0**			**x**		x2*
Analyze data	**0**			**0**			**0**			**x**		x2*
Training												
MS degree training S Camilo	**0**			**0**			**x**	x3*		**0**		
nondegree training	**0**			**0**			**0**			**x**	x	
training in PVS and MAS at EAP	**x**			**0**			**0**			**0**		
strengthen research infrastructure at	**0**			**x**	x		**0**			**0**		
strengthen research and training capa	**x**	x		**0**			**0**			**0**		
multilingual web delivery of root resea	**0**			**0**			**x**	x		**0**		
Name of the U.S. Lead PI submitting this Report to the MO	JC Rosas			M Miguel			JP Lynch			J Findeis		

Signature **Date**

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

1 - A new set of lines from EAP will be sent to IIAM after a visit of J.C. Rosas (Jan. 2013) to review the performance of the set of lines previously sent to IIAM and discuss the need of specific germplasm with IIAM researchers.

2 - ex post surveys not yet complete- expected spring. This was delayed by need to have two seasons of on-station testing before seed distribution.

3 - in progress

4 - The introgression of root traits started this year but we did not check as a completed activity in this period because most of the crosses will be made in the next bean season. Seeds of selected potential parents were increased and phenology data that is need to plan crosses was also collected up to this period. Additionally, under this objective, seed of about 290 lines developed for low P adaptability from Andean gene pool were increased and preliminary trials for yield performance. These lines were developed from parents with long and dense root hair, shallower roots, and more basal root whorls and basal roots. One of the parents used to develop these lines include G 19833 known to have good root traits for low P adaptation.

5 - Before conducting the PVS, we had to carry out a number of activities, which includes the training of the technicians and enumerators participating in the PVS. Now that all these activities have been done the PVS has been scheduled for March 2013 after the return of the technicians from Honduras.

6 - Due to the hight cost of irrigation during the dry season the field evaluation of RP and mulching will be done during the rainy season in Zambezia province in January 2013

Dry Grain Pulses CRSP						
PERFORMANCE INDICATORS/TARGETS for FY 12						
(October 1, 2011 -- September 30, 2012)						
	PII-PSU-1			EAP	IIAM	% change actual fror
	2012 Target	**2012 Actual**		**2012 Actual**	**2012 Actual**	
Output Indicators	**(Oct 1 2011-Sept 30, 2012)**					
Degree Training: Number of individuals who have received degree training						
Number of women	0	0		0	0	
Number of men	1	1		0	1	0.0%
Short-term Training: Number of individuals who have received short-term training						
Number of women	10	4		2	2	-60.0%
Number of men	16	10		8	2	-37.5%
Technologies and Policies						
Number of technologies and management practices under research	21	29		20	9	38.1%
Number of technologies and management practices under field testing	9	13		10	3	44.4%
Number of technologies and management practices made available for transfer	21	28		3	25	33.3%
Number of policy studies undertaken	0	2		0	2	
Beneficiaries:						
Number of rural households benefiting directly from CRSP interventions - Female Headed households	150	200		100	100	33.3%
Number of rural households benefiting directly from CRSP interventions - Male Headed households	850	700		500	200	-17.6%
Number of agriculture-related firms benefitting from CRSP supported interventions	7	7		2	5	0.0%
Number of producer organizations receiving technical assistance	65	220		20	200	238.5%
Number of trade and business associations receiving technical assistance	5	6		0	6	20.0%
Number of community-based organizations receiving technical assistance	5	25		20	5	400.0%
Number of women organizations receiving CRSP technical assistance	8	5		5	0	-37.5%
Number of public-private partnerships formed as a result of CRSP assistance	1	6		6	0	500.0%
Number of HC partner organizations/institutions benefiting	6	4		3	1	-33.3%
Developmental outcomes:						
Number of additional hectares under improved technologies or management practices	5125	5250		5000	250	2.4%

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

Principal Investigator
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Collaborating Scientists
Jeffrey D. Ehlers, University of California, Riverside, USA
Ndiaga Cisse, CNRA, Bambey, ISRA, Senegal
Issa Drabo, INERA, Burkina Faso
Antonio Chicapa Dovala, IIA, Angola

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 2011. Elite novel dry grain 'green blackeyes' were evaluated in two on-station trials for grain quality, yield, disease and insect resistance and data collected to support the best one for release. In Senegal, the line ISRA-2065 with thrips and aphid resistance was released in 2011 as 'Pakau.' 600 kg of Foundation Seed was produced in 2011 and an estimated 1500 kg in the 2012 off-season. Following the advanced multi-location yield trials and on-farm tests conducted in 5 seasons (2008 – 2012) 3 new lines will be proposed for release as varieties in Senegal based on grain quality, yield, disease and insect resistance. About 600 new breeding lines were tested in preliminary trials in Senegal. They combine high yield, grain quality, and abiotic and biotic stress resistance traits. Another 1500 lines were advanced to F6 stage in 2012. Under the seed production and delivery systems objective, the following was achieved: In Burkina Faso**,** Breeder Seed of 11 improved varieties was grown at Saria and Pobe-Mengao. Foundation Seed of 7 varieties was produced at Saria, Pobe-Mengao Kamboinse, and by individual farmers' organizations and agro-dealers. More than 40 MT of Foundation Seed of 7 varieties will be sold to Certified Seed producers in 2013. Another 90 lead farmers were trained as Certified Seed producers in 2012. In Senegal, 2 ha each of Melakh, Yacine and Pakau Foundation Seed was produced at Bambey to supply the EWA NGO seed producer network (RESOPP). 60 ha each of Melakh and Yacine Certified Seed was produced by farmers in 2011, primarily in the Louga, Tivaouane, 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) and the former Louga station manager (Moustapha Diop). A student from Mozambique started PhD degree training in cowpea pathology genetics and breeding at UC Riverside. Multi-location trials of diverse cowpea lines were completed in Angola and IIA established contact with extension institute "IDA" to coordinate seed production and distribution.

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), for-profit seed cooperatives (NGO-established, now largely self-sustaining) and for-profit individuals or groups, but limited scope reflects insufficient quantities of Breeder and

Foundation Seed. We are supporting 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 US using modern plant breeding tools.

Collaborators

Moctor Wade (weed scientist), Centre National Recherches Agronomie, Bambey, Institut Senegalais de Recherches Agricole (ISRA), Senegal.
Tignegre Jean-Baptiste (breeder) and Mme. Clementine Dabire (entomologist), INERA, Kamboinse, Burkina Faso.
Jose Pedro, Centro Nacional de Recursos Fitogenéticos (CNRF)/Faculdade de Ciências/ Universidade Agostinho Neto, Luanda, Angola.
David Kiala, Faculdade de CIências Agrárias (FCA)/Universidade José Eduado dos Santos, Huambo, Angola.
Antonio Castame Francisco, Instituto de Investigacao Agronomica, Luanda, Angola.

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 in 2013 following Breeder Seed production during FY12. In Senegal, the indicated ISRA lines, focused on large-seeded types, were planted in 20 demonstration trials during FY11, with a second year of on-farm demonstration trials in 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), large seed size (at least 25 g 100-seed weight), and plot 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 30 farmers at 6 sites in the Central (Saria, Poa, Rana) and Northern (Djouroum, Pobe, Titao) zones. Sites were considered as replications and each plot was 300 m^2 (20 x15m). The six new varieties were compared to one local check (traditional variety or KVx396-4-5-2D) at each site.

In Angola, cowpea field evaluations were conducted in 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 two years (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 December 2011 at the start of the FY12 work plan period was used to help coordinate these activities. The Angolan materials were SNP-genotyped to enable association mapping comparisons for major mapped cowpea traits.

In California: 12 new advanced dry green breeding lines were screened in replicated trials at two locations in 2011, and from these, the seven best yielding/grain quality types were field tested in replicated plots at Riverside and Kearney.

In California, for continued development and testing of new elite blackeye lines, nine advanced lines selected from 2010 and 2011 trials were tested in replicated plots at Riverside and Kearney under insect protected conditions. These breeding lines were derived from crosses between CB50, CB46 and other elite blackeye types.

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. A subset of these lines were selected based on their performance in lygus screening trials conducted in 2010 and 2011, and evaluated for grain yield and grain damage under lygus protected and unprotected conditions at Kearney and unprotected at Riverside in replicated yield trials again in 2012. At Kearney, we also conducted large unprotected strip trial yield tests of the three 2011 highest performing lygus tolerant lines. 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 and screened in an unprotected nursery at Kearney under strong selection for resistance to lygus and for desirable grain quality were advanced in 2012.
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 included in the elite blackeye field trials described above. This line also 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. The best lines

were field tested at South Coast field station in 2012. 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 and advanced to F2 in 2011as part of the process of transferring aphid resistance to adapted varieties. In FY12, these lines were advanced to F3 for screening.

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 resistance. In FY12, these crosses were introduced in preliminary yield trials. Screen house and field techniques were used to evaluate the different populations and 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 FY12 Senegal and Burkina Faso recurrent backcross populations were advanced and inbred to the BC2F5 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 inbred BC and segregating populations 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 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 F1s 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. The F4 and F5 families were planted in replicated field trials (2 rows x 3 reps) in Senegal and Burkina Faso in the off-season and main 2012 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 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 in Burkina Faso. Data will be analyzed soon and the best lines will be evaluated in farmers' field tests.

In California, Pigeon pea selections made in earlier years at UCR from GA-1, originating from materials supplied by Dr. Sharad Pathak at the University of Georgia, were tested in 2011 and 2012. Using 4-fold replicated field station plantings, data from a yield trial conducted at Kearney in 2011 with 10 selections was used to identify the best six selections for yield and grain quality tests at Kearney and UC-Riverside in 2012.

Results, Achievements and Outputs of Research

Final Testing and Release of Varieties

In Burkina Faso (INERA). Results of two years of testing indicated 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 Seed 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. In 2012, 8000 kg of Certified Seed of KVx 442-3-25 were produced. Details of the 6,136 Kg of Breeder Seed produced in Burkina Faso from 2005 to 2010 were presented in Table 1 of our FY11 report. Note that a total of 879kg of seeds of KVx421-2J, IT98K-205-8 and Melakh were obtained. We are projecting to produce at least 40 tons of Foundation Seed of these 3 varieties and 3 others varieties in 2012, 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 2013.

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 have been made since 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. Following demonstration trials in the South zone of the peanut basin (Kaolack, Nioro and Kaffrine) zone in 2009 and 2010 with large plots (2500 m^2) on 30 farms, 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 following season. 600 kg of Foundation Seed was produced in 2011 and about 1500 kg in 2012 off-season. Following the advanced multi-location yield trials and on-farm tests conducted over the last five seasons (2008 – 2012) 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 the highest ranked lines were tested at seven sites (Mazozo-Luanda, Kilombo-Kwanza Norte, Alto Capaca-Benguela, Cela-Kwanza Sul, Humpata-Huila, Calussinga-Bié, and Chianga-Huambo areas). In the trial planted in Mazozo in March 2012, the highest performing varieties with were 2870-5 (775 kg/ha), 124/2469-1(572 kg/ha) local varieties and UCR 288(Tvx1948) (988 kg/ha), IT90K-284-2 (427 kg/ha) improved varieties. These varieties are strong candidates to include in production seed systems because their yield performance did not differ from that in the trials evaluated by António David in Puerto Rico in his Master's Degree study.

In California. Replicated small plot tests of new dry-green blackeye advanced lines were conducted to determine varietal candidates. Yields of these seven dry-green breeding lines were significantly less than elite blackeye variety CB46 in the Kearney trial (Table 1). A similar trend was found in the Riverside trial, although the three best yielding dry-green lines were not significantly less than the CB46 control (Table 2). However, yields in the Riverside trial were overall much lower than at Kearney. It is possible that there is a sufficient positive price differential for the dry green blackeye selections compared to blackeyes that growers and industry personnel will be interested in the best of these new advanced lines. We will retest the best three lines in large strip-trials next year with the aim of releasing the best line. 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, and the better performers advanced in 2012.

Table 1. Yield performance of blackeye cultivar CB46 and dry-green advanced breeding lines grown under Lygus protected conditions at Kearney in 2012.

Line	Number of replications	Mean yield (lbs/ac)	Fisher's protected LSD test ($P < 0.05$)	Coefficient of Variation (%)
CB46	4	3672	a	7.7
10-11-664	4	2425	b	26.1
10-11-673	4	2377	b	21.6
10-11-701	4	2368	bc	17.4
10-11-735	4	2248	bc	7.2
10-11-757	4	2139	bc	20.2
10-11-718	4	1999	bc	17.5
10-11-721	4	1822	c	21.1

Table 2. Yield performance of blackeye cultivar CB46 and dry-green advanced breeding lines grown under Lygus protected conditions at UC Riverside in 2012.

Line	Number of replications	Mean yield (lbs/ac)	Fisher's protected LSD test (*P* < 0.05)	Coefficient of Variation (%)
CB46	4	1951	a	13.4
10-11-664	4	1806	ab	7.3
10-11-701	4	1724	ab	7.2
10-11-757	4	1664	bc	19.3
10-11-735	4	1603	bcd	9.8
10-11-673	4	1442	cd	13.6
10-11-721	4	1441	cd	17.5
10-11-718	4	1398	d	6.5

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. The best nine performing lines were retested at Riverside (Table 3) and Kearney (data not yet finalized) in 2012. Positively several lines had yields comparable to CB46 and CB50, and one (line 10K-4) had significantly higher yield than these current varieties (Table 3). The best performing lines will go into larger scale multi-location trails next year. The yield of the CB46 line (CB46RK2) backcrossed to add in the Rk2 gene stronger level of root-knot nematode resistance had similar yield to CB46 and CB50 at Riverside (Table 3). The 100-grain weight data for 2012 are not finalized but this line has typically smaller grain size than CB46, although it may be of value to the blackeye canning market.

Table 3 Yield performance of elite blackeye breeding lines grown under Lygus protected conditions at the UC Riverside in 2012.

Line	Number of replications	Mean yield (lbs/ac)	Fisher's protected LSD test (*P* < 0.05)	Coefficient of Variation (%)
10K-4	4	2317	a	11.2
10K-19	4	2076	ab	5.7
10K-83	4	1976	bc	11.2
10K-121	4	1973	bc	12.1
CB46	4	1937	bc	19.6
CB50	4	1918	bc	2.4
10K-27	4	1876	bc	7.4
10K-23	3	1849	bc	11.7
10K-77	4	1812	bc	8.0
CB46Rk2	4	1779	bc	4.7
10K-115	4	1728	c	9.3
10K-29	4	1651	c	31.5

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 field trials conducted in 2010 and 2011, a subset of these lines was selected and evaluated for grain yield and grain damage under lygus protected and unprotected conditions at Kearney (Figure 1) and under unprotected conditions at Riverside in 2012 (Table 4). In the Kearney trial (Figure 1), there was no significant interaction between cultivars and protection treatment, while the difference between protected and unprotected treatments was significant ($P < 0.001$). Breeding line 07KN-74 showed the best performance under both conditions, but the results require finalizing the grain damage index data for full interpretation. However, line 07KN-74 had excellent yield in both protected and unprotected plots at Kearney and in unprotected plots at Riverside compared to CB46 and CB27.

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 and F_3 in 2012.

The second trial ('unprotected' only) had six advanced 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. Four lines had yields similar to CB46 (Table 4). These breeding lines are approaching 'blackeye' grain quality and agronomic characteristics needed by growers in commercial cultivars. A subset from the 2012 performance trials will be retested in 2013, to further determine their release potential.

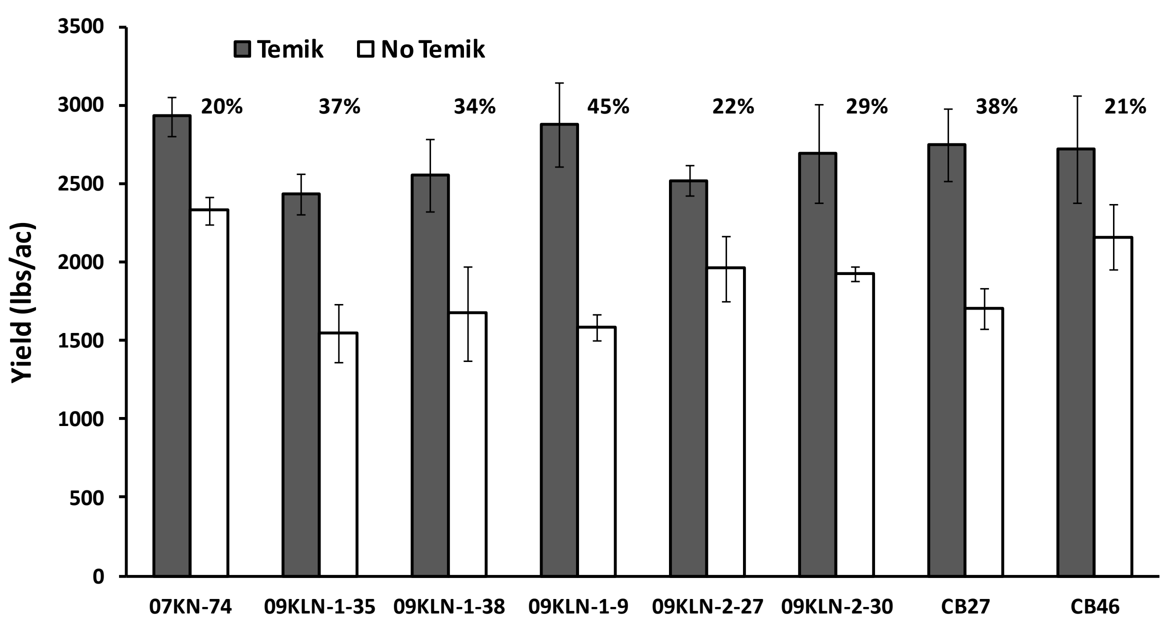

Figure 1. Yield performance of CB46, CB27 and six lygus resistant advanced breeding lines grown at Kearney in 2012 under Lygus protected (dark bars) and unprotected (white bars) conditions. Error bars are standard errors of the means of four replications. The percentages are

yield differences between protected and unprotected conditions divided by yield under the protected condition.

Table 4 Yield performance of CB46, CB27 and four lygus resistant lines grown under Lygus unprotected conditions at UC Riverside in 2012.

Line	Number of replications	Mean yield (lbs/ac)	Fisher's protected LSD test (*P* < 0.05)	Coefficient of Variation (%)
09KLN-1-9	4	1586	a	12.4
07KN-74	4	1581	a	10.7
CB46	4	1566	a	3.5
09KLN-2-30	4	1544	a	10.3
CB27	4	1494	a	22.4
09KLN-2-27	4	1436	ab	21.0
09KLN-1-35	4	1151	bc	12.3
09KLN-1-38	4	1017	c	16.9

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.

<u>Short-Term Breeding Strategy</u>

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.

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 80 lines were re-evaluated at Pobé Mengao in 2012 main season. From previous trials in 2009 and 2010, on-farm test using the best three varieties, KVX442-3-25 with an average yield of 1125 kg/ha was superior to the two others. Farmers preferred that variety and it was officially released under the name 'Komcalle' together with two others varieties in July 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 with 4-fold replication 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 Pakau. The trials were used for yield and agronomic characterization of each line, and harvest data were collected. Another 20 lines with medium maturity were selected from the first trial based on 2008 performance and included in four replicated yield trials in farmer fields in 2009 and 2010 in the Mekhe and Louga areas. 20 lines were also selected based on grain size (100 grain-weight > 25g) from the second 2008 trial and tested under the same conditions. In 2011, 20 on-farm trials were conducted in the Louga and Mekhe areas with 10 lines selected from the previous years. In 2012 the 5 best lines selected from tests conducted from 2008-2011 were introduced in large plots for the last on-farm trials (Table 5).

Table 5. Results of the 5 best lines of Trial 2 in 2011 at Bambey, Senegal.

Lines	1st Flower	50 % Flowering	95%Maturity	100 Grain-weight	Rdt kg/ha
2065 N	33.50	37.00	63.75	20.70	1686.
MOURIDE	34.75	38.00	64.75	16.65	1146.
ISNI -2007-3217	32.25	35.50	63.50	28.60	1566.
ISNI -2007-3178	33.25	36.00	63.50	27.35	1564.
Mélakh	33.25	36.75	63.25	20.65	1793.
Yacine	37.25	40.00	64.25	22.10	1294.
ISNI -2007-3205	34.25	38.25	65.00	29.80	1714.
ISNI -2007-3201	34.00	36.50	64.50	29.55	1555.
ISNI -2007-3211	33.50	36.25	64.25	27.25	1357.
Mean	33,618	36,563	64,201	26,012	1349,94
LSD 0.05	1,456	1,728	1,567	1,6	341,557

Crosses for developing new breeding lines

In Burkina Faso, progenies of 25 new crosses made by Dr. Drabo were advanced to the F5 stage during 2010. The F6 bulk of these crosses were harvested in 2011 for planting in 2012 at Pobé Mengao. Single plant selection was made 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.

In Senegal, for introgressing Striga resistance, Yacine was crossed with line IT90K-76. 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 Pakau, 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 and TN88-63 x 58-57 crosses, which are part of the 'High x High' elite line long-term breeding strategy were also made. These new materials were advanced in 2012 to the F6 stage. .

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 were shared with our African partners at the end of 2011 and intercrossed in an attempt to pyramid drought tolerance factors.

In Burkina Faso, 27 families of the crosses using the set of parents IT84S-2246, IT93K-503-1 and Mouride were evaluated in a replicated trial at Pobé during the main 2012 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 and families 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 6). 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 were grown 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 for 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 6. 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		Heat tolerance
IT89KD-288	IITA	1		Yes	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	Yes		*multiple resistance traits - see list at bottom
IT00K-1263	IITA	2	Yes	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 in 2012 at Saria and Kamboinse 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 KASP genotyping system run by KBiosciences (LGC Genomics). Leaf samples from the NARS and California trials have been sent to KBiosciences 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 KBiosciences SNP platform was conducted in 2010 – 2012 to 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 used as a source of further selection based on yield and grain quality. A small-plot 4-fold replicated trial at Kearney with entries that included 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 was harvested in November 2011. Based on yield differences observed among selections, seed of the six most promising lines was used for larger-scale 2012 trials at both Kearney and Riverside planted in late May and early July. These trials are nearing harvest at this time, and data will be used to select the two best lines for large-scale testing in 2013.

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 limits Certified Seed production. Insufficient resources limit growing, harvesting and storing Breeder Seed increases, in turn limiting Foundation Seed and Certified Seed for farmers. This is due to insufficient resources 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. Working with the national extension services in Senegal (ANCAR), Burkina Faso (DVA), and Angola (SENSE) to reach the farmers' organizations in different communities is being 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. 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 and KVx735-33-2) and 7 existing varieties (Gorom Local, KVx61-1, KVx396-4-4, KVx396-4-5-2D, KVx414-22-2, KVx745-11P, Telma). Up to 40 tons of Certified Seed will be produced in seven provinces by trained farmers in 2012. Breeder Seed will be produced in the off-season for three varieties (IT98K-205-8, KVx 442-3-25, KVx775-33-2) on 5000 m^2 per variety. Foundation Seed production will be made to ensure an adequate capacity on each of the four INERA stations (Saria, Pobe,Dori and Kamboinse). This activity will generate about 6 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 Saria (Bulkiemde province) and Pobe (Soum province). A target of 90 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, Dr. Cisse will produce 2 ha of Melakh,2 ha of Yacine, and 2 ha of Pakau 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 5 locations (Thilmakha region, Merina district, Mekhe, Louga 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 Africare, CRS and ADRA-Angolana, to determine opportunities for advancing the cowpea seed system. The Legume program of IIA with the support of CRSP can coordinate the breeder seed by having a strong partnership with National Extension Service (IDA) and National Seed Service to train future seed producers. 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 Saria more than 40 tons of Foundation Seed was produced in 2012 using part of the Breeder Seed produced in 2011. More than 3 tons of Breeder Seed were produced in 2011. A part of these seeds have been used to produce Foundation Seed during the 2012 main season. Foundation Seed will be produced during the off season from February to March 2013. We anticipate a production of at least 40 tons of Foundation Seed in 2012 main season and 10 tons during the off season. Part of the money obtained by selling the Foundation Seed in 2011 was used for supporting 2012 seed production activities in attempts to establish a self-sustaining plant seed production and delivery system.

In Senegal. Initially, 3 ha each of Melakh and Yacine and 1 ha of Pakau Foundation Seed was produced at the ISRA Bambey station, andat least 100 kg of each variety was 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 planted about 50 ha of Mélakh and Yacine Foundation and Certified seeds in 2011 and 61 ha in 2012. 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. In 2012 they cultivated the same acreage with seeds obtained the year before. Certified Seed production was also conducted in collaboration with a farmers' union (UGPM) in Mekhe with 10 ha of Melakh and Yacine each in 2010s. These acreages were raised to 25 ha in 2011. In 2012, 3 ha of Pakau were added to their operation. 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, of whom 55% are women. The same acreage was conducted in 2011 and 2012. With the closing of the EWA activities in the Louga area, we supplied 8 ha of Certified Seed production to the farmers' cooperative RESOPP and 7 ha in 2012 including 2 ha of Pakau. 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, 2011 and 2012 seasons for seed production consisted of field selection, removal of off-types and diseased plants, and both harvest and post-harvest handling. Triple bags obtained from the PICS project are being provided to farmers for storage of the 2012 seed.

<u>Objective 3</u>: Technology Dissemination (Seed of Improved Cowpea Varieties in West Africa)

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<u>Approaches and Methods</u>
INERA, Burkina Faso. In Burkina Faso during FY 12, Breeder Seed of eleven improved cowpea varieties will be produced at Saria and Pobe. Theory and practical training will be conducted at two locations. This activity will train farmers, of which at least 1/3 will be women. The trained farmers also will be guided in producing Certified Seed of the INERA improved cowpea varieties. Two visits by the INERA national cowpea research team will be made to each farmer's field to provide updates on practical training and advice. Breeder and Foundation Seed of the seven varieties have also been produced during the 2012 growing season (July-October), with estimated yield of 1000 kg to 2500 kg of Breeder Seed of each variety and a total of 40 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, Pakau to supply new Certified Seed to growers. The plan was to produce 2 T of Foundation Seeds during the off-season (March – May 2012) under irrigation to complement the Foundation Seed obtained during the rainy season of 2011. During the 2012 rainy season 6 ha of Melakh, Pakau and Yacine foundation seeds 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 dry 2011 growing season 1-2 T of Foundation Seed production was achieved at the ISRA Bambey Research Station. In 2012, 5-6 T of Foundation Seed is under production. Support was provided to the Millennium Project, the NGO FONGS, growers at 3 new villages (Maka Diop, Guidila, Mewane) and RESOPP organization, set up by EWA to expand their cowpea seed production. One private seed company (ARSM) and an individual (Moustapha Diop) have been engaged for production of Certified Seed on 20 ha in 2012.

Results, Achievements and Outputs of Research:

INERA, Burkina Faso: In Burkina Faso during FY 12, Breeder Seed of eleven improved cowpea varieties (IT98K-205-8, IT99K-503-2-1, Melakh, KVX 771-11P, KVX421-2J, KVX 61-

1, KVX442-3-25, KVX775-33-2, KVX 771-10, Telma and Gorom Local) was produced on 8 ha. This yielded about 250 to 900 kg of Breeder Seed of each variety. Theory and practical training was conducted at two locations (Saria and Pobé-Mengao), during the period April – June, 2012. This activity trained 90 farmers, of which 25 were women. The 90 trained farmers were guided in producing Certified Seed of the INERA improved cowpea varieties. This activity is estimated to have generated 35 T of Certified Seed produced on a total area of 50 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 of seven varieties was also produced during the 2012 growing season (July-October) by individual seed producer farmers, Farmers Organizations, Agro dealers and NGO's. An estimated 40 T of Foundation Seed will be produced when all harvest is counted.

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, Pakau) to supply new Certified Seed to growers. 2 T each of Melakh and Yacine and 1500 kg of Pakau Foundation Seeds were produced during the off-season (March – May 2012) under irrigation to complement the Foundation Seed obtained during the rainy season of 2011. 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 and 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 the 2012 harvest. Seed is being 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 50 ha was planted. During the 2012 growing season 5-6 T of Foundation Seed was produced at the ISRA Bambey Research Station. Support was provided to the NGO FONGS, RESOPP and Millennium objectives project to expand cowpea seed production.

As part of the cowpea seed systems expansion effort, a meeting of cowpea scientists and breeders was held in May 2012 in Niger (with Dr. Moutari, INRAN) 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 (large seeded) was conducted in Senegal, Burkina Faso and in Niger during the 2012 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. Results from Saria indicated that KVx30-309-6G and Melakh performed well. 120 kg of Breeders Seed of KVx30-309-6G were given to Dr Moutari, Dr Baoua and one seed producer named Marico in Niger to produce Foundation Seeds. Collaboration with Dr. Toure from Mali was difficult because of the political situation.

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, USA
David Kiala, Faculdade de FCA/Universidade José Eduardo dos Santos, Angola
Antonio David, Instituto de Investigação Agronómica, 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 African scientists is being undertaken with the goal of developing the next generation of cowpea breeders. Mr. Arsenio Daniel Ndeve from Mozambique started in the Plant Pathology Graduate Program at UC Riverside in the Winter Quarter 2012 (January 2012). Mr. Ndeve 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 Jonathan 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 (LGC Genomics) KASP SNP genotyping platform populated with 1057 informative markers derived from the Illumina SNP-genotyping platform we developed for cowpea. Starting in 2011, 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 in a two-day training workshop conducted in conjunction with the Pulse CRSP Global meeting held in February 2012 in Kigali, Ruanda. We also invited the Pulse CRSP common bean breeders and trained at the Kigali workshop. Training was also conducted at meetings in Addis-Ababa, Ethiopia in May 2012, linked with CGIAR 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 beyond FY12, in order to build by experience the necessary competence within the project team.

Degree Training

MS Student 1
First and Other Given Names: António
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

<u>PhD Student 3</u>
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

<u>PhD Student 4</u>
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

<u>MS Student 4</u>
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 February 2013
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

<u>Under Objective 1</u>. 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 in December 2011helped to better coordinate this effort and more trials are being conducted during 2012, with some completed with good yield data.

<u>Under Objective 4</u>. 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 started in January 2012.

Networking and Linkages with Stakeholders

We worked 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 worked closely with the California Dry Bean Advisory Board and its Blackeye Council on research priorities of the industry. We are worked 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 Dr. Jonathan Lynch at the Penn State 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 Koadba" at Donsin near Ouagadougou; "Six S" at Pobe Mengao; Producteurs de Semences de Diouroum; Producteurs de Semences at Pobe Mengao; and Producteurs Semenciers Song Woaga at Saria. In addition, collaboration was continued with a Seed Producer Association named Venegre and two seed entrepreneurs (Famille Kabre and Agrisem). Linkages also have been made with two Agro Dealers.

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), an individual (Moustapha Diop) 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, multistakeholder partnerships are increasingly becoming a common feature of agricultural research for development. We have been working with the Faculty of Agrarian Sciences, Institute for Agrarian Development, AFRICARE, an American NGO, and Small Farmers Association/Community Based Organizations (CBOs).

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.

Leveraged Funds

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

California Dry Bean Advisory Board and its Blackeye Varietal Council (funds currently and typically set at $20,000 per year) funded for cowpea breeding in California. This is a continuing, long-term research arrangement to support UC Riverside cowpea breeding.

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), focused on development of phenotyping protocols for cowpea drought tolerance, with work in the West Africa partner countries, California and Texas. This provided direct leveraging opportunities for the drought tolerance efforts.

A Southwest Consortium on Plant Genetics and Water Resources project (via USDA-CSREES) was funded for $30,000 per year for two years for 2010 and 2011 and with no-cost extension until 2013 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 INERA received: - $59,000 from CGIAR GCP/TL1 project (Improving tropical legume productivity for marginal environments in sub-Saharan Africa) and $ 11,500 from CGIAR GCP/TLII project (Improving the livelihoods of smallholder farmers in drought-prone areas of sub-Saharan Africa and South Asia through enhanced grain legume production and productivity). A new cowpea seed systems project was started in 2010 with funding in 2012 of $42,000 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 was 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)

Chicapa-Dovala, A.; Roberts, P.; Ehlers, J.; Buta´, T; Castame-Francisco, A.; Baptista, L. J.; Ndala, A. P. And Jorge Muondo. 2012. Cowpea (*Vigna unguiculata* (L.) Walp. in Angola. Instituto de Investigacão Agronómica, Angola and University of California Riverside, USA.

David, A.N., Beaver J.S., Porch T. G., Goenaga. R., Ehlers. J. and Roberts, P.A. 2010. A comparison of agronomic characteristics and seed elemental composition of cowpea germplasm from Angola and other international sources. University of Puerto Rico.

Belko, N., M. Zaman-Allah, N.N. Diop, N. Cisse, G. Zombre, J.D. Ehlers, V. Vadez. 2012. Restriction of transpiration rate under high vapour pressure deficit and non-limiting water conditions is important for terminal drought tolerance in cowpea. Plant Biology. German Botanical Society and The Royal Botanical Society of the Netherlands.

Belko, N., M. Zaman-AllahB, N. Cisse, N. N. Diop, G. Zombre, J. D. Ehlers and V. Vadez. 2012. Lower soil moisture threshold for transpiration decline under water deficit correlates with lower canopy conductance and higher transpiration efficiency in drought-tolerant cowpea. *Functional Plant Biology*. www.publish.csiro.au/journals/fpb. published online 28 March 2012.

Badiane, F.A., B.S. Gowda, N. Cissé, D. Diouf, O. Sadio and M.P. Timko. 2012. Genetic relationship of cowpea (*Vigna unguiculata*) varieties from Senegal based on SSR markers. *Genetics and Molecular Research* 11 (1): 292-304.

Muchero, W., J.D. Ehlers, T.J. Close and P.A. Roberts. 2011. Genic SNP markers and legume synteny reveal candidate genes underlying QTL for *Macrophomina phaseolina* resistance and maturity in cowpea [*Vigna unguiculata (L) Walp*.]. *BMC Genomics* 12:8.

Xu, P., X. Wu, B. Wang, Y. Liu, J.D. Ehlers, T.J. Close, P.A. Roberts, N.N. Diop, D. Quin,T. Hu, Z. Lu, and G. Li. 2011. A SNP and SSR based genetic map of Asparagus Bean (*Vigna. unguiculata* ssp *sesquipedialis*) and comparison with the broader species. PLoS One 6: e15952.

Muchero, W., P.A. Roberts, Ndeye-Ndack Diop, I. Drabo, N. Cisse, T.J. Close, S. Muranaka, O. Boukar and J.D. Ehlers. 2011. Genetic architecture of delayed senescence, grain and biomass yield under drought stress in cowpea. PLoS ONE (resubmitted).

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.

Literature Cited

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

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

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

Muchero, W., J.D. Ehlers, and P.A. Roberts. 2009c. QTL analysis for resistance to foliar damage caused by *Thrips tabaci* and *Frankliniella schultzei* (Thysanoptera: Thripidae) feeding in cowpea (*Vigna unguiculata* L. Walp.). *Molecular Breeding* 25:47-56.

Muchero, W., N.N. Diop, P.R. Bhat, R.D. Fenton, S. Wanamaker, M. Pottorff, S. Hearne, N. Cisse, C. Fatokun, J.D. Ehlers, P.A. Roberts, and T.J. Close. 2009d. A consensus genetic map of cowpea [*Vigna unguiculata* (L) Walp.] and synteny based on EST-derived SNPs. *Proceedings of the National Academy of Sciences*, USA 106:18159-18164.

Sawadogo, A., B. Thio, S. Kiemde, I. Drabo, C. Dabire, J. Ouedraogo, T. R. Mullens, J.D. Ehlers, and P.A. Roberts. 2009. Distribution and prevalence of parasitic nematodes of cowpea (*Vigna unguiculata*) in Burkina Faso. *Journal of Nematology* 41:120-127.

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

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

<u>Capacity Building Supplement</u>. 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 and applied to achieving project goals.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2011 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

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	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1 - Breeding																		
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**			**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**	x		**0**			**0**		
Objective 2 - Improve Seed Systems																		
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**			**0**			**0**			**0**			**0**			**0**		
Assess seed system - Angola	**x**	x		**0**			**0**			**x**	x		**0**			**0**		
	0			**0**			**0**			**0**			**0**			**0**		
0	**0**			**0**			**0**			**0**			**0**			**0**		
0	**0**			**0**			**0**			**0**			**0**			**0**		
Objective 3 - Seed Dissemination																		
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 - Training																		
MS Training Angola/UPR	**0**			**0**			**0**			**0**			**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. A. Roberts			N. Cisse			I. Drabo			A. Chicapa								
Name of the U.S. Lead PI submitting this Report to the MO																		

######

Signature **Date**

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

Dry Grain Pulses CRSP		
PERFORMANCE INDICATORS/TARGETS for FY 12		
(October 1, 2011 -- September 30, 2012)		
	PII-UCR-1	
	2012 Target	2012 Actual
Output Indicators	(Oct 1 2011-Sept 30, 2012)	
Degree Training: Number of individuals who have received degree training		
Number of women	**1**	1
Number of men	**1**	1
Short-term Training: Number of individuals who have received short-term training		
Number of women	**80**	85
Number of men	**140**	142
Technologies and Policies		
Number of technologies and management practices under research	**13**	15
Number of technologies and management practices under field testing	**10**	10
Number of technologies and management practices made available for transfer	**5**	5
Number of policy studies undertaken		

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	**16000**	18000
Number of rural households benefiting directly from CRSP interventions - Male Headed households	**12000**	13000
Number of agriculture-related firms benefitting from CRSP supported interventions	**19**	19
Number of producer organizations receiving technical assistance	**65**	65
Number of trade and business associations receiving technical assistance	**1**	1
Number of community-based organizations receiving technical assistance	**10**	11
Number of women organizations receiving CRSP technical assistance	**18**	18
Number of public-private partnerships formed as a result of CRSP assistance	**5**	5
Number of HC partner organizations/institutions benefiting	**27**	26
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	**37200**	40000

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

Principal Investigators
Barry Robert Pittendrigh, University of Illinois at Urbana–Champaign, USA
Malick Ba, INERA, Burkina Faso (co-PI)
J. Bello-Bravo, University of Illinois at Urbana–Champaign, USA (co-PI)

Collaborating Scientists
Clémentine Dabiré, INERA, Burkina Faso
Ibrahim Baoua, INRAN, Niger
Mohammad Ishiyaku, IAR, Nigeria
Mamadou N'diaye, IER, Cinzana Research Station, Mali (Activities were suspended at the request of USAID and CRSP-MO due to political problems in Mali)
Manuele Tamò, IITA, Benin

Abstract of Research Achievements and Impacts

Our project is focused on **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 nonoption 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 of these pest control approaches. We have made significant progress in FY12 to build a capacity to address all of 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 we have created 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; this second season of results have been highly positive.*** Most notably we have a neem-virus combined spray that is as effective as or better than traditional pesticides in increasing cowpea yields in the field.

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. This past year, the program has exploded to include over two dozen partner groups around the planet. The animation technologies and deployment strategies have been used for cowpea related activities in West Africa across multiple groups. Additionally, the SAWBO program and infrastructure is now being to address many other education-related issues, including (beyond this CRSP project and CRSP funding) how to educate people in the United States on how to properly use their medications in order to increase the effectiveness of outpatient care and other major world health and agricultural problems.

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. Work by our group (Onstad *et al*., 2012) has demonstrated that any *Bt* cowpea deployed in the field will need a two-gene (for two pyramided *Bt*'s) construct; this revelation may push off the safe release of Bt cowpea by upwards of one more decade. 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, biocontrol 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 biocontrol 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 biocontrol 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 biocontrol 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 biocontrol 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 biocontrol 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 biocontrol agents should be deployed at a regional level for the suppression of *M. vitrata* populations).

Collaborators
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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

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

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

Results, Achievements and Outputs of Research

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

<u>Implications for pest control strategy</u>
Thus, for the release of biocontrol agents that will establish in the *M. vitrata*, and suppress the populations in large-scale over the long-term, biocontrol 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 biocontrol releases and viral sprays, should be concentrated in the South and midpart of the country.

<u>Details of Efforts over FY12</u>
We have both (i) a large collection of *M. vitrata* from throughout Burkina Faso and Niger and (ii) have been and we completed studies 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*., 2012; Huesing *et al*., 2011).

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; Agunbiade et al., In press). Our initial experiments, with light trapping and scouting data, have resulted in several publications (Ba et al. 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 baseline 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 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 biocontrol 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 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 published this past year (Onstad et al., 2012). Based on this work, Drs. Pittendrigh and Tamò were also co-authors on a expert panel paper that has been published in the journal "GM Crops" (Huesing et al., 2011).
7. All of the molecular tools we have developed, along with their applications for insect control, were applied, in FY2011 and FY2012, to the other pest insects that attack cowpea. This past year we applied these tools to the sequencing and use of polymorphic markers of two of the biocontrol agents (*Apanteles taragamae* and *Ceranisus femoratus*) that have also been released in field trials. This same molecular marker information will ultimately be used demonstrate (i) that successful biocontrol agents came from our release populations and will (ii) ultimately determine if there are specific molecular markers associated with successful biocontrol agents that have been released (in order to help identify populations of biocontrol

agents that may be most successful in a biocontrol 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 FY12 in order to perform the same type of studies as we have done with *M. vitrata*. Thus, we now have used these molecular marker approaches for all of the other 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)

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

Objective 2: Insect Pests on Cultivated Cowpeas

This activity has provided the basis for a better understanding of the problems of pest insects of cowpeas within the host countries. It has also allowed 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 and *Sericothrips occipitalis* Hood. These are the pests we have studied in this objective.

Collaborators

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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

Approaches and Methods

The data sharing from our preliminary work and the experimental design for the field studies on the insect pests of cultivated cowpeas was completed in the 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. Over FY11 and FY12 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 were checked with our statistician (Dr. William Muir of Purdue University) to ensure proper experimental design and analysis of the datasets.

Results, Achievements and Outputs of Research

Summary of our findings

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 were used for SNP analysis is FY12.
2. Major pest problems by region have been defined and we now have three seasons of baseline 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 and FY12. 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% in FY11).*** (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 biocontrol 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 FY12

We have performed the above experiments over the past five field seasons (summer of 2008, 2009, 2010, 2011 and 2012). 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 that we expect to publish in 2013.

We have also performed field experiments where (1) we have tested pest tolerant varieties 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 ecoagricultural 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 summers of 2010, 2011 and 2012 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.

Objective 1: 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.

Collaborators

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 were assessed over FY12. The experiments were 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

<u>Summary of our findings</u>

1. Identification of important wild alternative hosts.
2. Collection of insects necessary for genomics work in FY12
3. Insect populations assessed with genomic tools

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

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 biocontrol agent releases locally should support local pest populations over the long-term.

<u>Details of Efforts over FY12</u>

In keeping with these objectives, we have performed a series of scouting trips in Niger, Benin, and Burkina Faso prior. 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 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). At least 14 plants species belonging to the Fabaceae family are alternate host for *M. vitrata* in Western Burkina Faso: *Vigna gracilis, Vigna nigritia, Crotalaria ochroleuca, Crotalaria naragutensis, Rynchosia pycnostachya, Rynchosia hirta, Dolicos lablab, Mucuna pogei, Daniella oliveri, Sesbania pachycarpa, Sesbania candida, Tephrosia bracteolata, Tephrosia nana, Cajanus cajan* (Traore F., PhD thesis findings).

Most of these host plants maintain the population of *M. vitrata* during the cowpea off-season. 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.

In FY11 and FY12 we continued to extend these combined scouting and molecular approaches to the other pests of cowpeas in order to best determine where the biocontrol 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 biocontrol agents in our Pulse CRSP Technology Dissemination Project.

<u>Publications</u>

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.

Manuscript in Progress
Traore F., Dabire, C Ba, N.M., Sanon A, and B.R. Pittendrigh. Seasonal abundance of the cowpea pod borer *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) on cultivated cowpea and wild alternate host in Western Burkina Faso. In preparation for the International Journal of Tropical Insect Science.

<u>Objective 6:</u> 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 interinstitutional 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 biocontrol 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 biocontrol 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;
    a. 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, use of biocontrol agents to suppress pest populations, and proper preparation and use of Neem sprays. Three of these 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 ten thousand downloads of these videos). The biocontrol video, developed with CRSP funds, has been completed is is soon to be released. 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. Over FY12 SAWBO has developed links with over 30 partner groups around the planet who are helping to create new videos, do voice overlays in local languages, and perform local deployment of these videos.

6. Between known field-deployment (where we have feedback from organizations), views & downloads from our online systems we estimate impact of well over 100,000 people.
7. In FY12 we have performed studies to address the potential for spreading of these animations through cell phone networks in Burkina Faso and Niger. The results suggest that the videos do spread through Bluetooth® from cell phone to cell phone.
8. The SAWBO program has expanded (with outside funding) to having produced over 20 other videos on malaria, dengue, prevention of postharvest losses, tuberculosis, West Nile virus prevention, removal of cyanide from cassava flour, proper use of medical devices for people in the U.S. medical system and a host of other important topics.

Collaborators

- Peace Corps
- Scientific Animations Without Borders (UIUC organization)
- ADM Institute for the Prevention of Postharvest Loss
- Indian Society for Indian Society of Agribusiness Professionals
- IIAM (Mozambique)
- An incomplete list of SAWBO partner groups can be found at http://sawbo-illinois.org/outreach.htm
- 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 FY12, 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, and Burkina Faso 2012 (activities in Mali were suspended). The FFS represent multimonth 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. 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. Animations on cell phones were also distributed into villages in order to explore the potential strategies that were tested in multiple projects in FY12 in controlled experiments.

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 and combined neem-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) intercropping approaches, (6) hermetic storage of cowpeas, (7) soil preparation and planting density testing, (8) how to minimize the use of traditional pesticide sprays in areas where farmers typically spray their cowpea crops, 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 baseline 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 have and will release biological control agents. 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 published a paper 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 (Bello-Bravo et al., 2011).

We are also collaborating with Dr. Madhu Viswanathan of UIUC on our extension strategies (including assessment), especially as they relate to issues of low literate learners. Dr. Madhu Viswanathan is (1) a Professor in the Department of Bus. Admin. (Marketing) at UIUC, (2) the director of the Coordinated Sciences Laboratory, and Women and Gender in Global Perspectives Program at University of Illinois, (3) an author on numerous books and publications on extension/education strategies for oral/low literate learners in developing nations, and (4) known for his efforts of developing novel educational and assessment tools for low literate learners in developing nations. He was recently awarded the “2010 Bharat Gaurav Award” by the INDIA INTERNATIONAL FRIENDSHIP SOCIETY (please note other recipients of the award include the late Mother Teresa and a former Vice President of India).

<u>Technician Training</u>

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

Publications Specific to this Activity

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

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. 2(4): 49–62.

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 over FY11 and FY12.

3. A detailed field experiment in Benin confirmed the good results obtained last year with the viral sprays. In the first cropping season (FY10), 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%). These were repeated in FY11 and FY12, including work in Burkina Faso and Niger.

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

Approaches and Methods

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

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

Results for Year 3 (FY12)

The germinating cowpea sprout method validated in FY11 is currently in use for rearing *M. vitrata* at IITA in Benin and Nigeria, and in our collaborators lab in Burkina Faso and Niger. This cheap and efficient rearing method is also routinely used to rear the *M. vitrata* parasitoids *Apanteles taragamae* and *Nemorilla maculosa*. With regard to *A. taragamae*, detailed biological studies have been carried out to compare the nutritional effects of the cowpea sprout diet with those of the standard artificial diet. The suitability of germinating seeds from three cowpea varieties, Kpodji-guèguè, Tawa and TVX3236, as substrates was tested for rearing *A. taragamae* under laboratory conditions. The seeds that were soaked for 48 hours were the most suitable for larval rearing with up to 87% larval survival. Depending on cowpea variety, between 69 and 86% and 70 and 85% of the larvae died when reared on seeds that were soaked for 0 and 72 hours, respectively. The shortest development time of *M. vitrata* was obtained on germinating grains of cowpea varieties, as compared to the artificial diet. Likewise, higher lifetime fecundity and longevity were recorded on cowpea sprouts of the three varieties. Female moths lived longer than males regardless of feeding substrates (Table 1).

Table 1. Development time (mean ± SE), longevity (mean ± SE), lifetime fecundity (mean ± SE), egg hatching (mean ± SE), larval and adult survival (mean ± SE) and sex ratio (mean ± SE) of *Maruca vitrata* larvae reared on grains of three cowpea varieties soaked for 48 hours and compared to standard artificial diet.

Parameters	rearing substrate			
	Kpodji-guègué	Tawa	TVX3236	Artificial diet
Development time (days)[b]				
Larval-pupa	11.81 ± 0.2a	11.57 ± 0.25a	12.06 ± 0.1a	12.76 ± 0.3b
Pupa-adult	6.21 ± 0.2a	7.92 ± 0.3b	5.46 ± 0.2c	9.90 ± 0.3d
Egg-adult	21.08 ± 0.1b	22.50 ± 0.2b	20.51 ± 0.2c	24.88 ± 0.3a
Longevity (days)				
Adults	12.70 ± 0.5a	12.00 ± 0.5a	12.27 ± 0.5a	9.70 ± 0.7b
Pre-oviposition period	1.23 ± 0.1a	0.90 ± 0.1b	1.13 ± 0.1a	0.8± 0.1b
lifetime fecundity (egg/Female)	609.70 ± 45a	595.70 ± 54a	500.27 ± 49a	308.90 ± 32b
Hatching rate (%)	88.40 ± 3.3a	85.10 ± 5.2a	86.13 ± 5.6a	85.60 ± 5.8a
Larval survival rate (%)	87±1.7a	83.00 ± 8.8a	75.00 ± 3.8b	60.00 ± 8.3c
Adult survival rate (%)	52. 60 ± 8a	42.84 ± 7.7a	42.80 ± 8.3a	33.58 ± 7.5a
Sex ratio (F/(M=F)	42.65 ± 7.3a	35. 63 ± 3.2a	36.05 ± 3.0a	35.05 ± 3.03a
Pupal weight	56.30 ± 0.7bc	57.60 ± 0.5c	54.02 ± 0.7a	54.70 ± 0.6ab

The crambid sex ratio was not influenced by the feeding substrates. The highest parasitism rate of *M. vitrata* larvae by *A. taragamae* was observed on the local variety Tawa. Compared to artificial diet, the development cycle of the parasitoid was shorter on Tawa sprouts which also induced the highest lifetime fecundity (Table 2).

Table 2. Development time (mean ± SE), longevity (mean ± SE), lifetime fecundity (mean ± SE), daily fecundity (mean ± SE) of *Apanteles taragamae* reared on two day-old *Maruca vitrata* larvae fed artificial and Tawa variety based natural diets

Parameters	Food regime	
	Artificial died	Tawa
Development time (days)		
Egg-pupa	8.54 ± 0.10a	7.97 ± 0.70a
Pupa-adult	6.27 ± 0.10a	5.81 ± 0.10a
Egg-adult (cycle)	15. 11 ± 0.15b	13.11 ± 0.14a
Development cycle (days)		
Male	14.66 ± 0.21Bb	12.31 ± 0.12Ba
Female	15.37 ± 0.16Ab	13.91 ± 0.21Aa
Longevity (days)		
Adult	11.03 ± 0.38b	16.03 ± 0.63a
Male	12.67 ± 0.53Aa	13.47 ± 1.70Aa
Female	9.40 ± 0.36Bb	19.03 ± 1.24Ba
Lifetime fecundity (pupa/female)	46.13 ± 1.60b	57.43 ± 2.60a
Daily fecundity (pupa/female/day)	5.89 ± 0,30a	6.39 ± 0.22a

Female wasps took longer to develop compared to males regardless of feeding substrates. Significant differences were observed in the wasp longevity between Tawa and artificial diet, and females lived longer than males on all feeding substrates. The parasitoid sex ratio varied significantly between feeding substrates with a higher proportion of female wasps on the improved varieties TVX2336 and local variety Kpodji-guègué. Rearing *M. vitrata* larvae on germinating cowpea grains is 4.38 times cheaper than on artificial diet, just calculating the cost of the ingredients. If the cost of the equipment and energy is also factored, the ratio increases to 22.3 times. These results have been summarized in a peer reviewed journal article.

Cowpea sprouts from the variety Tawa are currently been used to produce the *Mavi*MNPV virus. Two technicians of the self-help communal enterprise Bio-Phyto in Glazoue, Central Benin, are currently doing their industrial attachment at IITA-Benin to acquire the necessary knowledge and skills for being able to produce the virus in commercial quantity with their group. A local student is also carrying out his MSc thesis on the optimization of the methodology to make it more efficient. The work is still ongoing, but early results clearly indicated that, for virus production, the same soaking time of 48 h remains the best, while the infestation of the sprouts with neonate *M. vitrata* larvae is best delayed until appearance of the first green parts of the germinating seed. Infesting two layers of sprouting cowpea seeds with the larvae, and subsequently inoculating the virus at the 3rd instar, has demonstrated to give the highest yields in terms of viral OB. Also, by using advanced sprouting stages of the seeds makes it easier to separate the moribund larvae for harvesting the virus. This work should be completed by early 2013.

Following up on the successful field deployment of the combination of neem oil and MaviMNPV reported in FY11, more detailed studies have been carried out to assess the nature of these interactions. Lab studies have investigated the effect of the compounds, alone or in combination, on key insect pests of cowpea, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae), *Aphis craccivora* Koch (Homoptera: Aphididae) and *Megalurothrips sjostedti* Trybom

(Tysanoptera: Thripidae). Second-instar *A. craccivora* and *M. sjostedti* nymphs, and third-instar *M. vitrata* larvae reared in the laboratory, were treated with various concentrations of one of the control agents separately or in combination. The numbers of insects killed were recorded each day for five days (*A. craccivora* and *M. sjostedti* nymphs) or fourteen days (*M. vitrata*) and the larval and pupal development as well as adult emergence were assessed. Combination of *Mavi*MNPV resulted in a significantly higher larval mortality than treatment with either virus or botanical insecticide alone at the corresponding concentrations. Co-infected insects died sooner than those infected with only one control agent. Combinations between *Mavi*MNPV and botanical oils produced additive or synergistic effects. No evidence of antagonistic effects was noted. Larval as well as pupal development was significantly extended and the adult emergence was significantly reduced in the combined treatment of *Mavi*MNPV and botanical oils.

Also, in the meantime the neem oil has been reformulated as an emulsifiable mixture of neem and essential oil from lemon grass, which is planted by women groups and sold to the self-help enterprise together with the neem seeds, thus providing additional household income. This mixture is being sold commercially by the Bio-Phyto communal enterprise under the brand name "Top-Bio." Right now, we are assessing the viability of the MaviMNPV virus kept in the Top-Bio for several months, in order to determine if the two components can be premixed and sold in the same container. At the same time, Top-Bio has been dispatched with the virus to out collaborators in Burkina Faso, Niger and Nigeria for proper multilocational field testing. The trials are being harvested at the time we are writing this report, and the preliminary results should be available within weeks from now.

Figure 1. Picture (left): storage room containing 80t of neem seeds collected by a community of 800 women and sold to the communal enterprise Bio-Phyto. Picture (right): 4500 liters of pure neem oil awaiting transformation into the compound bio-pesticide Top-Bio.

There is clearly an enormous potential and synergy working with self-help communal enterprises such as Bio-Phyto. A second enterprise should be established soon in Parakou, and we have been invited to participate in their various strategy meetings.

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

Approaches and Methods

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

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

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

Dr. Manu Tamò will be primarily responsible for the collection and shipping of insect samples to UIUC. Dr. Pittendrigh’s laboratory will receive samples of the biological control agents from IITA, sequence populations of insects, and determine molecular markers useful in the monitoring of these pest populations. Thus, we have worked with and are working with *Apanteles taragamae* and *Ceranisus femoratus* for the molecular component of this project. Where time and resources permit the Pittendrigh laboratory will also perform these genomics studies on the other biological control agents.

Results for year 1 (FY12)

1. *Apanteles taragamae* samples from our rearing at IITA-Benin have been processed for RNA extraction in our labs and sent to UIUC for sequencing. This was accomplished and polymorphisms have been identified and used in molecular studies.
2. Samples of *C. femoratus* have been collected from Benin, Ghana and Cameroon, and have been processed for RNA extraction in our labs and sent to UIUC for sequencing. This was accomplished and polymorphisms have been identified and used in molecular studies.

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

Approaches and Methods

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

Against *M. vitrata*

1. The trichogrammatid, *Trichogrammatoidea eldanae*. This parasitoid is locally available in the moist savanna of West Africa. We used field cages to demonstrate its potential (year 1), while at the same time we developed simple and efficient rearing and delivery systems for field inoculations (FY12).
2. The tachinid, *Nemorilla maculosa*. We introduceed this parasitoid from AVRDC Taiwan and develop rearing and delivery systems (FY12).

Against *C. tomentosicollis*

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

Results for Year 2 (FY12)

A detailed study was undertaken in view of optimizing 1) the mass production of *Trichogrammatoidae eldanae* Viggiani (Hymenoptera: Trichogrammatidae) , a major egg parasitoid of *M. vitrata*, on eggs of the factitious host *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae) in the laboratory and 2) the release system of this parasitoid in the field.

Four feeding substrates were compared for *C. cephalonica* larval rearing: whole millet grains; a mixture of 50% whole millet grains and 50% millet flour); a mixture of 50% whole millet grains and 50% broken millet grains; and flour of milled cowpea grains. The results of the impact of feeding substrates on the performance of *T. eldanae* on its factitious host *C. cephalonica* is presented in Table 3. It appears that mixing whole millet grains with either broken grains or flour gives better results both in terms of egg parasitism, adult wasp emergence and also, and more important for trichogrammatid egg parasitoids, the proportion of female wasps.

Table 3: Biological parameters of the egg parasitoid *Trichogrammatoidea eldanae* as influenced by the rearing substrate fed to the factitious host *Corcyra cephalonica*

Feeding substrate	Whole millet grains	½ whole millet grains + ½ broken grains	½ whole millet grains + ½ millet flour	Cowpea flour
Developmental time (days)	10,13± 0,08a	9,609±0,09b	9,46± 0,07b	9,652±0,09b
Egg parasitism (%)	53,3± 15,72a	64,4±16,16a	64,4±9,59a	47,8±13,82a
Wasp emergence (%)	100,4± 25,98a	109,3±27,69a	135,1±12,45a	74,8±19,36a
Proportion of female wasps (%)	73,9c	81,9a	79,2b	82,6a

Releases of *T. eldanae* were performed using a novel rearing-cum-release device in the laboratory, in the greenhouse and on an experimental plot in the field.

Figure 2. Outside container showing the exit holes covered with mesh to allow exiting of the egg parasitoid *Trichogrammatoidea eldanae.*

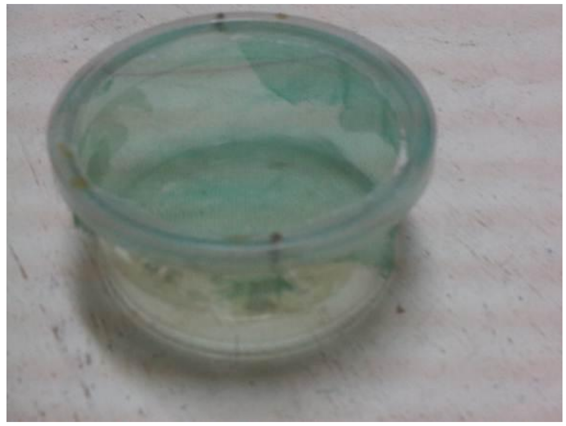

Figure 3. Inside rearing device with the facticious host *Corcyra cephalonica* and adults of *Trichogrammatoidea eldanae*

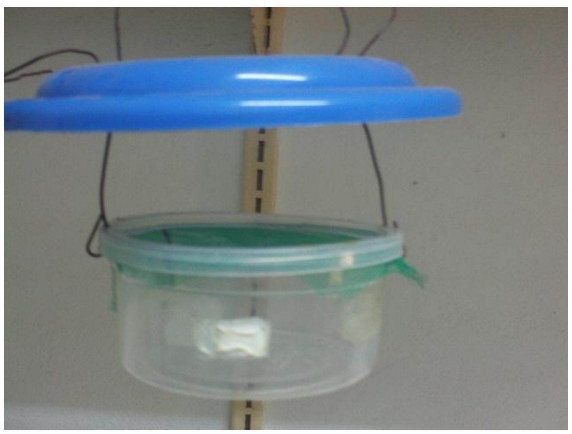

Figure 4. Rearing device mounted with the lid of the outside container

Figure 5. The assembled rearing-cum-release device

The results so far are showing that this device is suitable both for rearing *C. cephalonica* under field conditions, and at the same time for releasing *T. eldanae* adult parasitoids. Under field conditions, sentinel eggs of both *C. cephalonica* and *M.vitrata* were discovered by the parasitoids emerging from the device and parasitized up to a distance of 50 meters from the release site.

Following the robust establishment of a quarantine colony rearing of the parasitoid *Nemorilla maculosa*, a series of prerelease studies, focusing on host range were initiated in FY12.

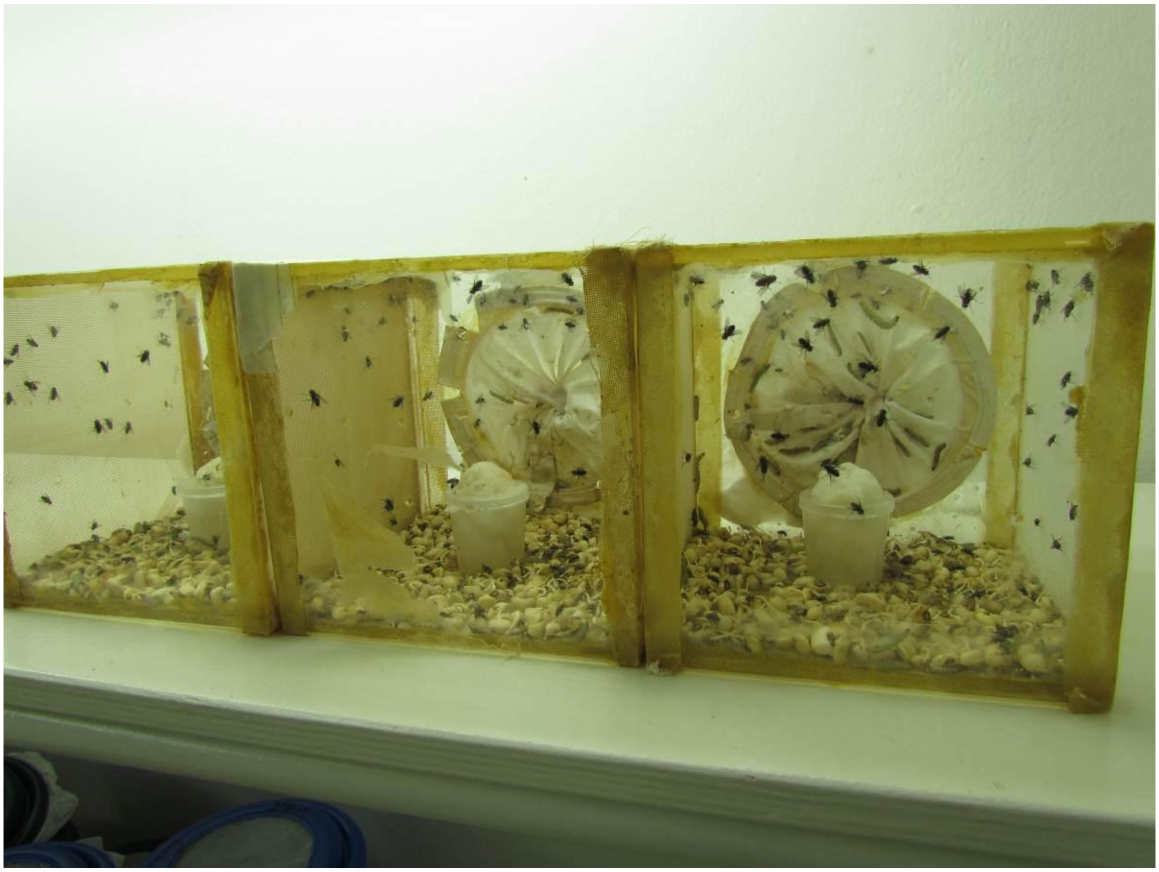

Figure 6. Colony rearing of the parasitoid *Nemorilla maculosa* on *M. vitrata* larvae feeding on sprouting cowpea seeds

Right now we are assessing host specificity for the following organisms: *Helicoverpa armigera, Spodoptera littoralis, Plutella xylostella, Sesamia calamistis* and *Corcyra cephalonica*. We have already noticed parasitism on *H. armigera* and *S. littoralis*, but will have to wait until the full experiments, which are part of an MSc study, are concluded, before making any quantitative inference.

Also, chemical ecology studies using a modified 4-arm olfactometer are being carried out to assess the preference of the parasitoid for odor sources of different origin. In a first step, we are studying the potential of *N. maculosa* to discriminate between different hosts being offered individually or simultaneously. Also, we will be assessing the host finding behavior of the parasitoid in the presence of kairomones derived from different host plants, such as cowpea, *Tephrosia platycarpa*, *Sesbania rostrata* and *S. cannabina*.

Additional result: with cofunding form CRP GL, an experiment has been initiated to assess multiple interactions between two soil beneficial microorganisms (Mycorrhiza and the endophyte *Beauveria bassiana*) alone and in combination, different watering regimes simulating drought stress at different phonological stages of the cowpea plant, the cowpea plant and the legume pod borer *M. vitrata*. This experiment is being carried out both in a rainout shelter and under open field conditions towards the end of the short rainy season.

Figure 7. Rainout shelter experiment assessing multiple interaction between soil beneficial micro-organisms, drought stress, the cowpea plant and the pest *M. vitrata.*

Objective 6: Other Institutional Capacity Building training activities in rearing and release of biological control agents

Approaches and Methods

The collaborating host country scientists will perform cross-training of each other and each other's staff in developments that lead to better rearing, release and monitoring of biological control agents. This will occur throughout the three years of the project and will occur continuously during the project as needed. Also, interactions with other groups such as Peace Corps, NGOs, and Farmer Field Forums also occurred.

Results for year 1 (FY12)

This cross-training activity has occurred in FY12 by exchanges of technicians between institutions and by intra- and interinstitutional one-day and multiple-day training sessions.

Training

Nondegree 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* and *N. maculosa* 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 currently two interns (one female; all citizens of Benin) on industrial attachment to acquire knowledge and skills for producing *Mavi*MNPV.

From 19th June to 5th July 2012: Training on the rearing of *Maruca vitrata* and Mavi NPV virus production at IITA Cotonou (Benin). Karimoune Laouali (a CRSP trainee held this workshop).

Research project: survey for farmer field school diagnostic and implementation in five villages of Maradi conducted by Fati Bacharou, student Agricultural college of Kollo, Niamey.

Farmers' perceptions on cellular video in five villages of Maradi conducted by Yasmina Hamidou Kobika, student Agricultural college of Kollo, Niamey

On 11–12th July 2012, Training of 48 students, including 16 females from 16 farmer's field schools on the process of FFS establishment at CERRA Maradi

On 24th–July 21st August Training of 240 students occurred on IPM of cowpeas. Topics taught included pest identification, use of neem extract, virus and chemical extract at 16 farmers field schools in the region of Maradi at village level.

Multiple non-CRSP groups have used our animations short-term training programs.

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 a Howard Hughes Medical Institute Pre-Doctoral grant and hence her support is completely through cost-sharing provided by the HHMI. 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 HHMI 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 (Traore Fousseini and Sanou Appoline) through the University of Ouagadougou. These students are directly funded by the CRSP and they completed their MSc respectively in 2008 and 2010. The two students are all now enrolled in PhD programs as part of the CRSP program. Traore Fousseini is currently working on the manuscript of his dissertation and he is due to complete his PhD in March 2013.

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
Estimated Program Completion Date: July 2013
Training Status during Fiscal Year 2012: ongoing
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— Completed) Currently a PhD student 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 and as an research assistant by Department of Entomology funds.
Host Country Institution to Benefit from Training: Laura is actively working on extension materials that will be used in 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 2012: ongoing
Type of CRSP Support (full, partial or indirect): none

First and Other Given Names: Alice
Last Name: Vossbrinck
Citizenship: USA
Gender: Female
Degree Program for training: MS at UIUC
Program Areas or Discipline: Entomology. She is currently contributing to the project both on the molecular studies and in the development of extension materials. She is fully funded by UIUC as a teaching assistant.
Host Country Institution to Benefit from Training: Alice is actively working on extension materials that will be used in Niger, Burkina Faso, and Nigeria.
Training Location: USA
Supervising CRSP PI: Pittendrigh

Start Date of Degree Program: 2010
Program Completion Date: July 2013
Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): none

First and Other Given Names: Fousseni
Last Name: Traore
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
Start Date of Degree Program: 2009
Program Completion Date: March 2013
Training Status during Fiscal Year 2012: In progress
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Apolline
Last Name: Sanou
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
Start Date of Degree Program: 2011
Program Completion Date: July 2014
Training Status during Fiscal Year 2012: In progress
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 2013

Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Jeanine
Last Name: Biaou
Citizenship: Beninese
Gender: Female
Degree: MSc
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 2012
Program Completion Date: March 2013
Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Kamarou Din
Last Name: Adebiyi
Citizenship: Benin
Gender: Male
Degree: MSc
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 2012
Program Completion Date: July 2013
Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Karimou
Last Name: Zanana
Citizenship: Benin
Gender: Male
Degree: MSc
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 2012
Program Completion Date: July 2013
Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Edinam
Last Name: Afatchao
Citizenship: Togo
Gender: Female
Degree: BSc
Discipline: Entomology/Biology
Host Country Institution to Benefit from Training: Togo, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamò
Start Date of Degree Program: May 2012
Program Completion Date: Dec 2012
Training Status during Fiscal Year 2012: ongoing
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Medetissi
Last Name: Adom
Citizenship: Togo
Gender: Male
Degree: BSc
Discipline: Entomology/Biology
Host Country Institution to Benefit from Training: Togo, IITA
Training Location: IITA Benin
Supervising CRSP PI: Tamò
Start Date of Degree Program: May 2012
Program Completion Date: Dec 2012
Training Status during Fiscal Year 2012: ongoing
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 2012
Training Status during Fiscal Year 2012: Completed and currently working as an intern at INRAN, Maradi
Type of CRSP Support (full, partial or indirect): partial

First and Other Given Names: Adére
Last Name: Sanouchi
Citizenship: Niger
Gender: Male
Degree Program for training: MS at University of Niamey
Program Areas or Discipline: Pests of cowpea, use of MaviPn virus fore the control of Maruca vitrata
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:October 2012
Training Status during Fiscal Year 2012: Completed
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 2012
Training Status during Fiscal Year 2012: Completed and currently working as an intern at INRAN, Maradi
Type of CRSP Support (full, partial or indirect): partial

Host Country Institution to Benefit from Training: INRAN, INERA and IITA. The UIUC student on a HHMI scholarship 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, HHMI, 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).

Projected Completion Date: The completion date of the UIUC student will be in 2013 or 2014 (her HHMI funding is for the next 3 years).

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, biopesticides
Status of this Activity as of September 30, 2012: ongoing
When did the Short Term Training Activity occur? Aug–Nov 2012
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? Technicians, students

Number of Beneficiaries by Gender:	Male:	3
	Female:	2
	Total:	5

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:	>500
	Female:	>500
	Total:	>500

Type of Training: Online Video Materials on SusDeViKI, SAWBO site, e-mail distribution, in country distribution, 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, Uganda, and India)

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 : >20,000
SusDeViKI downloads of cell phone ready CRSP video—>10,000
YouTube views of various Scientific Animations Without Borders Videos —>60,000
SAWBO views and download of videos (only up since the beginning of September)—>10,000 views and downloads
The SAWBO and SusDeViKI sites have been shared 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.
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. NGOs, universities, and government in Niger, Burkina Faso, Mozambique, and a long list of other countries, have used various SAWBO videos in their training programs, web sites, and other professional activities.

Explanation for Changes
Delays in one field study with cell phone video experiments. Activities are occurring during this no-cost extension period.

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).

In Benin, efforts are underway to work with the biggest federation of agroecological 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 has partnered with NGOs 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). The INRAN group estimates that at least 50,000 persons were impacted discovering new improved cowpea varieties and treatment by the use of neem, neem+ virus, chemical (in Niger). Some of these activies were cofunded by PDSA/BA funded by CARITAS international and Belgium Funds for Food security and ONG VIE funded by DDC working in Dakoro zone.

IITA, in close collaboration with DGP–CRSP and other partners, successfully organized the 5th World Cowpea Research Conference in Saly, Senegal, Sept 26–Oct 2, 2010. This has provided an excellent discussion platform for scientists from a very broad range of disciplines, extension agents, farmer and donor representatives, journalists and policy makers, for sharing the progress made along the value chain of cowpea. DGP–CRSP sponsored the participation of four CRSP scientist, and a total of 6 papers were authored/co-authored by DGP–CRSP PIs. ***This meeting provided us an opportunity to meet with a CORAF representative, Professor Abdourahamane Sangare (he is part of Biotech/Bio-security at CORAF), to explain our project in detail, and outline the beginnings of our future interactions with CORAF. 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
See http://sawbo-illinois.org/outreach.htm for an incomplete list of groups collaborating with SAWBO on deployment of materials

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 (Onstad et al., 2012).
2. Part of Dr. Pittendrigh's time at UIUC has been cost-shared.
3. Dr. Onstad's time was donated.
4. Drs. Dabire, Ba, and Baoua 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 $18,000 from GIZ/BMZ for work on the biocontrol of M. vitrata.
8. Dr. Tamò received $12,000 from CRP GL for work on the climate change x cowpea pest interactions

9. Drs. Pittendrigh and Bello received $160,000 from the ADM Institute for the Prevention of Postharvest Loss for the SAWBO/SusDeViKI systems.
10. Dr Ba has received $50000 from CORAF for work on dissemination of cowpea technologies in Burkina Faso

Scholarly Activities and Accomplishments

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Literature Cited

Included in the body of the text for easier reading.

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 forum (also known as farmer field schools). One project was 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.

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 FY12, 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 (FY10–12)
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. An animated video on biocontrol for *Maruca* was created in collaboration with IITA and SAWBO (UIUC).

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 have been 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, and Burkina Faso 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, 2012 -- September 30, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

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 (as associated with control strategies)				X	X		X	X		X	X							
Objective 2 Development of molecular margers to study populations of five pests of cowpeas																		
Collect insects necessary for use of the molecular marker tools				X	X		X	X		X	X							
Finalize collection of insects				X	X		X	X		X	X							
Use polymorphisms to understand insect populations	X	X																
Objective 3: Development and deployment of extension materials for IPM for pests of cowpea and assessment studies																		
Develop videos for training in pest control technologies	X	X		X	X		X	X		X	X		X		X (1)	X	X	
Voice overs of videos in new languages	X	X								X	X							
Interact with partner organizations to distribute matetrials	X	X					X	X										
Impact and impact pathways	X	X					X	X		X	X							
Baseline studies for future impact assessment (wih P3-MSU)	X	X					X	X										
Extension experiments (with P3-MSU)	X		X (2)				X		X (2)									
Objective 4: Integrative Pest Management Strategies																		
Viral cottage product systems developed and deployed				X	X		X	X		X	X							
Viral + neem testing - HPR (to control key pests of cowpea)				X	X		X	X		X	X							
Assesment of yield increases of control strategies				X	X		X	X		X	X							
Trip parasitoid releases in nursery plots																		
Pod sucking bug bicontrol agent field testing																		
M. vitrata parasitoid release deployment system finalized																		
Use of M. vitrata parasitoid release system																		
Objective 5: Collect Biocontrol Agents for Sequencing and Development of IPM-omics																		
Biocontrol agent polymorphism testing	X	X																
Pipeline of discovery and deployment of other biocontrol agents				X	X		X	X		X	X							
Completion of white paper/publication of cowpea IPM-Omics	X	X		X	X		X	X		X	X							
Objective 6: Institutional capacity building																		
Technician, Peace Corps, and NGO training programs	X	X		X	X		X	X		X	X		X		X (1)			
Farmer field fora / Cell phone videos				X	X		X	X		X	X		X		X (1)	X	X	
Audio and videos fro control strategies for pests of cowpea	X	X		X	X		X	X		X	X		X		X (1)	X	X	
Non-degree training				X	X		X	X		X	X		X		X (1)	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 10/8/2012 **Date**

Tasks not completed
1) Due to the political situation in Mali we had to discontinue this work (at the request of USAID).
2) These experiments are current in progress and are slated to occur this fall.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2011 -- September 30, 2012)

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	**2012 Target**	**2012 Actual**
	(October 1, 2011-Sept 30, 2012)	
Degree Training: Number of individuals enrolled in degree training		
Number of women	3	>3
Number of men	2	>2
Short-term Training: Number of individuals who received short-term training		
Number of women	5000	>5000
Number of men	5000	>5000
Technologies and Policies		
Number of technologies and management practices under research	5	5
Number of technologies and management practices under field testing	5	5
Number of technologies and management practices made available for transfer	5 (five)	5
Number of policy studies undertaken	N/A	N/A
Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	500	>500
Number of rural households benefiting directl from CRSP interventions - Male Headed households	>5000	>5000
Number of agricultural-related firms benefiting from CRSP supported interventions	6	6
Number of producer and/or community-based organizations receiving technical assistance	100	100
Number of trade and business organizations receiving technical assistance	10	10
Number of women organizations receiving CRSP technical assistance	100	100
Number of public-private partnerships formed as a result of CRSP assistance	3	>3
Number of of HC partner organizations/institutions benefiting	7	>7
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	5000	>5000

Notes - (1) Dr. Ibrahim Baoua (in Niger) has deployed technologies, through collabations with other incountry organizations to well over 10,000 individuals in Niger.
(2) The animated videos have gone out to well in excess of 100,000 people worldwide, and over 10,000 people in the host countries.

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 Tropical Agriculture Research Station (TARS), Puerto Rico

Collaborating Scientists
Juan Carlos Rosas, (EAP–Zamorano), 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 during the past year toward research and training objectives. The small red, disease resistance bean cultivars "Tayní" was released in Costa Rica and "Campechano JR," "Don Kike" and "Chepe" were released in Honduras. The small red cultivars "San Antonio FP1," "La Presa JF" and "Guazapa 1" were released in El Salvador, using participatory plant breeding (PPB) approaches. Web blight and common bacterial blight resistant germplasm lines PR0401-259 and PR0650-31 were released in cooperation with the UPR, the USDA-ARS-TARS and Zamorano; and multiple-stress-tolerant black bean germplasm TARS-MST1 and SB-DT1 were released in cooperation with the UPR, the USDA-ARS-TARS and the U. of Nebraska. 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. Black and white bean breeding lines that combine resistance to bruchids, BGYMV, BCMV and BCMNV have been developed. White bean lines have been selected that combine resistance to BGYMV, BCMV, BCMNV and all races of rust when tested at Beltsville, MD. A soil cylinder technique and large pots were used at Zamorano to measure the response of bean lines to specific strains of *Rhizobium*. Greenhouse trials conducted in Honduras identified lines with higher nodulation scores and greater root and shoot dry weights under low N conditions. Inbred-backcross populations were developed to study the expression of nodulation and N_2 fixation traits. Selected lines were evaluated in the field using inoculation and N fertilizer treatments. The most promising F_4 lines derived from crosses between diverse parents having good nodulation selected in FY11 were recombined to form the second cycle of recurrent selection for enhanced biological nitrogen fixation. During FY12, populations were developed and advanced to the F_4 generation. Lines from these populations will be screened for higher nodulation in 2013. Significant *Rhizobium* strain x bean line interaction for seed yield was observed in field trials planted at Isabela, Puerto Rico. Lines were identified that nodulated and yielded well when inoculated with either strain CIAT899 or UMR1597. USDA and UPR scientists collaborated in the identification of the dominant gene, *Xap-1*, which confers resistance to common bacterial blight (CBB). Preliminary results suggest that an additional recessive gene is needed to achieve high levels of CBB resistance. The response of common bean to *Macrophomina phaseolina* (ashy stem blight) was evaluated in the field and greenhouse using

different techniques. An inoculation technique using Band-Aids proved to be successful in the identification of Andean bean lines with greater levels of resistance to ashy stem blight. A CAPS marker using ENM-FWe/RVe primers and the *Rsa*I restriction enzyme showed potential for indirect 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 Republic and 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 field trials planted at Isabela, Puerto Rico and Mazozo, Angola. Genotypic evaluation using SNP markers was also completed. Elemental composition of seed from the Puerto Rico trials was measured 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 were tested in Honduras, the U.S., Angola and Puerto Rico and two lines with superior performance are being considered for release as improved germplasm. 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 Laura Lara (Zamorano student) at the USDA-ARS-TARS. Workshops describing research techniques dealing with biological nitrogen fixation and *Rhizobium* inoculant production were conducted in Honduras in November 2011 and in March 2012, and in Mozambique in April 2012.

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 common 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 15 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. During the past five years, the Pulse CRSP project has developed a sizeable number of black bean breeding lines that have been distributed to bean research network members in Nicaragua, Guatemala and Haiti. The bean research network supported by the Pulse CRSP is a key element in the success of the cultivar development program in Central America. Although this Dry Grain Pulse CRSP project emphasizes the development and 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 breeding lines that have resistance to BGYM, BCMNV and other diseases of economic importance.

The Pulse CRSP breeding programs are in the position to continue 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 in an advanced stage of development. The Pulse CRSP project collaborates with 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 have proven to be useful in Angola, given the similarity in agro-ecological zones and production constraints. Some small red and black bean cultivars and breeding lines developed in Central America and the Caribbean 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 BCMNV, common bacterial blight and web blight may be of particular value to northeastern Angola or Tanzania where small red beans are produced. 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. Black beans are often the highest-priced seed type in the markets of Luanda, Angola. The lowland bean breeding team has also developed Andean (red mottled, yellow 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 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, 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 Central 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 Central America and the Caribbean for testing in on-farm trials. Performance of the varieties in the on-farm trials 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.

During the past five years, 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. During the past few years, breeding lines derived from crosses between local landraces and sources of disease resistance have been field tested in Angola.

Results, Achievements and Outputs of Research
Development of breeding populations
Small red, black, white and Andean bean breeding populations were developed and evaluated during the past year. The overall goal is to incorporate disease resistance and abiotic stress tolerance into black, small red, white, red mottled and yellow bean breeding lines. Parents used in the crosses include 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 improved 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 and F_3 to F_5 families 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. One group of crosses has been identified as the "Seda Connection" were made by crossing the landrace "Seda" with elite high yielding, disease resistant cultivars and breeding lines. The cultivar "Seda" is an early maturity, well adapted Honduran small red landrace that has tolerance to drought and low fertility. The performance of "Seda" has been outstanding in most field trials. This landrace nodulates well and possesses root traits associated to tolerance to drought and low fertility. 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.

The performance of breeding lines derived from crosses between landrace x improved cultivars to improve the most common Honduran small red bean landraces (“Paraisito,” “Cincuenteño” and “Marciano”) and the widely grown Salvadoran landrace “Rojo de Seda” was validated in farmer fields in several bean production areas in Honduras. During the past year, several of these lines were tested under on-farm conditions, and at least one cultivar will be ready to be released in Honduras in 2013. Some of these improved landrace cultivars and lines should prove to be useful for Nicaragua and El Salvador, where landraces with characteristics similar to those in Honduras are commonly grown by small-scale farmers. Moreover, one of these improved landrace lines will be released in Nicaragua.

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 the past few years (ICTAZAM and ICTA Petén in Guatemala; and Aifi Wuriti and DPC-40 in Haiti). 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. In El Salvador, the best black bean cultivars and breeding lines are being tested for a similar export initiative. Promising breeding lines derived from crosses, including the black bean cultivar “Vaina Blanca Negro” from Costa Rica, were evaluated in farmer fields in Costa Rica. This has resulted in the programmed release of a black bean cultivar for the 2012-13 “apante” season in the North Huetar region.

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. BC_1S_4 families were selected for superior agronomic performance, desirable seed traits and SCAR markers for BGYMV and BCMV resistance. These selected BC_1S_4 lines will be screened for resistance to BCMNV at the University of Puerto Rico during the upcoming year. 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 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 were largely susceptible to ALS (Table 1), which are important diseases based on disease evaluations made in Angola (Estevez de Jensen et al. 2011).. Several of the Angolan lines showed good BNF potential, while most were not well adapted to high temperatures in Puerto Rico (data not shown). Based on testing of improved varieties and breeding lines in Angola over the past 5 years, lines were selected that are adapted to Angola and have resistance to BCMV, BCMNV, CBB, and ALS. Populations were developed from crosses between the commercial seed types used in Angola and 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. Monica Martins in Huambo, Angola has begun to evaluate over 400 F_3 lines, 130 $F_{4:5}$ lines, and 46 $F_{6:7}$ lines during this last year.

Figure 1. Bean seed types found in the public market in Huambo, Angola.

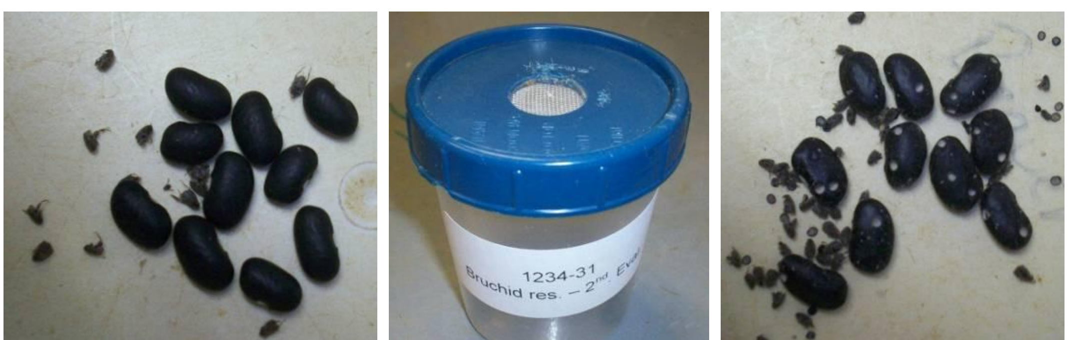
The yellow bean is a preferred seed type in Haiti and Angola (Figure 1). Azufrado bean breeding lines from Mexico were obtained from Dr. Jorge Acosta, INIFAP bean breeder and former Bean/Cowpea CRSP HC-PI. These yellow bean lines were crossed with red mottled bean breeding lines that have multiple disease 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. The performance of a group of the yellow bean breeding lines with BGYMV and BCMV resistance was tested in Haiti, Puerto Rico and Angola (Table 3). During the upcoming year, the most promising lines will be tested in Haiti and Puerto Rico in replicated yield trials. If the lines continue to perform well, a variety release in Haiti will be considered. We provided Dr. Acosta with seed of the yellow bean breeding lines for use as parents in the INIFAP breeding program because most azufrado bean cultivars in Mexico do not have BCMV resistance.

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 $BC_3F_{3\text{-}4}$ 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 4). Three light red kidney lines from the OSU populations had useful levels of resistance to the common bean weevil. 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*). These results demonstrate the vulnerability of bean cultivars in Central America, the Caribbean, Ecuador and Angola to common bean weevil damage.

The common bean weevil resistant red kidney line AO-1012-29-3 was crossed with black and white bean breeding lines having BGYMV, BCMNV and BCMV resistance. During the past year, individual plants with commercially acceptable seed types and superior agronomic traits were selected in F_3 and F_4 nurseries planted at Isabela, Puerto Rico. Seed of each F_5 line was infested with *Acanthoscelides obtectus* Say in laboratory trials conducted at the Isabela Substation. Lines which expressed resistance to the bruchid were re-infested. Residual seed of the F_5 lines was used to screen the lines in a greenhouse at the UPR Campus for reaction to BCMNV using the NL3 strain of the virus. DNA was extracted from the plants in the greenhouse and screened in Dr. Porch's laboratory using markers for resistance to BGYMV and BCMV. Six black, one white and one dark red line were identified that combine bruchid and virus resistance (Table 5). Seed of these lines were increased at the Isabela Substation during the summer of 2012 so that preliminary performance trials can be conducted in Puerto Rico, Haiti and Honduras during the upcoming year. UPR graduate student Abiezer González screened these lines for common bean weevil resistance as part of his M.S. degree research. Results from this research were presented at the 2011 meeting of the Bean Improvement Cooperative and the 2012 meeting of the PCCMCA.

During the past year, AO-1012-29-3 was also crossed with red mottled bean breeding lines having BGYMV, BCMNV and BCMV resistance. A similar approach will be used during the upcoming year to develop Andean bean lines that combine bruchid and virus resistance.

Figure 2. Resistant and susceptible reactions to the common bean weevil and the containers used to conduct the evaluations.



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. During the upcoming year, NSS researchers plan to study the inheritance of 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 the National Bean Programs (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 70 small red and black bean breeding line VIDAC nurseries and ECAR trials were distributed to collaborators from the 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 6 to 9. In addition 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, 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 2011 regional VIDAC nurseries and ECAR trials were presented at the 2012 meeting of the PCCMCA which was held in Panama.

Almost 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 distributed to the NBPs of Costa Rica, Honduras, Panamá, Nicaragua, El Salvador, Guatemala and the Dominican Republic as part of the collaboration with the Red SICTA Project to select bean lines 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”), the Seed for Development Project of FAO and the NGOs FIPAH and PRR which are collaborating with Zamorano in PPB activities. In addition, the project participated in the regional evaluation of a Bean Adaptation Trial from CIAT to study climatic change adaptation in common beans using the DSSAT model.

ERMUS trials (Table 10) 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 19 advanced lines selected from the previous year that combine WB, BGYMV and BCMV resistance, agronomic adaptation and commercial seed types and 5 checks (Talamanca, VAX 6, Tío Canela 75, Carrizalito and ICTAZAM).

The project is developing small red and black breeding lines that recombine resistant to BGYMV and BCMV, tolerance to drought and low fertility with resistance to angular leaf spot (ALS).

During the past year, a regional trial including ALS resistant lines (ERMAN Trial) was evaluated in Costa Rica and Honduras. In this ERMAN Trial, some small black and red lines show foliar and pod resistance to ALS similar to the best resistant check, the Andean accession G05686 (Table 11).

The UPR developed red mottled bean lines that combine resistance to BGYMV, BCMNV, BCMV and common bacterial blight. Seed of the most promising lines was increased in Puerto Rico during the past year. The red mottled lines were also evaluated in trials from 2009-2011 in Haiti, the Dominican Republic and Puerto Rico (Table 12). PR0633-10 and PR0737-1 were among the highest yielding lines in the trials. Both lines have the *bgm-1* gene for resistance to BGYMV and the *bc3* gene for BCMV and BCMNV resistance. PR0633-10 also has the SW12 QTL associated with resistance to BGYMV and the SAP6 QTL associated with common bacterial blight resistance. PR0633-10 and PR0737-1 produced mean seed yields as great as or greater than check varieties “PC-50” and “JB-178” in trials conducted in Puerto Rico, the Dominican Republic and Haiti. PR0633-10 and PR0737-1 are candidates for release as cultivars in Haiti and should serve as useful sources of resistance to BGYMV, BCMV, BCMNV and common bacterial blight.

Elite black bean breeding lines from the UPR were evaluated in Haiti and the Dominican Republic during g the past year (Table 13). Two of the lines which had been selection for adaptation to low N soils performed as well as DPC-40 and XRAV-40-4.

Five white bean breeding lines (PR0806-80 to PR0806-84) have resistance to BGYMV, BCMV, BCMNV and rust (Table 14). SR2 and SW12 marker results suggest the presence of *bgm* gene and the QTL for BGYMV resistance. Resistant reactions to NL3 in the greenhouse suggest the presence of the *bc3* resistance gene). These lines were also resistant to all rust races when evaluated at Beltsville, MD by Dr. Pastor Corrales. PR0806-80, 81 and 82 have both the SA14 marker for the *Ur4* gene and the SI19 marker for the *Ur5* gene for rust resistance. PR0806-83 and 84 have the SI19 marker for *Ur5* but do not have the SA14 marker for the *Ur4* gene. These white lines had less powdery mildew that most other bean lines in the DR during the 2011-2011 growing season. Common blight has not been a problem in the field but the lines were susceptible when inoculated in the greenhouse with the 3353 and 484A strains of *Xap*. All of the lines are moderately susceptible to angular leaf spot in Puerto Rico with scores not > 4 using the CIAT 1-9 scale. Mean seed yield of the breeding lines was similar to the checks “Verano” and “Morales” (Table 14). These lines will be considered for release as improved bean germplasm.

Lines developed for Central America and the Caribbean were evaluated in Angola during the main production seasons from 2008-2012. Results from these trials helped to identify economically important diseases in different bean production regions in Angola. Field trials were planted in Angola from 2008 to 2011. Results from these trials identified bean breeding lines with different seed types (Matterhorn, Beníquez, IBC301-204, BelDakMi RMR 22 and PR9745-232) that were well-adapted, had good yield potential and were resistant to disease. It should be noted, however, that delays in obtaining results from field trials conducted in Angola impeded the identification of potential parents for the breeding program.

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. One small Agrosalud line was released as the cultivar “Chepe” in Honduras; another Agrosalud line is expected to be released during 2012; both lines were selected by farmer CIAL groups using PPB approaches. The PASEBAF trial, a Red SICTA activity including CIAT and Zamorano lines tolerant to drought and low fertility, was funded by IICA/COSUDE from 2007 to 2010. These lines were distributed for testing in Central America during the past two years with support from the Dry Grain Pulses CRSP project. The cultivar “INTA Fuerte Sequía” released in Nicaragua in 2010, and the small red cultivars “Campechano JR” and “Don Kike” released in Honduras in 2012 were entries included in the initial PASEBAF trial.

There is increased interest in the lowlands of Guatemala in the production of small red beans for export to El Salvador and to 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 a Pulse CRSP 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 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. The goal is to develop and release bean cultivars which combine the seed traits and earliness of the landraces with the disease resistance and yield potential of 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, FAO/Seeds for Development Project, World Vision, 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 summers of 2011 and 2012, the National Seed Service in Haiti produced 10 MT of DPC-40 at Savane Zombi. This basic seed was distributed in Haiti in collaboration with the Feed the Future supported Bean Technology Dissemination project. During the past year, > 200 kg of basic seed stocks of BGYMV, BCMNV and BCMV resistant black bean lines XRAV40-4 and MEN2201-64 ML were produced in Honduras and shipped to Haiti for further multiplication.

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.

During FY 12 the disease resistance small red bean cultivars "Tayní" was released in Costa Rica. The small red cultivars "Campechano JR," "Don Kike" and "Chepe" were released in Honduras, and cultivars "San Antonio FP1," "La Presa JF" and "Guazapa 1" in El Salvador, using participatory plant breeding (PPB) approaches. These PPB cultivars are very well adapted to conditions on small farms in the regions where they were selected. Their agronomic adaptation in other bean production regions of these countries needs to be validated before recommending them as cultivars at national level.

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. In Honduras, seed production and dissemination of the cultivars released on 2011-12, was conducted in FY12 in collaboration with farmer CIALs and NGO technical personnel.

The small red cultivar "CENTA Chaparrastique" was released in El Salvador during 2011, as a BGYMV 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 FY11–12.

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 was published in the *J. of Plant Registrations*.

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 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, Populations from the Cycle 2 of recurrent selection for increasing BNF in common beans were developed from crosses between 24 lines selected from the screening of F_4 families from 25 bean populations from Cycle 1 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). Cycle 2 populations were advanced to the F_3 generation in FY12. During 2013, these populations will be advanced to the F_4 generations and at least 20 families per population (total of 240 families) will be tested for higher nodulation under greenhouse conditions similar to that used on cycle 1. The 24 (10%) best F_4 families from cycle 2 will be recombined using a partial diallel crossing design to develop the populations for the third cycle of recurrent selection for nodulation. The most promising F_4 families from Cycle 2 will be advanced and evaluated for desirable agronomic and commercial traits and determine their potential to be included in future regional trials. In addition, lines from Cycles 0, 1 and 2 will be compared for nodulation and growth in different environments with low soil N content, to estimate gain from selection for enhanced BNF.

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.

During the 2012 summer season, improved small red and black lines from the VIDAC, ECAR and ERSAT regional trials were tested under inoculation with a mixture of the three *Rhizobium* strains mentioned previously. The lines were grown without soil added fertilizer and under drought stress (150 mm of irrigation until the pre-flowering stage) conditions. Nodulation and shoot dry weight were recorded at flowering and seed yield at maturity. In general, nodulation, plant growth and seed yield were lower due to the low fertility and drought conditions. However, some small red and black breeding lines and the landrace cultivar Seda performed well under the limited conditions of these trials (Table 15).

A set of 32 (17 Mesoamerican and 15 Andean) bean genotypes are being tested with single and mixtures of inoculants, to develop a set of differential genotypes for evaluating the response of

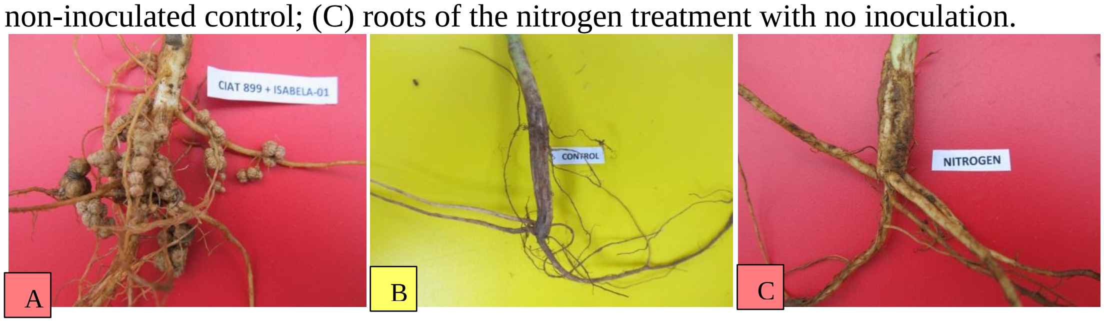
Rhizobium strains and bean germplasm in diverse soil and climatic conditions. Preliminary results indicate a wide variation in nodulation to specific and mixtures of inoculants. Further studies including the evaluation of a Mesoamerican x Andean RIL population with single and mixtures of strains, will be continued in 2013.

Field experiments conducted over a two year period in Puerto Rico identified breeding lines with greater N use efficiency in low N soils. In trials planted at Isabela, Puerto Rico over a two-year period, the mean seed yields of the black bean line PR0443-151 and the small red lines VAX 3 and IBC 309-23 ranked no lower than 9^{th} in the – N plots. 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.

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 the *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 16). 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 and strain x bean line interaction was not significant for seed yield. The Isabela Substation had a lower native rhizobium population and better response to inoculation. Strain competitiveness probably was also important in Fortuna. In subsequent experiments the effectiveness of inoculants produced with single strains and/or a combination of different *Rhizobium tropici* and *Rhizobium etli* strains was evaluated. Inoculants with a single or a combination of *Rhizobium* strains increased nodulation. There were significant differences when compared to the control, NPK and N treatments. The mean nodulation score of *Rhizobium tropici* CIAT 899 in a combination with the Isabela 1 strain was 5.7 (1-9 scale). Nodule size ranged between 1- 3 mm diameter and most of these nodules were located in the upper 5 cm of the root (Fig. 3). Another combination of *Rhizobium* strains that produced outstanding nodulation due to the size and location of nodules was CIAT 899 and UMR 1597. Strain 1597 alone had a positive effect in dry matter and yield. Strains CIAT 899 in combination with all the tested strains had a synergistic effect on nodulation. The non-inoculated control had the lowest number of nodules. the use of both combinations of *Rhizobium* strains resulted in the highest grain yields along with the NPK treatment. The non-inoculated control had the lowest grain yield.

Figure 3. (A) Cultivar "Verano" nodulated with strains CIAT 899 and Isabela 1, (B) roots of the non-inoculated control; (C) roots of the nitrogen treatment with no inoculation.



In the trial in Damien, Haiti, the response of inoculation using the same strains and combinations resulted in no differences in nodulation and seed yield among the NPK, Nitrogen; inoculation with CIAT 899 + CIAT 632 Control; CIAT 899 + Haiti 1; the non-inoculated control and UMR 1597 treatments. Strain CIAT 899 inoculated alone had higher yields compared to other strains and the highest yield was obtained from the inoculant containing a combination of the Haiti 1 strain and CIAT 632 strains. The number of soil rhizobia in the field indicated the presence of a high number of rhizobia that were able to nodulate and produced good yields. This field at Damien had been planted in beans during the dry season for at least the past 20 years. The number of nodules did not differ among treatments and the application of fertilizer did not affect nodulation. The results from this field trial may not reflect the performance of these inoculants in farmers' fields.

Fig.4.Nodulation of 10IS-2435 with *Rhizobium tropici* strain CIAT 899 at 30 days after planting.

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 un-inoculated 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.

As result of the advances in the identification of superior *Rhizobium* strains and implementation of the inoculant production technology, extensive testing and dissemination activities are being conducted in Honduras, Guatemala, Nicaragua and Haiti. More than 2,000 farmers received small bags to inoculate their bean fields with a mixture of the best Rhizobium strains in Central America. Guatemala produced 1,000 inoculant bags and distributed to the growers. In Haiti, a total of 7,000 inoculant bags have been delivered to 7,000 growers. The inoculants were applied to a 15,000 kg of seeds which is sufficient to plant 300 hectares.

Fig. 5. Participants in the BNF workshop held at Zamorano in November 2011.

Fig.6. BNF workshops held in Maputo, Mozambique in May and Zamorano in March 2012.

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 Pulse CRSP project evaluated the usefulness of the RAPD molecular markers and found that they were not effective markers. New recombinant inbred line populations are being 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 developed, but single genes that confer this resistance have not been identified. 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 (2008-2010) 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 17). The experiment was 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.

In addition, the Andean Diversity Panel (ADP) has been screened using a novel "Band-Aid" inoculation method and markers will be evaluated based on the SNP genotyping of that population of ~350 lines. Once SNPs have been identified, indel markers can be screened for the development of breeder-friendly markers.

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 high level of CBB resistance 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 soil borne 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 the beginning of this Pulse CRSP project, the USDA and CIAT bean germplasm collections had 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 served 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 bean. 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 bean (*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 were 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. Seed of one photoperiod insensitive landrace will be multiplied and offered for sale to farmers in Puerto Rico.

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 as part of a regional trial (ERLIMA) which has been distributed to collaborators from Honduras, Nicaragua and El Salvador. 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 and in Mazozo, Angola in 2012. 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 in Puerto Rico >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. Disease and pest pressure was greater and cowpea seed yields were lower in the trial conducted at Mazozo.

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. During 2012, ERCAUPI trials has been provided to collaborators from Honduras, Nicaragua and El Salvador. 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 would have better consumer preference in the Central American region where people mostly consume small red bean. During 2012, seed of the best red seeded cowpeas accessions were increased for distribution to collaborators from Honduras, Nicaragua and El Salvador.

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 planted in Haiti in November 2011. Some of the cowpea landraces from Angola were well adapted and productive. These lines will be evaluated in Haiti during the upcoming year in replicated trials.

Superior lines of tepary beans were evaluated in 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, bacterial blight resistance, drought and heat tolerance, bruchid resistance, and yield (Table 18). Several of these lines (Tep 22 and Tep 32) are being considered for release and have been distributed to programs in Burkina Faso, Angola, Rwanda, Mozambique, Honduras, Haiti, and the U.S. Future efforts will include efforts to transfer BCMV and BGYMV resistance from common bean to tepary bean.

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: Abiezer González-Vélez
- Citizenship: U.S.
- Gender: Male
- Degree Program for Training: M.S.
- Program Areas or Discipline: Plant Breeding and Genetics
- Host Country Institution to Benefit from Training: U.S.
- University to provide training: University of Puerto Rico
- Supervising CRSP PI: James Beaver
- Start Date: August 2010
- Completion Date: May 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: $2,000/year
    - Indirect cost: None
- U.S. or HC Institution to receive CRSP funding for training activity: The University of Puerto Rico

Trainee # 2

- Name: Marcelino Guachambala Cando
- Citizenship: Ecuador
- Gender: Male
- Degree Program for Training: M.S.
- Program Areas or Discipline: Plant Breeding and Genetics
- Host Country Institution to Benefit from Training: Ecuador
- University to provide training: University of Puerto Rico
- Supervising CRSP PI: James Beaver & Tim Porch
- Start Date: January 2010
- Projected Completion Date: December 2012
- Type of CRSP Support (full, partial or indirect): Partial
  If providing Indirect Support, identify source(s) of leveraged funds
  Amount Budgeted in Work plan, if providing full or partial support:
  Direct cost: $15,000 ((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: Laura Melissa
- Last Name: Laraíaz
- Citizenship: Guatemalan
- Gender: Female
- Degree Program for training: B.S.
- Program Areas or Discipline: Crop Science
- Host Country Institution to Benefit from Training: Guatemala
- University to provide training: EAP
- Supervising CRSP PI: J.C. Rosas
- Start Date: Jan 2012
- Projected Completion Date: Dec 2012
- Type of CRSP Support (full, partial or indirect): indirect
  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

Indirect cost: $
U.S. or HC Institution to receive CRSP funding for training activity: EAP

Trainee #4

- First and Other Given Names: Sara
- Last Name: Valentinetti
- Citizenship: Italy
- Gender: Female
- 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 2012
- Projected Completion Date: Dec 2012
- 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: Biological Nitrogen Fixation.
- Location: Zamorano
- Duration: 4 days
- Scheduling of training activity: November 2011
- Participants/Beneficiaries of Training Activity: 9
- Anticipated numbers of Beneficiaries (male and female): 5 M and 4 F
- Amount Budgeted in Work plan:
  - Direct cost: $ 9100
  - Indirect cost: $ 0
- If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: Institutional building funds were used to support the BNF workshops.

Training activity # 2

- Type of training: Workshop
- Description of training activity: Biological Nitrogen Fixation .
- Location: Mozambique
- Duration: 3 days
- Scheduling of training activity: May 2012
- Participants/Beneficiaries of Training Activity: 14
- Anticipated numbers of Beneficiaries (male and female): 9 M5 F

- Amount Budgeted in Work plan:
  - Direct cost: $ 19,780
  - Indirect cost: $0
- If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: Institutional building funds were used to support the BNF workshops..
  Comments: Participants were technicians and scientists from Eastern and Southern Africa.

Training activity # 3

- Type of training: Internship
- Description of training activity: Laboratory techniques related to plant breeding.
- Location: USDA-ARS Tropical Agriculture Research Station
- Duration: 4 months
- Scheduling of training activity: Tim Porch
- Participants/Beneficiaries of Training Activity: Laura Melissa Lara Santisteban
- Anticipated numbers of Beneficiaries (male and female): 1F
- Amount Budgeted in Work plan:
- Direct cost: $ 3,200
- Indirect cost: $0
- If leveraged funding is to be used to Support this Training Activity, indicate the Source and Amount: None.
- Comments: After the internship Laura returned to Zamorano to complete her B.S. degree.

Explanation for Changes

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 May 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. Two of these lines were among the most resistant lines to white mold (> G122) in straw tests conducted in seven states (McCoy et al. 2012 Use of multi-site screening to identify and verify partial resistance to white mold in common bean. Ann. Rep. of the Bean Improv. Coop. 55:153-154). This is an example of how breeding lines derived from interspecific crosses can be of potential value to bean production in the U.S.

The UPR bean breeding program collaborates with Dr. Graciela Godoy-Lutz, Instituto Dominicano de Investigaciones Agropecuarias y Forestales (IDIAF) plant pathologist, in a locally-funded project entitled "Evaluación, multiplicación y adopción de líneas avanzadas de habichuela con resistencia a limitantes bióticas desarrolladas en el proyecto Bean/Cowpea CRSP" that was 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 has resulted in the development and release of disease resistant black and red mottled bean lines such as PR0737-1 and PR0633-10 of potential benefit to farmers in Haiti and the Dominican Republic.

The UPR Pulse CRSP breeding program collaborated with the MSU bean breeding program in the evaluation of a RIL population derived from the cross "Zorro x Puebla 152." This is part of the PhD dissertation research of MSU graduate student Jim Heilig. The lines were planted in a low N field at the Isabela Substation and were inoculated with a mixture of *R. tropici* strain CIAT 899 and *R. etli* strain UMR 1597 provided by Dr. Consuelo Estevez. Differences among lines were observed for nodulation, vigor, leaf SPAD scores and seed yield. The small red check line 10IS-2423 yielded as well as the most productive RILs in the trial (18).This line was among the highest yielding lines in other trials in Puerto Rico conducted in low N soils. The evaluation of the RILs will be conducted in Puerto Rico and Michigan over a two-year period.

Fig. 7. Evaluation of "Zorro x Puebla 152 RILs
in Isabela.

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

- Name of PI receiving leveraged funds: Management office of the Dry Grain Pulse CRSP and PII-UPR-1 project personnel.
  - Description of leveraged project: Associate award from USAID-EGAT to promote the production and dissemination of seed of improved cultivars and to promote biological nitrogen fixation in Central America and Haiti.
  - Dollar Amount: $ 3,300,000 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. 2012. Registration of PR0401-259 and PR0650-31 dry bean germplasm lines. J. Plant Reg. 6:81–84.

Beaver, J.S., M. Zapata, M. Alameda, T. Porch, J.C. Rosas, G. Godoy-Lutz y E. Prophete. 2012.Common bean Improvement in the Caribbean. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Brisco, E.I., T. Porch and J.D. Kelly. 2012. Influence of leaf color in a dry bean mapping population on *Empoasca* sp. populations and host plant resistance. Ann. Rep. Bean Improv. Coop. 55:83–84.

Estévez de Jensen, C., T. Porch and J. Beaver. 2012. Root rot in 15 lines of *Phaseolus vulgaris* inoculated with rhizobium in Isabela, Puerto Rico. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Estévez de Jensen, C., T. Porch, , J. Beaver, A. Chicapa Dovala, L. Baptista. 2011. Disease incidence in *Phaseolus vulgaris* in the regions of Chianga, Cuanza Sul and Malange, Angola. Phytopathology 101:S277.

Estévez de Jensen, C., T.G. Porch, J.S. Beaver, A. Chicapa Dovala and L. Baptista. 2012. Disease incidence on common bean in Chianga, Kwanza Sul and Malange, Angola. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

González Vélez, A., F. Ferwerda, E. Abreu, J. Beaver, P. Kusolwa and J. Myers. 2012. Development of bean lines (*Phaseolus vulgaris* L.) resistant to BGYMV, BCMNV and bean weevil (*Acanthoselides obtectus* Say). Ann. Rep. Bean Improv. Coop. 55:89–90.

González Vélez, A., F. Ferwerda, E. Abreu, J.S. Beaver, P. Mbogo Kusolwa and J. Myers. 2012 Development of bean lines resistant to BGYMV, BCMNV and the common bean weevil. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Linares, A.M., C. Urrea, T. Porch and J.M. Osorno. 2012. A mapping population for severe drought tolerance in dry beans. Ann. Rep. Bean Improv. Coop. 55:107–108.

Mbui Martins, M., C. Estévez de Jensen, T. Porch and J. Beaver. 2012. Response of common bean lines to angular leaf spot. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Montero, M., J.S. Beaver, and D. Siritunga. 2012. Assessment of genetic diversity among Lima bean landraces from the Dominican Republic, Haiti and Puerto Rico. Ann. Rep. Bean Improv. Coop. 55:129–130.

Porch, T.G., C.A. Urrea, J.S. Beaver, S. Valentin, P.A. Peña and J.R. Smith. 2012. Registration of TARS-MST1 and SB-DT1 multiple-stress-tolerant black bean germplasm. J. Plant Reg. 6:75–80.

Porch, T.G. and P.D. Griffiths. 2012. Strategies to improve adaptation of common bean to high ambient temperature. Ann. Rep. Bean Improv. Coop. 55:9–10.

Porch T.G. and J.S. Beaver. 2012. Development of improved tepary germplasm. Ann. Rep. Bean Improv. Coop 55:123–124.

Porch T.G. and J.S. Beaver. 2012. Development of improved tepary germplasm. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Rosas, J.C., C. Estevez de Jensen and A. Vargas. 2012. Biological nitrogen fixation in common bean: research challenges. Ann. Rep. Bean Improv. Coop. 55:5–6.

Rosas, J.C., J.S. Beaver, T. Porch, S. Beebe, A. Llano, J.C. Hernández, A. Clara, J.C. Villatoro and E. Prophete. 2012. Common bean improvement in Central America. Poster presented at the Global Pulse Researchers Meeting held in Kigali, Rwanda. February 2012.

Zapata, M., J.S. Beaver and T.G. Porch. 2012. Ribotype characterization of *Xanthomonas axonopodis* pv. *phaseoli* pathogenic race XAPV1. Ann. Rep. Bean Improv. Coop. 55:119–120.

Professional Recognition, Awards and Accomplishments

- Consuelo Estevez received the 2012 National Director Award from the Plant Diagnostics Network
- Tim Porch received a Distinguished Achievement Award at the 2011 Meeting of the Bean Improvement Cooperative.
- Juan Carlos Rosas and James Beaver received Awards for Meritorious Achievement from the Bean/Cowpea and Pulse CRSPs at the 2012 Pulse CRSP Researchers Meeting held in Kigali, Rwanda.

Literature Cited

Estévez de Jensen, C., T. Porch, J. Beaver, A. Chicapa Dovala, L. Baptista. 2011. Disease incidence in *Phaseolus vulgaris* in the regions of Chianga, Cuanza Sul and Malange, Angola. Phytopathology 101:S277.

Mbogo K.P., J. Davis, J.R. Myers. 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 and common bacterial blight, 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.
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 visited Angola in December 2011 and reviewed 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. Other IIA staff members currently receiving graduate training in plant pathology in Spain are expected to use the laboratory on completion of their degrees. Threshers were purchased by the bean research programs in Haiti and Angola. This equipment will permit the harvest of larger quantities of bean and cowpea seed on a timely basis. The purchase of a 4WD vehicle for the National Seed Service in Haiti was approved by the BTD project.

Table 1. Mean readings of common bean and lima bean landraces from Angola after 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.

Table 3. Performance of the most promising yellow bean lines in trials planted at Isabela, Puerto Rico in October 2011 and Damien, Haiti in November 2011.

	Puerto Rico			Haiti		
Line	Seed yield (kg/ha)	Resistance genes	CBB score (1-9)	Seed yield (kg/ha)	Days to flower	Days to harvest
1146-42	2241	*bgm + I*	3	1463	32	66
52	2224	*bgm + I*	3	1713	32	65
53	2153	*bgm + I*	3	1725	32	65
123	1941	*bgm + I*	3	1638	32	67
124	2087	*bgm + I*	3	1713	32	67
129	2330	*bgm + I*	3	1550	32	67
130	1975	*bgm + I*	3	1525	32	65
131	1633	*bgm + I*	3	2238	35	67
132	1729	*bgm + I*	3	1863	35	65
135	2029	*bgm + I*	3	1475	32	67
137	1962	*bgm + I*	3	1400	32	67
138	2024	*bgm + I*	3	1425	32	65
Mean	1726			1485		

Table 4. Damage caused by bean weevil (*Acanthoselides obtectus*) in 20-seed samples of common bean lines of diverse origin.

Identification	Origin	Seed type	Total number 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

Table 5. F_5 lines selected for bruchid resistance at the University of Puerto Rico. The pedigree of AO-1012-29-3 is "Rojo*3/SMARC2///ICAPijao*2/G40199."

Line	Seed	Traits	Pedigree
1234-46-3	Black	*bgm,SW12,I,bc3* + bruchid resistance [1 score for first and second eval.]	AO-1012-29-3 / XRAV-40-4
1234-141-1	Dark red	*bgm,SW12,I* +bruchid resistance [1 score for first and second eval.]	AO-1012-29-3 / XRAV-40-4 // PR0806-70 / XRAV-40-4
1234-199-1	White	*bgm,SW12,I* + bruchid resistance [1 score for first and second eval.]	AO-1012-29-3 / XRAV-40-4 // AIFI WURITI / PR0634-13
1235-27-1	Black	*bgm,SW12,I* + bruchid resistance [1 score for first and second eval.]	AO-1012-29-3 / XRAV-40-4
1235-27-2	Black	*bgm,SW12,I* +bruchid resistance [1 score for first and second eval.]	AO-1012-29-3 / XRAV-40-4
1235-28-1	Black	*bgm,SW12, I,bc3* + bruchid resistance[1 first eval., 2 (1/1) for the second eval.]	AO-1012-29-3 / XRAV-40-4
1235-28-2	Black	*bgm,SW12, I,bc3* + bruchid resistance [1 first eval., 2 (1/1) for the second eval.]	AO-1012-29-3 / XRAV-40-4
1235-46-1	Black	*bgm,SW12,I, bc3* + bruchid resistance [1 score for first and second eval.]	PR1012-29-3 / XRAV-40-4

Table 6. Performance of the top 10 yielding, disease resistance elite small red bean breeding lines and two check cultivars from the VIDAC Rojo 2011-12 nurseries (70 entries) conducted in Central America during 2011 and 2012.

Line	Yield-11A/B (kg/ha)	Yield-12X (kg/ha)	AA	CV	BGY	CBB	MT	AR
NIC602-15	2184	1211	5	5	1	3	I	E
FPH22-37	2125	1294	5	4	1	3	I	E
SJC730-79	2104	1401	5	4	1	3	I	I
RS811-31	2060	1231	6	4	1	3	I	I
RS811-22	2045	1249	6	4	1	3	I	I
RS811-32	1998	963	5	4	1	3	I	I
RS811-44	1993	1148	5	4	1	5	E	I
RRH336-28	1970	1212	6	4	1	5	I	E
SRS2-33-60	1946	1046	6	4	1	5	I	E
SRS2-33-61	1944	1299	6	4	1	5	I	E
Improved check	1919	730	4	4	1	5	I	E
Local check	1292	460	7	3	8	7	E	P
LSD (0.05)	466	254						
No. locations	9	1	4	2	1	1	2	2

Yield: Mean from trials conducted under rainfall in the primera (A) and postrera (B) seasons. The trial in the summer (12X) season was irrigated and presented drought stressed conditions (150 mm irrigation before pre-flowering stage). AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); CV= Commercial value (1-9, 1=excellent, 9=poor); BGY and CBB (scale 1-9; 1-3=resistant, 7-9=susceptible); MT= maturity (E= early,I=intermediate and L=late); AR= plant architecture (E = erect, I= intermediate and P=prostrate).

Table 7. Performance of the top 10 yielding, disease resistance elite black bean breeding lines and two check cultivars from the VIDAC Negro 2011-12 nurseries (29 entries) conducted in Central America.

Line	Yield-11A/B (kg/ha)	Yield-12X (kg/ha)	AA	BGY	CBB	MT	AR
BIOF4-70	2401	1035	4	2.5	4	I	E
X02-33-159-1	2275	711	5	2	4	I	I
CR642-3	2258	942	4	2	4	I	E
SEQ341-99	2178	920	5	2.5	7	I	E
RBF7-25	2177	973	4	2	6	I	E
BIOF4-106	2169	451	4	2	5	I	E
SEN90	2167	1110	6	2	7	I	I
SEQ342-39	2148	1488	5	2.5	5	I	E
CR642-92	2138	632	7	2	6	I	I
BIOF13-17	2119	560	5	2.5	5	I	I
Local check	1717	469	5	4.5	4	I	E
LSD .05	511	266	2.4	1.8	2.5		
No. locations	9	1	2	2	2		

Yield: Mean from trials conducted under rainfall in the primera (A) and postrera (B) seasons. The trial in the summer (12X) season was irrigated and presented drought stressed conditions (150 mm irrigation before pre-flowering stage). AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); CV= Commercial value (1-9, 1=excellent, 9=poor); BGY and CBB (scale 1-9; 1-3=resistant, 7-9=susceptible); MT= maturity (E= early,I=intermediate and L=late); AR= plant architecture (E = erect, I= intermediate and P=prostrate).

Table 8. Performance of the elite small red bean breeding lines and two check cultivars from the ECAR Rojo 2011-12 trials conducted in Central America.

Line	Yield-11A/B (kg/ha)	Yield-12X (kg/ha)	AA	CV	BGY	CBB	MT	AR
RRH336-91	2903	580	5	4	1	4	I	E
SRS2-34-38	2897	1078	5	4	7	6	I	E
ALS 0532-6	2881	937	4	3	1	6	I	E
SRS2-3-23	2804	979	4	4	1	3	I	E
BIOF2-106	2766	734	5	4	1	4	I	E
GEN714-50	2729	726	5	4	1	4	I	E
SRS2-36-34	2648	1042	5	4	1	5	I	E
MHR311-32	2647	746	5	4	1	7	I	E
RRH336-24	2599	741	5	4	1	6	I	E
SRS2-37-50	2597	803	6	4	1	8	i	E
SRS2-38-14	2587	1035	4	4	1	4	I	E
MHR311-52	2553	742	5	4	1	6	I	E
FPY724-28	2546	803	5	4	1	6	I	E
SER218	2444	877	7	3	1	8	I	I
Improved check	2709	565	5	6	1	6	L	E
Local check	2379	928	7	3	7	8	E	P
LSD (0.05)	364	423	0.9	0.24		1.9		
No. locations	9	1	4	4	1	1		

Yield: Mean from trials conducted under rainfall in the primera (A) and postrera (B) seasons. The trial in the summer (12X) season was irrigated and presented drought stressed conditions (150 mm irrigation before pre-flowering stage). AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); CV= Commercial value (1-9, 1=excellent, 9=poor); BGY and CBB (scale 1-9; 1-3=resistant, 7-9=susceptible); MT= maturity (E= early,I=intermediate and L=late); AR= plant architecture (E = erect, I= intermediate and P=prostrate).

Table 9. Performance of the elite small black bean breeding lines and two check cultivars from the ECAR Negro 2011-12 trials conducted in Central America.

Line	Yield-11A/B (kg/ha)	Yield-12X (kg/ha)	AA	BGY	WB	MT	AR
SEQ341-55	2680	806	6	1	5	L	E
SJC730-40	2611	771	6	1	5	I	E
SEQ342-89	2584	1001	5	1	5	I	E
SJC730-74	2540	805	5	1	5	I	E
SJC730-70	2532	919	5	1	5	I	I
XRAV40-4	2494	768	6	1	4	L	I
SEN96	2470	772	5	7	4	I	E
MEN322-49	2400	943	6	1	4	I	E
RRH333-83	2388	632	6	1	5	I	E
SEQ344-22	2329	540	6	7	5	I	E
MHN322-9-63	2314	940	6	1	4	I	E
SJC729-11	2222	699	6	7	4	I	I
MEN2201-64ML	2086	770	6	1	6	E	I
SEQ341-108	2035	932	6	1	5	I	I
DOR390 (check)	2799	519	6	7	4	L	E
Local check	2587	1201	6	1	4	E	I
LSD (0.05)	274						
No. locations	10						

Yield: Mean from trials conducted under rainfall in the primera (A) and postrera (B) seasons. The trial in the summer (12X) season was irrigated and presented drought stressed conditions (150 mm irrigation before pre-flowering stage). AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); CV= Commercial value (1-9, 1=excellent, 9=poor); BGY, CBB and WB (scale 1-9; 1-3=resistant, 7-9=susceptible); MT= maturity (E= early,I=intermediate and L=late); AR= plant architecture (E = erect, I= intermediate and P=prostrate).

Table 10. Mean performance of the most promising web blight resistant lines from ERMUS trials conducted at four sites in Central America in 2011.

Line	Seed yield (kg/ha)	Web blight incidence (%)	Agronomic adaptation (1-9)	BGY (1-9)	Seed type (1-9)
MHR314-49	1748	43	4	1	5
MHC2-13-49	1689	30	4	1	5
MHN322-49	1635	23	5	1	Black
MHR314-21	1552	57	4	1	4
MHC2-1-28	1535	50	4	7	5
MH2-18	1456	47	4	1	5
MHC2-8-44	1445	40	5	1	5
MHC2-1-26	1426	67	4	1	5
MHR311-1	1342	23	5	1	4
MHC2-16-26	1304	30	4	1	4
MHC2-10-1	1303	37	5	7	4
MHR312-75	1279	40	4	1	5
MHC2-9-37	1244	27	3	1	4
MHC2-2-27	1232	37	5	1	4
MHR312-25	1218	50	5	1	5
MH2-2	1212	50	5	1	5
MHR314-45	1204	50	4	1	4
MHC2-9-29	1070	57	7	1	5
MHC2-8-50	1058	53	6	6	5
VAX 6	1264	27	4	5	5
Talamanca	1573	47	4	1	9
Tio Canela 75	1360	60	5	1	5
ICTAZAM ML	1596	67	7	1	Black
Carrizalito	1583	57	5	1	4
LSD (0.05)	534	21.6	1.6		

AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); WB incidence(Resistant= 0-25%; susceptible= 75-100%); BGY (scale 1-9; 1-3=resistant, 7-9=susceptible); seed type (small red 1-9, 1=excellent, 9=poor).

Table 11. Performance of the elite small red and black bean breeding lines selected for resistance to angular leaf spot (ALS) from the ERMAN Trial 2011-12 trials conducted in Central America.

Line	Yield-11A/B (kg/ha)	AA	CV	BGY	ALS (pods)	MT	AR
ALS 0546-60	1938	5	Black	1	3	L	I
628-SM15215-33-3	1778	7	4	1	6	I	I
ALS9951-101R1	1613	5	5	1	6	I	E
ALS0532-4	1579	7	4	1	4	I	I
SX14816-71	1510	6	4	1	5	I	I
ALS0546-78	1332	6	Black	1	3	I	I
MHR314-18	1284	7	3	1	6	I	E
AMFF1-12-1-17-1	1270	7	Black	1	6	I	I
ALS0531-97	1243	7	4	1	4	I	I
ALS0626-35	1241	7	3	1	5	I	I
ALS0546-97	1240	6	Black	1	3	I	I
ALS0532-6	1158	6	3	1	3	I	I
MER2221-20	1136	5	4	1	6	I	I
ALS0531-41	1097	6	4	1	3	L	I
AMFF1-12-1-16-1	1046	6	5	1	5	I	I
ALS0532-3	1044	6	4	1	3	I	I
Amadeus 77	1233	5	5	1	7	I	E
GO6727	922	7	Yellow	9	5	L	I
G05686	1146	6	Cream	7	3	L	I
Local check	1822	5	4	8	7	I	I
LSD (0.05)	593	0.9	0.9		1.3		

Yield: Mean from trials conducted under rainfall in the primera (A) and postrera (B) seasons. AA= Agronomic adaptation (scale 1-9, 1= excellent, 9= poor); CV= Commercial value for small reds (1-9, 1=excellent, 9=poor); BGMYV and ALS in pods (scale 1-9; 1-3=resistant, 7-9=susceptible); MT= maturity (E=early, I= intermediate and L=late); AR= plant architecture (E=erect, I=intermediate and P=prostrate).

Table 12. Performance of red mottled lines planted in Haiti, Puerto Rico and the Dominican Republic in 2010, 2011 and 2012.

Line	Traits	2009 Haiti seed yield (kg/ha)	2009 PR seed yield (kg/ha)	2010 PR seed yield (kg/ha)	2010 DR seed yield (kg/ha)	2010 Haiti seed yield (kg/ha)	2011 PR seed yield (kg/ha)	2011 DR seed yield (kg/ha	2011 Haiti seed yield (kg/ha)	Mean seed yield (kg/ha)	b	R^2
PR0633-10	bgm, SW12, I, bc3, SAP6	728	1928	1245	995	500	1509	975	948	1104	1.00	0.92
PR0637-46	bgm, I, bc3, rust, ALS	453	1901	1121	967	487	1390	849	878	1006	1.05	0.91
PR0637-132	bgm, I, bc3, rust, ALS	689	1726	1255	817	418	1339	792	1005	1005	0.92	0.91
PR0637-38	bgm, I, bc3, rust, ALS	527	2094	1310	935	413	1821	776	945	1103	1.25	0.82
PR0637-116	bgm, I, bc3, rust, ALS	359	2024	1288	692	448	1658	836	735	1005	1.24	0.83
PR0637-134	bgm, I, bc3	828	2111	1469	942	489	1509	896	1025	1159	1.14	0.94
PR0633-9	bgm, I, bc3	528	1869	1209	905	428	1671	799	1060	1059	1.06	0.81
PR0633-11	bgm, bc3	539	1328	1113	905	354	1309	779	910	905	0.70	0.76
PR0737-1	bgm, bc3	899	1972	1408	1142	530	1168	942	2153	1277	0.86 (0.95)[1]	0.46 (0.97)[1]
PR0661-75	bgm, I	724	2289	1508	882	509	870	1036	1113	1116	1.21	0.90
PR0661-76	bgm, I	878	2196	1265	802	514	908	932	685	1023	1.12	0.88
PR0661-77	bgm, I	961	2283	1526	701	422	1000	1028	770	1086	1.24	0.87
PR0661-78	bgm, I	511	2283	1538	901	494	1115	1073	670	1073	1.33	0.93
PR0661-79	bgm, I	919	2237	1285	970	407	950	1121	783	1084	1.17	0.91
PR0661-80	bgm, I	520	2039	1315	1005	479	828	1110	1058	1044	1.07	0.89
PR9745-232	bgm, I	1039	2406	1348	750	345	993	1082	935	1112	1.29	0.88
JB-178	I	664	1474	1178	1200	377	953	1156	688	961	0.71	0.73
PC-50	I, rust	645	1816	1178	1280	349	445	1359	1025	1012	0.86	0.56
Mean		703	1921	1251	968	452	1150	954	928			
LSD (0.05)		353	387	NS	261	133	377	278	680			
CV(%)		40.2	16.1	29.4	21.5	24.2	26.1	23.3	58.5			

[1] Haiti 2011 not included in the regression.

Table 13. Performance of elite black bean lines planted in Damien, Haiti in November 2011 and San Juan de la Maguana, Dominican Republic in May and November 2011.

				Haiti			Dominican Republic (Arroyo Loro)		Dominican Republic (Jagua)	
Line	Other identification	Pedigree	Traits	Days to flower	Days to maturity	Seed yield (kg/ha)	100 seed weight (g)	Seed yield (kg/ha)	100 seed weight (g)	Seed yield (kg/ha)
PR1165-3		DPC-40 / Zorro	*bgm,I,bc3*	38.0	65.8	2475	16.5	1903	17.8	1083
PR1165-5		DPC-1 / N06705	*bgm,I,bc3*	38.0	64.4	2150	18.6	1663	17.7	1052
PR1165-17	PR1147-1	PR0518-10 / PR0401-257	*bgm,I, low soil fert.*	36.6	64.4	2615	17.6	1473	19.1	1073
PR1165-19	PR1147-6	"	*bgm,I, low soil fert.*	38.4	64.4	2785	17.7	1624	20.0	1094
DPC-40			*bgm,I,bc3*	36.6	64.4	2568	17.6	1753	20.1	1127
Aifi Wuriti			*bgm,I*	37.8	65.0	2580	17.6	1424	19.5	1101
XRAV-40-4			*bgm,I,bc3*	37.2	63.2	2685	17.2	1366	17.5	1404
Mean				37.5	64.7	2532	17.6	1580	18.7	1043
LSD (0.05)				NS	NS	NS	0.8	NS	NS	NS
CV (%)				4.1	2.1	19.4	3.8	20.0	9.0	24.0

Table 14. Performance of white lines from PR0301-181/ BelMiDak RMR 12 with *bgm, bc3*, rust resistance planted in Puerto Rico, Haiti and the Dominican Republic.

Line	CBB score[1]			Seed yield (kg/ha)								Days to flower	Days to maturity
	PR Oct. 2008	Haiti Nov. 2009	PR Oct. 2010	PR Oct. 2008	Haiti Nov. 2009	PR Oct. 2009	PR Oct. 2010	PR Nov. 2010	Haiti Nov 2011	DR Nov. 2011	Mean	Haiti Nov. 2011	Haiti Nov. 2011
PR0806-80	3.3	3.8	3.2	3145	1057	2596	1618	1417	1929	1521	1898	40.0	66.0
81	3.0	3.4	3.4	3308	1253	2283	1903	1503	2120	1617	1998	38.8	66.0
82	3.0	3.4	3.8	3018	1430	2521	2082	1338	1641	1281	1902	39.4	65.6
83	3.0	4.2	3.2	3237	904	2182	1449	1454	1931	1669	1832	38.0	66.0
84	4.0	3.4	3.8	2873	1222	2154	1549	1554	2657	1952	1994	38.4	66.0
Morales (ck)	3.0	3.8	3.4	3408	1245	2439	1601	1169	1953	1593	1915	38.0	65.6
Verano (ck)	2.3	2.2	3.0	3764	1460	2591	2011	1540	1873	1621	2123	39.0	65.9
Mean	3.3	3.7	3.6	3788	1112	2395	1872	1519	1904	1534		39.0	65.9
LSD(0.05)	1.3	2.1	0.9	835	675	614	641	382	543	390		1.5	NS
CV(%)	25.0	44.5	19.1	13.7	48.2	20.4	27.2	20.0	22.6	20.0		3.0	1.2

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

Table 15. Nodulation (1-9 score) and seed yield of superior bean lines and checks from regional nurseries and trials evaluated under no soil added fertilizer and drought stress (150 mm) conditions. Zamorano, Honduras. January 2012.

Lines	Nodulation (1-9)	Shoot DW (g/pl)	Seed yield (kg/ha)
VIDAC- Small Reds			
SRS 2-37-54	4	7.4	977
NIC 10-3	4	7.3	804
Check (Amadeus77)	2	7.0	730
Range (n=70)	1-6	5.3-10.5	460-1260
VIDAC- Small blacks			
SEQ 342-39	4	6.8	1488
SEQ 341-99	4	9.0	920
Check (DOR390)	2	7.9	469
Range (n=29)	1-4	5.0-11.3	306-1488
ECAR- Small reds			
SRS2-38-14	4	7.2	1035
SRS2-3-23	4	8.0	979
Check (Seda criollo)	5	8.6	928
Range (n=16)	1-5	5.1-8.6	565-1078
ECAR-Small blacks			
SEQ 342-89	4	6.0	1001
MHN322-49	5	6.4	943
Check (DOR390)	3	6.8	519
Range (n=16)	2-5	4.9-7.9	519-1001
ERSAT-Small Reds			
IBC 301-204	5	8.7	2285
628-SM5215-33-3-VB	4	7.2	1523
Check (Seda criollo)	6	11.5	1627
Range (n=16)	2-6	6.3-8.8	895-2285
ERSAT- Small blacks			
SEN 96	6	8.9	1621
MEN2201-64 ML	6	7.8	1597
Check (ICTA Ligero)	5	7.5	1751
Range (n=16)	2-6	6.2-8.9	710-1621

Nodulation score (1-9: 1= none or very few small, white ineffective nodules; 9= >40 large, red effective nodules).

Table 16. Nodulation, shoot, root dry weights and yield after inoculation with *Rhizobium tropici* and *Rhizobium etli* in Juana Díaz, Puerto Rico, 2012.

Treatments	Nodulation score[1] (1-9)	Shoot dry weight (g/plant)	Root dry weight (g/plant)	Seed yield (g/plot)
Control	1.0 b	20.5 bc	2.4 b	819 d
NPK	1.0 b	30.6 abc	2.5 ab	1,230 a
Nitrogen	1.5 b	26.9 abc	2.5 b	1,102 ab
CIAT 899	5.0 a	23.8 abc	2.8 ab	939 abc
UMR 1597	4.0 a	35.6 abc	3.0 ab	1,110 ab
CIAT 632	5.2 a	14.8 c	2.1 b	683 d
UMR 1597 + CIAT 632	6.1 a	23.9 abc	2.4 b	862 bcd
CIAT 899 + UMR 1597	5.0 a	44.0 a	2.6 ab	1,121 abc
CIAT 899 + CIAT 632	6.0 a	22.0 abc	2.4 b	1,036 abc
CIAT 899 + Haiti 1	4.7 a	42.1 ab	3.8 a	1,105 ab
CIAT 899 + CR 477	5.2 a	22.7 abc	2.2 b	985 abc
CIAT 899 + Isabela 1	5.7 a	35.1 abc	2.1 b	1,126 ab
Mean	4.3	28.5	3.6	1,009

[1] Rated on a score from 1 to 9 where: 1 = < 10 nodules and 9 = > 80 nodules/plant.

Table 17. 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

Table 18. Yield of tepary breeding lines and a common bean cultivar tested in multiple trials in Puerto Rico 2011 and 2012.

Genotype	Yield (kg ha^{-1})					
Genotype, Genus (P, *Phaseolus*), Species (v, *vulgaris*; a, *acutifolius*)	2011 Juana Diaz Trial 1 Heat stress Drought stress†	2011 Juana Diaz Trial 2 Heat stress No moisture stress	2012 Juana Diaz Trial 3 Drought stress	2012 Juana Diaz Trial 4 Non-stress	2012 Juana Diaz Trial 5 Heat stress, Extremes in moisture stress	Average Yield Across Trials
TARS-Tep 22; Pa	599*	2303	984	1481	626	1199
TARS-Tep 32; Pa	609*	1739	918	1775	810	1170
Neb-T-1-s; Pa	590	1304	675	1145	629	869
PI _502217-s; Pa	389	1941	866	1158	628	996
Verano; Pv	4	1219	741	1632	139	747
Mean	399	1661	845	1451	637	
LSD (0.05)	278	441	240	435	191	
CV %	49	18.7	20.2	21.2	23.5	

† Drought stress was intermittent stress starting just before flowering through plant maturity
*Not replicated

Table 19. Performance of lines planted in a low N soil at Isabela, Puerto Rico in January 2012.

Line	Seed yield (kg/ha)	Harvest index
B11588	1665	0.42
B11593	1654	0.45
10IS-2423	1607	0.46
B11616	1541	0.51
Zorro	1206	0.42
PR0443-151	1276	0.51
Medalist	504	0.32
Puebla 152 MX	440	0.26
Verano	344	0.16
No-Nod	257	0.37
Mean	822	0.39
LSD(0.05)	681	0.17
CV(%)	51.6	26.8

Dry Grain Pulses CRSP

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

(For the Period: April 1, 2012 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by Oct 6, 2012

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

	Abbreviated name of institutions														
	UPR			USDA-ARS			EAP			NSS-Haiti			IIA- Angola		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	**9/28/2012**	**Y**	**N***	**9/28/2012**	**Y**	**N***	**9/28/2012**	**Y**	**N***	**9/28/2012**	**Y**	**N***	**9/28/2012**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)														
Objective 1: Development, release and dissemination of improved common bean cultivars for Central America, the Caribbean and Angola															
Germplasm adquired and tested for major biotic and abiotic constraints	X	X		X	X		X	X		X	X		X	X	
Breeding populations developed and tested	X	X		X	X		X	X		X	X		X	X	
Advanced trials conducted	X	X		X	X		X	X		X	X		X	X	
Promising lines validated on farms							X	X		X	X				
Basic seed multiplied	X	X		X	X		X	X		X	X		X		X
Improved germplasm or cultivars released	X	X		X	X		X	X		X	X				
Objective 2: Selection of beans for adaptation to low N soils.															
Complete field and greenhouse evaluations to identify most promising sources of BNF germplasm	X	X		X	X		X	X		X	X				
Complete the second cycle of recurrent selection for enhanced BNF							X	X							
Identify efficient Rhizobium strains	X	X					X	X							
Develop breeding lines that combine better adaptation to low N soil and disease resistance or drought tolerance	X	X		X	X		X	X							

Objective 3: Develop molecular markers for disease and pest resistance genes.															
Sources of ashy stem blight resistance acquired and tested	X	X		X	X										
Existing RAPD markers tested				X	X		X	X							
Identification of gene(s) for resistance to common blight	X	X		X	X										
Objective 4: Evaluation of other dry pulse crops for Central America and the Caribbean															
Field testing of cowpeas in PR, Haiti, and Central America	X	X		X	X		X	X		X	X		X	X	
Characterize the phenological, morphological, and agronomic traits of P. lunatus (Haiti, PR)	X	X					X	X		X	X				
Objective 5: Capacity building															
M.S. degree training of Abiezer Gonzalez and Marcelino Guachambala	X	X		X	X										
B.S. degree training of Sara Valentinetti and Lara Melissa Laraíaz				X	X		X	X							
BNF workshop in Honduras	X	X					X	X		X	X		X		
BNF workshop in Mozambique	X	X		X	X								X	X	
-															
Name of the PI responsible for reporting on benchmarks		**J. Beaver**			**T. Porch**			**JC. Rosas**			**E. Prophete**			**A. Chicapa**	
Signature/Initials:															
			Signature							**Date**					

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

Dry Grain Pulses CRSP		
PERFORMANCE INDICATORS/TARGETS for FY 12		
(October 1, 2011 -- September 28, 2012)		
	PII-UPR-1	
	2012 Target	**2012 Actual**
Output Indicators	**(Oct 1 2011-Sept 28, 2012)**	
Degree Training: Number of individuals who have received degree training		
Number of women	**1**	2
Number of men	**2**	4
Short-term Training: Number of individuals who have received short-term training		
Number of women	**25**	33
Number of men	**25**	98
Technologies and Policies		
Number of technologies and management practices under research	**3**	20
Number of technologies and management practices under field testing	**3**	10
Number of technologies and management practices made available for transfer	**1**	5
Number of policy studies undertaken	**0**	

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	**25**	150
Number of rural households benefiting directly from CRSP interventions - Male Headed households	**75**	850
Number of agriculture-related firms benefitting from CRSP supported interventions	**1**	3
Number of producer organizations receiving technical assistance	**4**	4
Number of trade and business associations receiving technical assistance	**2**	3
Number of community-based organizations receiving technical assistance	**2**	5
Number of women organizations receiving CRSP technical assistance	**1**	2
Number of public-private partnerships formed as a result of CRSP assistance		6
Number of HC partner organizations/institutions benefiting	**5**	6
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	**2000**	10,000

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

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Abstract of Research Achievements and Impacts
Field demonstration trials were conducted on research station sites across a wide range of agro-ecological zones to test the effectiveness of locally-produced and US-produced inoculant for common beans. In Uganda, trials conducted at NaCRRI research stations yielded less than the equivalent of 1000 kg/ha, which is far less than yield potential of the varieties tested. Averaged across varieties, there was no consistent response to inoculant or phosphorous fertilizer. In Tanzania, trials conducted in cooperation with SUA indicate large G x E interaction for most yield and BNF traits. Likewise, response to inoculants and phosphorous fertility was highly variable. In Rwanda, trials conducted in cooperation with ISAR showed a large yield advantage of climbing beans. They also confirm inoculation alone or in combination with inorganic P did not always provide a consistent yield increase. Inoculant from Becker Underwood, however, increased seed yield about 10%, on average. The significant effects of inoculation on grain yield and yield parameters of climbing beans reflect their greater yield potential and positive response to intensive management.

Extensive phenotypic information was collected on 100 Recombinant Inbred Lines derived from BAT477 x Dor364 (parental lines with unique rooting characteristics with potential for improving BNF). Data are being used for QTL analysis with a pre-existing linkage map of SSR and SNP markers. Also, a panel of 284 Andean bean genotypes was SNP genotyped with 533 SNP markers. These diversity data shows clustering of many lines collected from Africa, which is useful in identifying the best Andean-derived parental lines for improving BNF. Phenotyping studies were conducted to determine if consistent relationships existed between ureide concentration in individual plant tissues and total plant N or biomass accumulation. Ureide concentrations measured post flowering varied dramatically among lines and plant tissues. Pods accumulated the highest concentrations of ureides, followed by stems, roots, petioles, and leaves.

Concentrations across tissues, however, were not consistent within an individual line. Analyses are in progress to relate these results to genetic variation in total N accumulation.

Training materials were developed to include; benefits of the Nitrogen fixing bacteria in the soil, safety precautions to be observed during storage of inoculum, and procedures to be followed when inoculating seeds. Extensionists and farmer trainers were trained in benefits of BNF and inoculant application techniques using these materials. Eighteen demonstration gardens were established with farmers groups in Kamuli District Uganda. On average, farmers harvested more beans from inoculated and fertilized plots. In most cases, yields were greater with a combination of FYM + BNF, than either treatment alone. These results indicate improved soil fertility management can help farmers achieve better bean yields in the lowland areas of Kamuli District, where bean yields are typically only 300 to 600 kg/ha. A Knowledge, Attitudes, and Practices survey revealed highly positive attitudes among small-landholder farmers about the technology, But they had little knowledge about benefits and uses. Three graduate students completed their thesis research; four others will complete their degree training by May 2013. All undergraduate internships were completed as planned.

Project Problem Statement and Justification

Common beans are the most important legume crop in Uganda, Rwanda and Tanzania occupying a very large proportion of land devoted to legumes. For example, over 45% of the protein intake by Ugandans comes from beans providing 25% of dietary calories. Likewise, over 75% of rural households in Tanzania depend on beans for daily subsistence. Common bean is an important source of protein for low-income families in rural and urban areas providing about 38% of utilizable protein and 12-16% of daily caloric requirements. Improved bean production in Uganda, Rwanda, and Tanzania offers a unique opportunity to address the deteriorating food security situation there and elsewhere in sub-Saharan Africa.

Loss of soil fertility is recognized as the most important constraint to food security in sub-Saharan Africa. Low levels of nitrogen and phosphorous are the primary fertility constraints. Because soils are increasingly becoming degraded, an affordable means of improving soil fertility and productivity of nitrogen-accumulating crops is critical. Properly nodulated legumes can leave up to 350 kg nitrogen per hectare in the soil, depending on effectiveness of the nitrogen fixation process, type of legume, length of time the legume is grown, soil nutrient levels and nitrogen already available. Because inoculum is much cheaper than inorganic fertilizer, use of inoculants can provide an affordable and sustainable way to improve production of nitrogen fixing legumes.

Numerous studies have shown the potential of improving legume productivity by enhancing nodulation through proper use of a biological inoculant. Yet field trials in sub-Saharan Africa have provided mixed results. Likely causes for variable response include poor quality control of inoculant formulation, failure to compete with local rhizobia, inhibition by indigenous microbial flora, or failure of the inoculant species to survive in low pH and/or droughty soils. Modern inoculant formulations designed to deliver a synergistic suite of biological and chemical enhancements for biological nitrogen fixation under stressful soil conditions have been made available to our collaborative research project by Becker Underwood, Inc. 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 have been shown to decrease chemical fertilizer use in crop rotations, increase legume yields, suppress root diseases, and improve rhizosphere conditions for root growth. 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 also is essential to identify germplasm with greatest capacity for this trait. Although common bean has the potential for BNF, it is reported to have the lowest percent N_2 derived from N fixation among legumes. Genetic variation for BNF has been reported within the primary gene pool, and lines with superior BNF have been identified. Superior BNF lines such as Puebla 152 and BAT 477 have been used as parents in crosses to generate populations for genetic studies and to examine selection and breeding for improved BNF. Few breeding lines with improved BNF, however, have been developed. The optimal selection environment for BNF is under low soil N since application of nitrogen fertilizer reduces N fixation capacity. Marker-assisted selection (MAS) under such conditions is highly sought after as a means to facilitate breeding for traits like BNF with low to moderate heritability. Molecular mapping in combination with germplasm screening and MAS would be a powerful way to improve locally adapted germplasm for BNF in a host country. Recombinant inbred populations currently available are ideal for tagging and mapping genes that influence quantitative traits (QTLs). Few QTLs associated with BNF, however, have been identified to date, and those identified have not been validated. Identifying and validating QTL-conditioning enhanced BNF would be a major contribution to the scientific community, and represent a major step toward effective marker-assisted selection for BNF.

Our BNF-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

Planned Project Activities in the Workplan Period (April 2012 to September 2012)

<u>Objective 1:</u> The *first strategic aim* is to 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.

Sub-Objective1a: To evaluate effectiveness of biologically stacked inoculants on local and improved germplasm.

1. Test common bean varieties along with non-nodulating controls and high/low-N treatments at all HC trial locations (NaCCRI, ISAR, SUA)
2. Quantify yield advantage of inoculation for second cropping season (NaCCRI, SUA, ISAR)

Sub-Objective 1b: To quantify genotype by environment interactions and constraints to enhancing BNF of inoculated plants.

3. Complete analysis of plant/soil/weather data (ISU, Makerere, NaCCRI, SUA, ISAR)
   a. Intitate modeling studies of seasonal soil moisture profiles and bean yield
4. Confirm phenotype and yield response to inoculant x genotype x environment (ISU, Makerere, MSU, WSU, NaCCRI, SUA, ISAR)
   a. Incorporate new inoculants from Becker Underwood and local companies in field trials
   b. Quantify plant N, biomass, nodule classes, ureide levels prior to pod fill.
   c. Quantify yield, yield components, NUE, NHI.
   d. Quantify nodule classes and occupancy
5. Confirm indigenous rhizobia levels and relate to local environmental conditions (ISU, WSU, MSU, Makerere)
6. Confirm soil rhizobia soil populations and strain diversity at field sites
   a. Collect nodules, soil samples at field sites, store for analysis
7. Initiate root/nodulation study in greenhouse on selected lines (ISU, MSU, WSU)
8. Complete initial studies on strain x host interactions for BNF (WSU)
9. Identify most effective genotype-inoculant combinations for each eco-zone tested in HC (Makerere, NaCCRI, SUA, ISAR)
10. Calculate economic return for inoculation treatments for season 1 and 2 field trials (NaCCRI, SUA, ISAR)

Methods and Materials

Uganda

The project had four demonstration sites established in Uganda on which objective one was to be carried out and accomplished. The sites included: Namulonge site at National Crops Resources Research Institute (NaCRRI) in Wakiso district (low altitude area), Mbarara stock farm site at Mbarara Zonal Agricultural Research Development Institute (MbaZARDI) in Mbarara district (medium altitude zone), Kabale site at Kachwekano Zonal Agricultural Research Development Institute (KaZARDI) in Kabale district (high altitude zone) and Nakabango site in Jinja district along the Jinja – Kamuli road (low altitude zone) and was established a season later. There were three common bean varieties considered and these had a high market preference that is K_{132}, Kanyebwa and K_{131}, where Kanyebwa is a land race. The site in high altitude was Kachwekano selected for climbing bean and also three varieties included: NABE10c, NABE12c and land race; all these the sites were planted and treated the same. The spacing was 10 x 50cm for non climber varieties in Namulonge, Nakabango and Mbarara sites. For the climbing varieties in Kabale 20 x 50 cm was considered.

Land preparation, demonstration layout and treatments. The field approximately 200m x 40m was mechanized to the fine seed bed. The block was demarcated and subdivided into smaller plots of 3x5m for NaCRRI and Nakabango and 3x2.5m for MbaZARDI and KaZARDI on station. The plots were laid out with 1m peripheral path. There were three major bio-inoculants the Mak-Bio-fixer (R_M) from Makerere University, Bio-N-fix (R_N) from Nairobi University and BioStacked® (R_U) from the Becker Underwood United States of America. On the other hand, phosphorus was applied to all treatment at two rates 0 kg P ha^{-1} and 40 kg P ha^{-1}.

Data collection. Soil samples were collected at the beginning of the season to evaluate fields with low nutrient especially nitrogen. The type of data collection used was a destructive method at both flowering and harvesting stages of growth within a season. Data collected flowering included: leaf area index, nodule numbers per plant, plant biomass, plant height, and at harvest: number of pods per plant, number of seeds per pod, 100 seed weight, and total yield.

Results

Low altitude zone: Namulonge site

In general, seed yields on the small research plots at the NaCRRI station were less than the equivalent of 1000 Kg/ha, which is far less than yield potential of the varieties tested. Averaged across varieties, there was no consistent response to inoculant or phosphorous fertilizer (Table 1). The combination of Nairobi University inoculant amd Phosphorus application provided the greatest positive response, but the yield of unfertilized plots was quite low and the increase relative to the non-inoculated plots was not significant.

Table 1: Response of seed yield (kg ha^{-1}) to Rhizobia inoculation and modest Phosphorous fertilization. Date are the mean of three replicate plots.

P (kg P ha^{-1})	**Rhizobia Inoculum**			
	Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
0	465	653	544	624
40	685	584	652	615
$LSD_{0.05}$		**116.4**		
CV(%)		**35.7**		

There was no significant ($P \leq 0.05$) or consistent impact of inoculum used or Phosphorus fertilizer application on 100 seed weight of the three varieties (Table 2 – Appendix 1). Seed size was fairly consistent across treatments except for K131, which responded positively to fertilizer P with Nairobi University inoculant, and negatively to phosphorus application with Makerere University inoculant. There was not apparent advantage of the Biostacked inoculant on this yield parameter.

The application of inoculant had a significant impact on the stability of seed weight, which varied about 30% between years in the non-inoculated controls (Table 3). The seed weight harvested from plots treated with Biostacked and Nairobi University inoculants varied less than 10% across years.

All varieties produced/supported a small number of nodules, which ranged from about 7 to 10 per plant, on average (Figure 1 – Appendix 1). The same varieties grown in the greenhouse typically support 50 to 100 nodules (data not shown). Application of inoculant had very little effect on nodule numbers measured on these field grown plants.

Medium altitude zone: Mbarara site

Seed yields at the Mbarara site were consistently greater than those at the lowland site (Table 2). The local variety, Kanyebwa, generally achieved the highest yields reaching nearly 2.8 ton/ha in response to inoculant and P fertilizer. Differences in the seed yield among varieties and inoculants and P levels were significant in many cases. Most notable were the K132 response to inoculant, and Kanyebwa response to P application. The positive response to inoculant and P inputs at the higher yield levels is consistent with results of inoculation studies in the N2Africa program (Kenton Dashiell, personal communication).

Table 2: Effect of Inoculation and Phosphorus on seed yield (kg ha^{-1})

Variety	**P (kg P ha^{-1})**	**Rhizobia Inoculum**			
		Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
K132	0	1437	1756	1707	1391
	40	1481	1621	1640	1125
Kanyebwa	0	2121	1865	1565	2022
	40	2763	2363	2156	1481
K131	0	1756	1624	1503	1630
	40	1048	1754	1625	1416
$LSD_{0.05}$		379.5			
CV (%)		23.9			

N.B. The other parameters measured were not significant.

High altitude zone: Kabale site

Climbing bean varieties were evaluated at the high altitude site in SW Uganda. In general, these varieties achieved the greatest seed yields of all three locations tested (Table 3). Yield response to P fertilizer were positive in most, but not all cases. The response of NABE12c was particularly variable. Likewise, the response to inoculant was inconsistent, with no particular trend evident across varieties or P levels.

Table 3: Yield response (g/m2) of three climbing bean varieties to Rhizobia inoculum and Phosphorous fertilization. Data are the mean of three replicate plots.

Variety	**P (kg P ha^{-1})**	**Rhizobia Inoculum**			
		Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
Land race	0	66.5	90.5	190.8	74.5
	40	94.6	104.3	258.5	109.6
NABE10c	0	184.2	107.8	144.1	87.9
	40	240.1	135.9	104.9	270.6
NABE12c	0	136.3	129.0	69.0	93.3
	40	142.1	99.8	115.5	76.2
$LSD_{0.05}$		40.23			
CV (%)		32			

Nodulation score for NABE10c responded positively to P fertilizer, except when the Makerere Univ. inoculant. Otherwise, there did not appear to be a benefit of inoculation on nodulation among climbing bean varieties tested. (Table 6 – Appendix 1). Averaged across varieties tested, there was a significant ($P \leq 0.05$) impact of Biostacked and Makerere Univ. inoculum on 100 seed weight (Table 7 – Appendix 1). Although there was no effect of Nairobi-sourced inoculum on seed weight, there were significant increase in 100 seed weight in response to 40 kg P ha^{-1} for non-inoculated and Nairobi Univ. inoculated plots.

Variation across ecological zones for yield and yield components reflects both the genetic potential of varieties examined and the local weather conditions during the two growing seasons. In 2011 for examples, Namulonge had the highest rainfall amounts in May while for Mbarara and Kabale, it was October and September respectively (Figure 1). For Mbarara and Kabale, the onset of the rains for the first season began in January as opposed to February in Namulonge. The dry spell for all the districts was generally June to August although Namulonge experienced substantial amount of rain in August. While rainfall in March and August are generally beneficial for bean yield, excessive rainfall and high temperatures during vegetative growth are most often detrimental. We have collected available weather data at all test sites and are using these data to assess yield limiting conditions and potential impacts on plant response to inoculants.

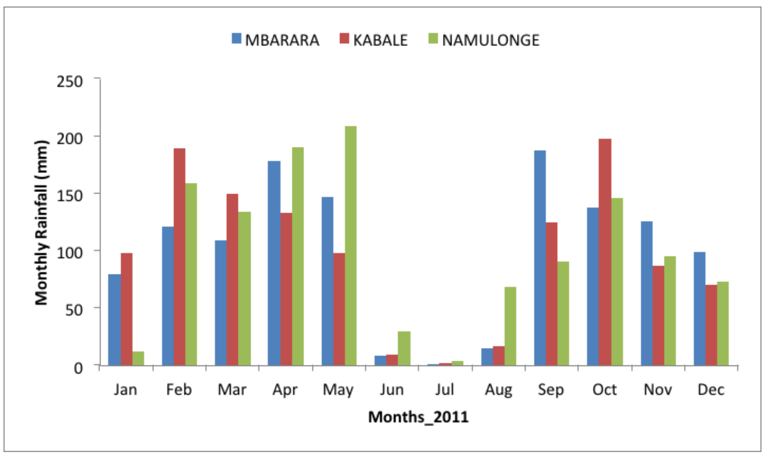


Figure 1: Typical pattern of monthly rainfall at the three ecological zones used for testing inoculant response. Data are for 2011.

Tanzania

Materials and Methods

Experiment 1: Field trials were established at Selian in Arusha (Mid altitude 1000-2000 masl) and SUA in Morogoro(Low altitude 450-600 masl) . In both locations soil samples were collected and analysed. The experimental design used was Complete Randomized Design in a split-split plot arrangement. The treatments included P application (P+ and P-), Rhoizobia application (Biofix inoculum-from Makerere, Nitrosua inoculum-from SUA, and Nitrofix-fromUniversity of Nairobi and the control i.e. without inoculation). Five bean genotypes were used (Bilfa 4, Kablanketi, Rojo, Jesca,). Phosphorous application was the main plot, rhizobia inoculation as sub-plots and genotypes as sub-sub plots.

Experiment 2: Field trials were established at three sites Selian in Arusha, SUA in Morogoro and Uyole in Mbeya (High altitude 2000-2500 masl). In this experiment 16 bean genotypes were used namely, Rojo, Kablanket, Bilfa 4, Lyamungo 85, Carioca, Njano, Pesa, BAT 477, DOR

364, Seliani 97, Zawadi, Mshindi, Maini, SUA 90, and two non nodulating (G4445-A and G51396-A) bean genotypes.

Data were collected on the following variables: leaf N, seed N, roots fresh and dry weights, shoot fresh and dry weight, 100 seed weight, number of pod per plant, number of seeds per pod, seed yield and nodule weight. For this experiment data for Leaf and seed N were not collected because of inadequate funds to perform such analysis.

Results

There was variation among genotypes and among rhizobia inoculant types. Overall, varieties Bilfa 4 and Jesca were the best performers (Table 4). Bilfa- 4 was selected from the Africa Low Soil Fertility Bean Nursery and has proven to do well both at low soil fertility and in well fertilized soils. Jesca is released from the Selian Agricultural Research Institute. About the Rhizobia, the results show that at Arusha Nitrosua was a better inoculant than others while at SUA, Biofix from Makerere and Nitrosua performed well compared to inoculant from Nairobi University.

Table 4. Yield response of local bean varieties to rhizobia inoculations with or without additional Phosphorous fertilizer. Data are the mean of three replicate plots grown at ARUSHA, TX in 2011. Yield (kg/ha)

		INOCULANT				
	Varieties	**BIOFIX**	**NAIROBI**	**NITROSUA**	**NO RHIZOBIA**	**Mean**
P-	Bilfa-4	1117	1040	1292	757	**1052**
	Jesca	1363	759	1347	1021	**1123**
	Kablanketi	748	533	786	628	**674**
	Rojo	790	607	1115	837	**837**
	Mean	**1005**	**735**	**1135**	**811**	**921**
P+	Bilfa-4	815	913	987	1254	**992**
	Jesca	1467	1194	1396	1072	**1282**
	Kablanketi	1036	1146	1325	1247	**1189**
	Rojo	822	919	820	694	**814**
	Mean	**1035**	**1043**	**1132**	**1067**	**1069**
	LSD				573	
	CV (%)				33.4	
-	SE	-	-	-	330.9	

There was no consistent impact of phosphorus on seed yield and other yield parameters Tables 8-11, Appendix 1). As expected, data on nodule counts and nodule dry weight had relatively high CV. Apart from the inoculated rhizobia there could be some native rhizobia in the field that were not distributed uniformly. Related measurement of indigenous soil rhizobia are aimed at detecting major trends in local populations, and likely would not suffice to document spatial variation encountered in this experiment.

Data for Experiment 2 in 2012 are still being analysed. But preliminary results show clear differences among genotypes and a large G x E interaction for most yield/BNF traits (Table 5). There are also good results for nodule number for this experiment currently being analyzed by one of the graduate students, which will be included in the final project report to be submitted early next year. Related measurements indicated that some of the bean genotypes develop at SUA have quite good nodulation (e.g. 'Zawadi', data not shown).

Table 5. Yield response of local bean varieties to rhizobia inoculations with or without additional Phosphorous fertilizer. Data are the mean of three replicate plots grown at Selian in Arusha, SUA in Morogoro and Uyole in Mbeya in 2012. Yield (kg/ha)

		INOCULANT				
	Varieties	**BIOFIX**	**NAIROBI**	**NITROSUA**	**NO RHIZOBIA**	
P-	Bilfa-4	2476	2334	3203	3197	**2803**
	Jesca	2053	1888	1894	1957	**1948**
	Kablanketi	1476	1386	1321	1641	**1456**
	Rojo	1846	1439	1601	2199	**1771**
	Mean	**1963**	**1762**	**2005**	**2249**	**1994**
P+	Bilfa-4	3047	2809	3314	2404	**2894**
	Jesca	2567	2344	2502	2647	**2515**
	Kablanketi	1818	1602	1258	2192	**1718**
	Rojo	1861	1956	2043	2239	**2025**
	Mean	**2323**	**2178**	**2279**	**2371**	**2288**
	LSD				777	
	CV (%)				20.4	
-	SE	-	-	-	436.4	

Soil samples from the two locations where trials were conducted have been analysed and the results are available. Sample of soil has been sent to WSU for analysis mineral Soil temperature data was not collected because equipment to do that is not available. Five years of weather data at the locations where trials were collected is available.

Soil sample from three regions in Tanzania (Morogoro, Mbeya and Arusha) were collected and sent to WSU for determining the presence of indigenous rhizobia levels. In addition, intensive study on this is has been conducted by the M. Sc. Student and the data is currently being analysed, this will be submitted as soon as it is ready. In this study the student identified bean plants that had high nodulation in the field, collected soil around that area to be used in the green house experiment and also he collected seed from those plants for further experimentation.

Rwanda

(Information taken wholly or in part from Tuyiringire, Justin B.S. Thesis, 2012. "Effect of rhizobial inoculation and phosphorous on nodulation and yield of beans" Umutara Polytechnic Faculty of Agriculture (Appendix 2).

Materials and Methods

- **Yield.** The size of each plot was 3m x 4m with seven harvested rows. Grain weight from each plot was expressed in kg/ha adjusted to 11% moisture.
- **Pods per plant** was determined by counting the total number of pods plant^{-1} for twenty randomly chosen plants per plot.
- **Seeds per pod** was determined from a random sample of 20 harvested pods per plot. The mean number of grains per pod in each plot was used for ANOVA.
- **100 seed weight** was estimated from a random sample of 100 seeds taken from the total harvested yield samples. Values also were adjusted to 11% moisture content.
- **Nodule position** on the root system was evaluated on a random sample of plants excavated from 1m of inner rows of each plot. Care was taken to recover as much of the root system as possible without separating nodules from the roots. The position of the nodules was coded as: 3 = crown and lateral nodulation, 2 = crown nodulation, and 1 = lateral nodulation.
- **Nodule interior color.** Pink color within the nodules reflects the presence of leghaemoglobin, which was taken as an indirect indicator of a nodule active in nitrogen fixation. A sample of 10 nodules was taken randomly and each nodule was cut to see its color inside then coded according to dominant color. Nodule clusters were graded from 0 to 5, where 0 = no pink nodules and 5 = all pink nodules.
- **Root length (cm).** Root lengths were estimated on entire root systems excavated for nodule counts and color. Lengths of individual roots were taken with a ruler and summed for the entire root.
- **Experiment design** was a 4 x 6 factorial in a randomized complete block design (RCBD) with three replications in blocks. Main factors were: varieties (bush varieties RWR1668 and RWR2245, climbing varieties MAC 9 and MAC 28); phosphate fertilizer (0, 40 kg/ha); and rhizobium inoculation (source: USA, Makerere University). The trial was composed of 72 treatments in various combinations of variety, fertilizer, and inoculant. Each plot was12 m^2 separated by a 50-cm pathway, and blocks separated by a 1-m pathway.

Results

As observed at the Uganda and Tanzania test sites, there was a significant interaction between bean variety and the $Rh^{\pm}P^{\pm}$ treatment combinations on bean grain yield (Table 6).. The $Rh^{\pm}P^{\pm}$ treatment combinations did not significantly affect bean grain yield in the climbing bean variety MAC 28 and the bush bean varieties RWR 1180 and RWR 2245, but had a significant effect in the climbing bean variety MAC 9. For the climbing bean variety MAC 9, bean grain yield did not significantly vary among five $Rh^{\pm}P^{\pm}$ treatments but was significantly lower in the $RhMP^{+}$ (rhizobium Makerere type inoculated plus phosphate fertilizer applied. (Data presented in Fig 1 – Appendix 2).

Table 6: Effect of bean variety and combinations of rhizobium inoculum and phosphate fertilizer on nodulation and seed yield at Nyagatare Research Station, Nyagatare district, Rwanda in season A, 2011-2012 season. (Rh+ = inoculated, P+ = phosphorous fertilizer added) Source: Table 3. TUYIRINGIRE JUSTIN B.S. Thesis, 2012.

Variety	Nodules position	Nodule colour pink	Nodule colour green or white	Root length (cm)	Pods $plant^{-1}$	Grains pod^{-1}	Grain yield ha^{-1}	100 grain weight (g)
MAC 28	2.444c	3.67b	2.78b	25.17c	11.8c	6.031d	1949.47a	51.64b
MAC 9	2.5c	3.44b	2.67ab	22.67b	11.63c	5.158c	2758.79c	55.46c
RWR 1180	1.556b	1.83a	2a	21.89b	10a	3.778a	1668.05a	43.86a
RWR 2245	0.889a	1a	1.06a	19.61a	10.94b	4.414b	2189.25ab	44.11a
P value	<.001	<.001	0.02	<.001	<.001	<.001	<.001	<.001
± s.e.d	0.202	0.433	0.589	0.994	0.33	0.1421	141.5	0.714
Innoculation treatment								
Rh-P-	1.583	2.25	1.58	22.33	11.15	4.808	2057.83	47.8
Rh-P+	1.917	2.42	2.75	23.67	11.14	4.904	2066	49.32
RhMP-	1.833	2.33	1.75	21.67	11.04	4.733	2217.13	48.72
RhMP+	1.833	2.5	1.83	23	10.72	4.7	1919.13	48.68
RhUSP-	2.083	2.42	2.92	23	11.44	4.875	2268.01	49.16
RhUSP+	1.833	3	1.92	20.33	11.05	5.05	2320.21	48.95
P value	0.518	0.773	0.317	0.109	0.654	0.388	0.195	0.589
± s.e.d	0.2474	0.53	0.721	1.217	0.404	0.174	173.301	0.875
Interactions								
Variety*innoculation								
P value	0.353	0.445	0.817	0.748	0.441	0.496	0.002	0.469
± s.e.d	0.4947	1.061	1.443	2.435	0.807	0.3481	346.602	1.75
CV%	22.7	21	20.5	3.6	2.8	0.9	1.8	0.3

The results of the Rwanda field study confirmed that climbing beans generally out-yield bush beans. They also confirm that inoculation alone or in combination with inorganic P did not always provide consistent positive effects on seed yield. However, the US inoculant whether in combination with phosphate fertilizer or not did increase seed yield about 10% ($P<0.01$). The significant effects on grain yield and yield parameters reflect the greater yield potential of climbing beans and their positive response to intensive management.

<u>Objective 2:</u> The *second strategic aim* is to examine the inheritance of genetic and environmental variation in BNF in common bean, and to identify molecular markers associated with QTL conditioning for enhanced BNF.

Sub-Objective 2a: To identify parental materials for inheritance studies of BNF.

11. Complete initial greenhouse screening on 50 selected lines for BNF response (WSU)
12. Evaluate correlative responses of BNF phenotypic characteristics in field and GH trials (ISU, MSU, WSU, NaCCRI, SUA, ISAR)
13. Confirm nodule rhizobia occupancy on selected lines from US and HC trials (WSU, SUA)
14. Test subset of BNF DP lines on low soil N +/- inoculants in HC field trials (MSU, WSU, NaCCRI, SUA, ISAR)
    a. Include high N treatment, non-nodulation lines for comparison

No information was provided from Washington State University for this portion of the report. Results and conclusions on nodule occupancy will be included in the final project report.

Sub-Objective 2b: To phenotype existing mapping populations for BNF response, populate with molecular markers, and conduct QTL analysis.

15. Characterize soil rhizobia soil populations and strain diversity at field sites
    a. Establish nodule rhizobia occupancy established on selected lines (WSU)
16. Confirm season 1 BNF phenotyping of selected populations [Bean CAP and South American Core]
    a. biomass, plant N, ureide levels prior to pod fill.
17. Conduct SNP analysis (SNP chip) on bean CAP and SA Core collection for association mapping with phenotype data (WSU, MSU).
18. Complete initial list of candidate genes associated with BNF for SNP associations (WSU, MSU).
19. Advance selected RILs to F3 (MSU,WSU)

Materials and Methods

Bat477 and Dor364 are two Mesoamerican bean genotypes known to have different root system architectures and contrasting responses to abiotic stress. Bat477 is tolerant to low P soils and Dor364 is drought tolerant. A RIL population of BAT477 x Dor364 consisting of 100 lines was evaluated for BNF capacity in a greenhouse screen. Three replications of each line were inoculated with rhizobia (CIAT 1899) and grown in eight inch plastic pots in a nitrogen free perlite/vermiculite mix until flowering. Low levels of P were given in a nutrient solution and sufficient levels of all other nutrients. At flowering root weight, shoot weight, and shoot N, P and S were measured.

Results

The means, ranges and correlations for these traits are shown in Tables 1 and 2 of Appendix 4. These data are being used for QTL analysis with a pre-existing linkage map of SSR and SNP markers.

A panel of 284 Andean bean genotypes was SNP genotyped with 533 SNP markers. The data was used to assess diversity, which is presented in an unrooted neighbor joining tree (Figure 2 below). The tree shows a clustering of many lines from Tanzania. There is also a clustering of many of the U.S. cranberry bean germplasm. This information is useful to help identify Andean materials for crossing. A portion of the Andean diversity panel (275 lines) was grown in

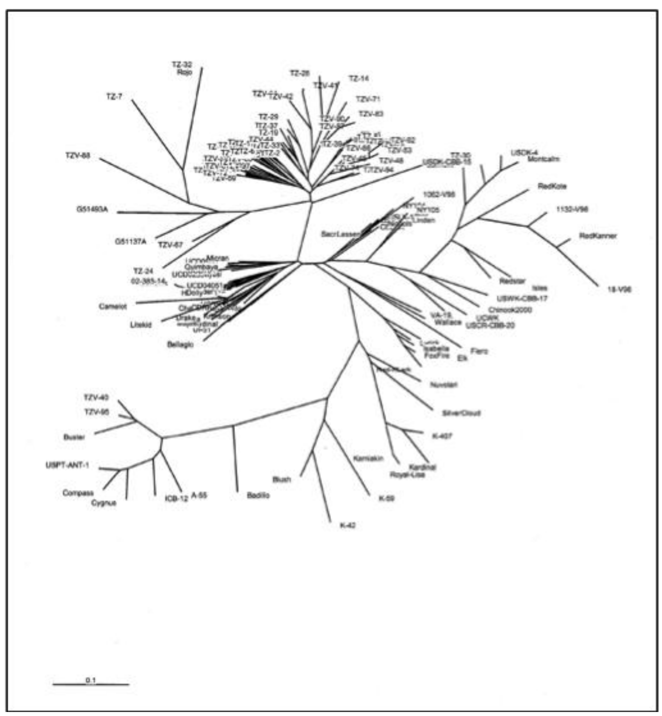


Figure 2. Unrooted neighbor joining tree of 192 *Phaseolus vulgaris* genotypes of the Andean Diversity Panel based on 533 SNP data points and developed with CS Chord (1967) method and 100 bootstraps.

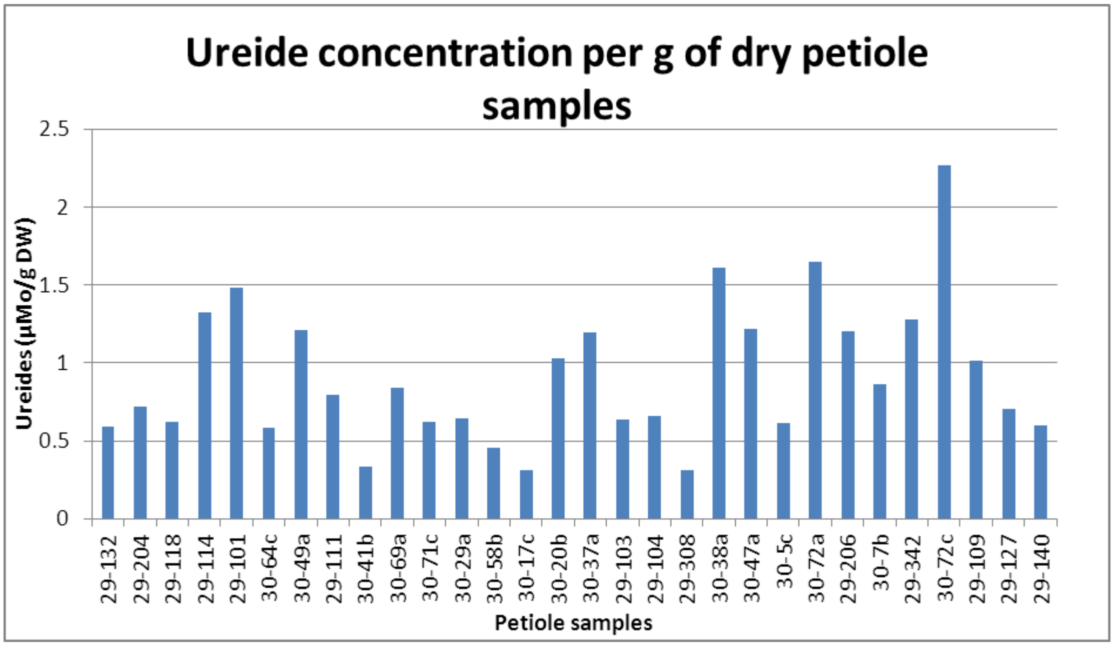
Entrican, MI in 2012 and evaluated for biological nitrogen fixation capacity. Nodulation was estimated at flowering by digging up three plants per genotype per replication (Figure 2-Appendix 4). Some lines were identified with large numbers of nodules but overall the CV for this trait was high (37%) (Figure 2; Table 3 – Appendix 4). Nodule score was weakly correlated to days to flower and plant growth habit (Table 4 – Appendix 4). Nodule score was negatively correlated to aboveground biomass at flowering. This may be because there was sufficient to high levels of N in the soil based on soil tests. The genotypes with the highest nodulation scores were mostly African in origin.

Development of Andean RIL populations with parental lines contrasting in BNF capacity continued with advancement to the F3 generation. Crosses were also made to improve BNF in kidney beans.

Analysis of tissue Ureide levels in selected common bean lines
Ureides (allantoin and allantoic acid) are the principal forms of nitrogen (N) transported in common beans,which originate predominantly from N2 fixation. As such, the level in tisues is an indirect indicator of the extent of N2 fixation in by the nodules. The variation among plant tissues, genetics, and environmental effects, however, make it difficult to relate tissue level to N2 fixation directly. In this study, we extracted ureides from plant tissues (petioles, stem, leaves and pods) and measured relative levels spectrophotometrically against an allantoin standard. The objective was to deterimine which plant tissue, if any, provided a consistent relationship between ureide concentrations and total plant N and biomass accumulation.

Typical results for petioles are shown in Table 7. Average values for individual lines varied nearly 10-fold, from 0.25 to 2.3 µMoles/g DW. Ureide concentrations of individual leaf petioles varied between 0.1 and 2.8 µMol/g dry weight .in the petioles (Table 7). Petioles from cultivar 30-72c had the highest level of ureide concentration while petioles from cultivars 29-308, 30-17c and 30-41b had the lowest ureide concentration levels.

Table 7. Variation in ureide concentration in petiole tissues of selected common bean lines. Data are expressed as allantoin equivalents on a dry weight basis. Values are the mean of three replicate samples.



Ureide concentrations in individual leaf samples varied between 0.1 and 0.8 µMol/g dry weight (Table 2 – Appendix 4). Leaves typically exhibited the lowest levels compared to values observed in stems pods or petioles. Leaves from cultivar 29-101 had the highest level of ureide concentration, while leaves from cultivar 29-111 had the lowest ureide concentration level.

The ureide concentrations varied between 0.1 and 3 µMol/g dry weight in stems (Table 3 – Appendix 4). Stems had the second highest levels of ureide concentrations. Stems from cultivar 29-111 had the highest level of ureide concentration while stems from cultivars 30-41b and 29-308 had the lowest ureide concentration levels.

The ureide concentrations varied between 1 and 90 µMol/g of dry weight in Pods (Table 4 – Appendix 4). Pods had the highest levels of ureide concentrations of all tissues measured. Pods of cultivar 30-20b had the highest level of ureide concentration while pods from cultivars 29-111 had the lowest ureide concentration level.

The results presented in the above figures clearly show that ureide levels varied dramatically among lines and plant tissues. While pods accumulated the highest concentrations of ureides, pod development and pod load was not uniform among all lines when samples were taken. Ureide concentrations typically correlated with tissue (petioles, leaves, stems and pods) biomass. Analyses are in progress to relate ureide and biomass values with total N accumulation.

<u>Objective 3:</u> The *third strategic aim* is to improve the productivity, profitability, and sustainability of agricultural systems on degraded soils through effective dissemination of new information and technologies to small-landholder farmers.

Sub-objective 3a: To improve farmer awareness of inoculation technologies

20. Conduct field days in each HC to sensitize farmers and present research results (VEDCO, NaCCRI, SUA, ISAR)

Sub-objective 3b: To conduct on-farm demonstrations comparing inoculant strategies

21. Conduct on-farm trials initiated with selected farmer cooperators in all HC (VEDCO, NaCCRI, SUA, ISAR)

Sub-objective 3c: To strengthen farmers' collective capabilities to purchase inoculants and incorporate them into a profitable and sustainable system for small landholders,

22. Create training materials to disseminate through PELUM farmer network
23. Conduct information dissemination meetings on BNF with PELUM-associated farmer groups in Rwanda, Tanzania, Uganda, and Kenya (VEDCO)
24. Incorporate research results into extension training programs, farmer advocacy meetings, and PELUM network website (VEDCO)
25. Determine potential for engaging international funding agencies to expand current technology transfer efforts (ISU, Makerere, VEDCO, NaCCRI, SUA, ISAR)
26. Conduct advocacy meetings with farmer groups and agribusiness interests (VEDCO)

VEDCO Farmer Outreach And Training

Create awareness among Extensionists at Host Country institutions on benefits of BNF and Inoculants use as seen in Soybeans: Four Community Based Trainers (1 female, 3 male) and two VEDCO Project Extension Officers were trained on benefits of BNF and inoculants by research staff at NaCCRI and Makerere University. The training involved understanding basic terms and definitions like BNF and the type of bacteria that fix nitrogen in the soil, and the importance of Nitrogen to crops as one of the macronutrients required by plants. The training also focused at the advantages and disadvantages of BNF versus other inputs (fertilizers and Farm Yard Manure). Extensionists were trained on handling of the inoculum during storage and the inoculation process for common beans. After the training, Extensionists visited one of the field demonstration sites where they participated in a practical session of identifying active and inactive nodules, differentiating between nodules and nematode egg sacs on plant roots, and observing the field performance of inoculated plants from Makerere University.

Initiate training materials on BNF and Seed inoculation for Extensionists, community based trainers, farmers: Training materials about BNF and seed inoculation were sourced from Makerere University through its Department of Agricultural Production. The content in the training materials include; benefits of the Nitrogen fixing bacteria in the soil, safety precautions to be observed during storage of inoculum, and procedures to be followed when inoculating seeds.

Evaluate Current farmer Knowledge, Practices and Attitudes (KAPS) about BNF and Inoculation: The KAPS data collection tool was developed, reviewed and approved with an input from all regional PIs and the lead PI from ISU. Upon approval of the tool, research assistants were mobilized and trained on how to collect information from the targeted respondents. Farmer surveys was preceded by pretesting of the tool and about 40% (400) of the total households in VEDCO operational areas where beans are grown as a food crop. This activity was monitored by the Monitoring and Evaluation team of VEDCO and the CRSP project implementing team with support from VEDCO's Community Based Trainers.

Table 7. Number of respondents interviewed per group based on a 40% of the total group size.

Parish Name	No. Groups	Male	Female	No. Households	Sample size	No. Respondents/ Group
Kasambira	20	38	168	206	80	4
Nawanende	27	60	143	203	80	3
Butansi	16	50	86	1366	54	3
Naluwoli	06	22	42	64	26	4
Naibowa	25	93	107	200	72	3
Bugeywa	16	39	130	169	68	4
Bwiiza	6	16	34	50	20	3
Total	**116**	**318**	**720**	**1028**	**400**	

Establishment of farmer field demonstration gardens with BNF as part of the treatments: Eighteen demonstration gardens (each approximately 1/2 acre) were established with farmers groups in Kamuli District Uganda during the second growing season of 2012. Four treatments were planned for each site. These included: seed inoculation (BNF), additiona of farm-yard manure (FYM), both seed inoculant and farm-yard manure (FYM + BNF), and an untreated control. The bean variety was the local one typically grown by the farmer groups. The goals for these demonstration gardens were: to introduce farmers to an alternative soil management technique that can help improve bean yields, to compare the performance of BNF with that of locally available manure, and to observe how the Makerere inoculum performed under the difficult soil conditions typical of Kamuli District. Of the 18 sites, 12 included un-treated areas to serve as a control comparison. Impact of the N treatments on harvested yields relative to the untreated areas is shown in Table 8.

Averaged across all locations, farmers harvested more beans from the inoculated and fertilized plots. Yields were almost always greater with a combination of FYM + BNF, than either treatment alone. These results indicate improved soil fertility management can help farmers achieve better bean yields in the lowland areas of Kamuli District, where bean yields are typically 300 to 600 kg/ha, which is well below genetic potential.

Table 8. Impact of rhizobium inoculation (BNF) and/or farm-yard manure (FYM) on bean yield harvested from on-farm demonstration gardens. Missing data indicate the treatment was not include at the site.

Farmer Group Name	**Relative Yield per Treatment**			
	FYM	**BNF**	**BNF + FYM**	**CONTROL**
2. Kamukamu	05	04	08	01
3. Ekiribaedda	04	03	04	04
5. Baligema Kumunwa	06	04	11	03
6. Bamusambandanda	03	03	10	01
7. Bwigaliro		07		05
9. Bugweya Disabled	04	04	09	02
10. Bugweya Agro Dev.	03	03	08	01
14. Biribawa	10	13	24	03
15. Seka Toyidi	05	03	09	02
16. Bakusekamajja	04	05	10	03
17. Bafuba kukola	06	08	14	05
18. Twisa Kilala	04	04	08	03
Average	**5.1**	**5.1**	**10.5**	**2.8**

Objective 4: Institutional Capacity Building

Capacity building in terms of degree training includes formal education for seven (7) MS level graduate students and five (5) undergraduate students from host countries. Two graduate students will be trained in the Soil Science Department at Makerere University under the direction of Dr. Mateete Bekunda, Professor of Soil Science. Two graduate students will be trained at Sokoine University of Agriculture under the direction of Dr. Susan Mchimbi, Associate Professor of Plant Breeding and Genetics. One HC graduate student will be trained at Washington State University under the co-direction of Dr. Lynn Carpenter-Boggs, Assistant Professor of Soil Microbiology and Biochemistry, and Dr. Phillip Miklas, Legume Research Geneticist with USDA-ARS. One HC graduate student will be trained at Iowa State University under the direction of the program PI, Dr. Mark Westgate, Professor of Crop Production and Physiology. And one HC graduate student will be trained at Michigan State University under the co-direction of Dr. Jim Kelly, Professor of Crop Breeding and Genetics, and Dr. Karen Cichy, Research Geneticist with USDA-ARS.

Capacity building in terms of non-degree training include formal internships for five (5) undergraduate students and training of HC laboratory technicians, field agronomists and extension staff on use and agricultural benefits of seed inoculants. Three undergraduate students were assigned to the field sites in Rwanda to assist in germplasm evaluation supervised by Dr. Augustine Musoni. They interact directly with US PIs during their visits to the field sites. Two undergraduate interns were assigned to work with VEDCO staff on information dissemination.

Host country M.Sc. Graduate Students

First and Other Given Names: **Mercy**
Last Name: **Kabahuma**
Citizenship: **Uganda**

Gender: **Female**
Training Institution: **Iowa State University**
Supervising CRSP PI: **Mark Westgate**
Degree Program for training: **M.S.**
Program Areas or Discipline: **Plant Physiology**
If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID? **YES**
Host Country Institution to Benefit from Training: **N/A**
Thesis Title/Research Area: **Shoot and Root Control of BNF**
Start Date: **Fall 2010**
Projected Completion Date: **Spring 2013**
Training status: **Active**
Type of CRSP Support for training activity: **Full**
Note: Mercy has been accepted for Ph.D. training in the Interdepartmental Genetics program at ISU.

First and Other Given Names: **Martha**
Last Name: **Abwate**
Citizenship: **Uganda**
Gender: **Female**
Degree: **Master of Soil Science**
Discipline: **Soil Science**
Host Country Institution to Benefit from Training: **Makerere University**
Training Location: **Uganda**
Supervising CRSP PI: **Dr. John Stephen Tenywa**
Start Date of Degree Program: **August 2010**
Program Completion Date: **August 2012**
Training Status during FY12: **Completing course work and data collection**
Type of CRSP Support: **Full**
Thesis topic: Influence of drought spells during a rainy season on BNF capacity and yield of common bush bean genotypes

First and Other Given Names: **Peter**
Last Name: **Ssenyonga**
Citizenship: **Uganda**
Gender: **Male**
Degree: **Master of Soil Science**
Discipline: **Soil Science**
Host Country Institution to Benefit from Training: **Makerere University**
Training Location: **Uganda**
Supervising CRSP PI: **Dr. John Stephen Tenywa**
Start Date of Degree Program: **August 2010**
Program Completion Date: **August 2012**
Training Status during FY12: **Completing course work and data collection**
Type of CRSP Support: **Full**

Thesis topic: Phosphorus and molybdenum management for enhanced BNF in common bean production

The BNF-CRSP MSc. students at Makerere University continued to participate in field experimental activities in the four sites, namely Namulonge, Nakabango, Mbarara and Kabale under the supervision of Drs. M. Ugen and J.S. Tenywa. Additionally, they conducted screen-house studies specifically towards their theses research. They completed the research activities and are completing their theses for submission. Each student is preparing a manuscript for possible publication in journals.

First and Other Given Names: **Charles Anselmo**
Last Name: **Komba**
Citizenship: **Tanzania**
Gender: **Male**
Degree: **M.S**.
Discipline: **Plant Breeding and Agronomy**
Host Country Institution to Benefit from Training: **SUA**
Training Location: **SUA, Morogorro**
Supervising CRSP PI: **Susan Nchimbi-Msolla**
Start Date of Degree Program: **Fall 2010**
Program Completion Date: **Summer 2012**
Training Status during FY12: **Coursework and data collection completed**
Type of CRSP Support: **Full**

First and Other Given Names: **Beata Paulo**
Last Name: **Khafa**
Citizenship: **Tanzania**
Gender: **Female**
Degree: **M.S.**
Discipline: **Plant Breeding**
Host Country Institution to Benefit from Training: **SUA**
Training Location: **SUA, Morogorro**
Supervising CRSP PI: **Susan Nchimbi-Msolla**
Start Date of Degree Program: **Fall 2010**
Program Completion Date: **Summer 2012**
Training Status during FY12: **Coursework and data collection completed**
Type of CRSP Support (full, partial or indirect): **Full**

First and Other Given Names: **Michael**
Last Name: **Lege**
Citizenship: **USA**
Gender: **Male**
Training Institution: **Washington State University**
Supervising CRSP PI: **Carpenter-Boggs, Miklas**
Degree Program for training: **M.S.**
Program Areas or Discipline: **Soil Microbiology/Biochemistry**

If enrolled at a US university, will Trainee be a "Participant Trainee" as defined by USAID?
YES
Host Country Institution to Benefit from Training: **Sokoine University Agriculture**
Thesis Title/Research Area: **N2 fixation of rhizobial strains**
Start Date: **Fall 2010**
Projected Completion Date: **Summer 2012**
Training status: **Active**
Type of CRSP Support for training activity: **Full**

Two undergraduate internships at VEDCO
Type of training: Undergraduate Internship on inoculant technologies, management and benefits
Description of training activity: Participation in field operations
Location: Varied, depending on staff and farmer group locations
Duration: 8 weeks
When did it occur? :Summer 2012
Participants/Beneficiaries of Training Activity: Undergraduate students
Anticipated numbers of Beneficiaries: 1 male, 1 female
PI/Collaborator responsible for this training activity: VEDCO, Musoke
List other funding sources that will be sought (if any)
Training justification: Adaptation of new technology requires user understanding of appropriate use, management, and pitfalls.

Three undergraduate internships at ISAR
Type of training: Undergraduate Internship on inoculant technologies, management and benefits
Description of training activity: Participation in field operations
Location: Varied, depending on staff and farmer group locations
Duration: 8 weeks
When did it occur?: Summer 2012
Participants/Beneficiaries of Training Activity: Undergraduate Students
Anticipated numbers of Beneficiaries: 2 female, 1 male
PI/Collaborator responsible for this training activity ISAR, Musoni
Training justification: Adaptation of new technology requires user understanding of appropriate use, management, and pitfalls.

Explanation for Changes
Activities not done
Ureide assay at Makerere University for confirmation of BNF could not be conducted owing to lack of the necessary reagents and equipment.

Yet to Be Accomplished
1. An economic analysis of the response to inoculant, manure, and P applications. This analysis will be included in the final report.
2. A complete assessment of the soil rhizobia communities at the test sites in HC and U.S. where inoculant trials were conducted. Soils have been samples and shipped to WSU. PI Boggs has not sent the info to the team as of yet. This information is an essential part of our project and will be included in the final report.

3. Dissemination of inoculant technology through the PELUM farmer association network. Two reasons: First is political pushback from PELUM organizations outside of Uganda. This is still being worked out through VEDCO's advocacy lead. As noted in the FY12 report, farmers were very receptive to learning more about the technology. Second is inconsistent results using HC-produced inoculant. There must be a dramatic improvement in laboratory capacity and quality control before a broad-based effort is launched to advocate this technology to small-landholder farmers (one of our lessons learned).

Challenges

Access to detailed information regarding the Biostacked inoculant was not possible. Accessing weather data from Rwanda remains a challenge due to heavy restrictions.

Networking and Linkages with Stakeholders

On-farm demonstrations

Dr. Tenywa and both students contributed to the construction of baseline data collection tools used by VEDCO to evaluate the knowledge gaps of the targeted farming communities. They also collaborated with VEDCO in the design and laying out of demonstration plots in Kamuli district. Furthermore, Dr. Tenywa coordinated the analysis of soil samples and processing of plant samples collected by VEDCO.

Other activities

An in-country inter-CRSPs meeting was held at Makerere University, on 25th April 2012, for the 9 CRSPs hosted by Makerere University. The BNF CRSP was one of them. As PI of the project, Dr. Tenywa made a PPT presentation on the project profiles and progress made, including collaborators. The students presented posters on their research activities. Martha Abwate, the female student on the project was selected as a fellow on the mentoring program of the African Women in Agricultural Research and Development (AWARD) based in Nairobi, Kenya. The cohort attended their first meeting and training at Mombasa in September 2012

Leveraged Funds

To be included in final project report

Scholarly Activities and Accomplishments

To be included in final project report

Tables/Figures

See Appendices for additional data not discussed in detail in this report.

Contribution of Project to Target USAID Performance Indicators

Graduate and undergraduate training is central to this project. Supporting advanced education for HC students with world-class scientist and training field technicians will contribute directly to HC capacity building.

Training of farmers and farmer groups on technologies to improve bean productivity will contribute to income and food security of small landholder farmers.

Improved on-farm productivity will enhance marketing opportunities for farmer associations.

Advancing inoculant technology for legumes will promote agricultural enterprise associated with inoculant production and sales.

New knowledge on bean germplasm x inoculant x environment interactions to inform ongoing variety development programs in the U.S. and host countries about specific improvements in BNF needed to realize enhanced yield, nutritional value, and marketability of dry beans and other pulses.

Seven graduate students and (at least) five undergraduate students trained in agricultural research and extension.

Contribution to Gender Equity Goal
Four of seven graduate students, and three of five undergraduate students trained through this program are female. These individuals are being mentored to continue their academic careers and assume leadership roles in agricultural fields.

Most (60 to 65%) of the small land holder farmers and farmer groups served by VEDCO are female. Improving productivity of common beans intentionally targets women farmers since they are generally in charge of growing this crop and managing the proceeds from it.

Progress Report on Activities Funded Through Supplemental Funds
To be included in project final report

Appendix 1: Field plot data

Data from Uganda field trials

Low altitude zone: Namulonge site

Table 1: Response of seed yield (kg ha^{-1}) to Rhizobia inoculation and modest Phosphorous fertilization. Date are the mean of three replicate plots.

P (kg P ha^{-1})	Rhizobia Inoculum			
	Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
0	465	653	544	624
40	685	584	652	615
$LSD_{0.05}$		**116.4**		
CV(%)		**35.7**		

Table 2: Namulonge site 100 seed weight (g)

		Rhizobia			
Variety	**P (kg P ha^{-1})**	**Nairobi Uni.**	**Biostacked**	**Makerere Uni.**	**Control**
K132	0	31.8	26.0	28.8	29.6
	40	34.3	33.8	29.4	28.6
Kanyebwa	0	44.7	43.7	40.4	41.0
	40	44.7	38.5	39.5	40.4
K131	0	34.2	35.4	38.5	29.9
	40	40.0	34.7	30.5	31.2
$LSD_{0.05}$			**6.6**		
CV (%)			**20**		

Table 3: effect of season and Rhizobia on 100 seed weight (g)

Seasons	Rhizobia Inoculum			
	Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
1	37.3	34.1	29.8	28.1
2	39.3	36.6	39.2	38.8
3	38.3	35.3	34.5	33.5
$LSD_{0.05}$			**4.7**	
CV (%)			**20**	

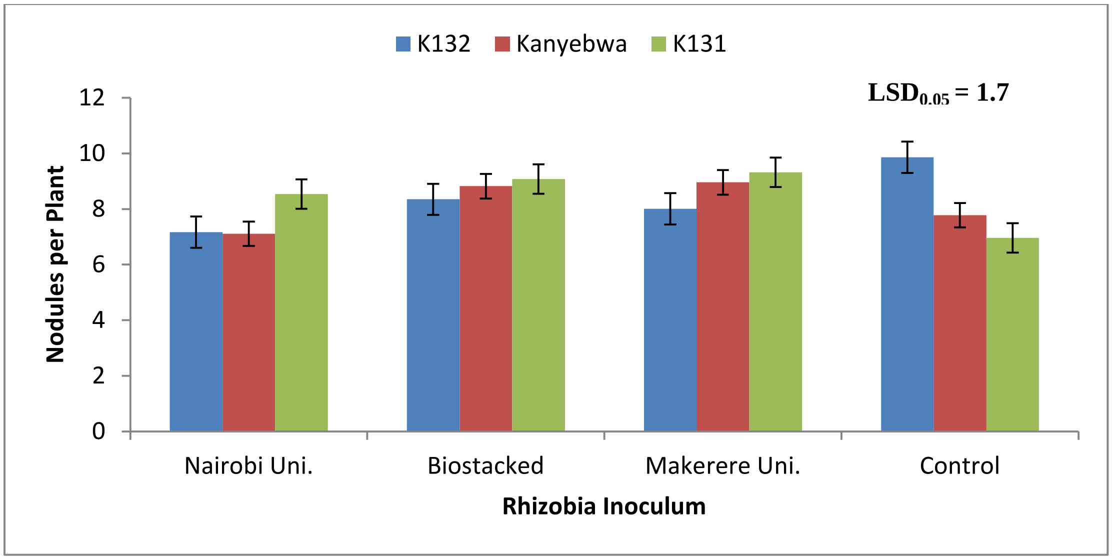


Figure 1: Variation in nodule number per plant at the Namulonge site. Names under the column groups indicate the inoculant applied at planting. Inoculation did not have a significant impact on average nodule number per plant.

Medium altitude zone: Mbarara site

Table 4: Effect of Inoculation and Phosphorus on seed yield (kg ha^{-1})

Variety	P (kg P ha^{-1})	Rhizobia Inoculum			
		Nairobi Uni.	Biostacked	Makerere Uni.	Control
K132	0	1437	1756	1707	1391
	40	1481	1621	1640	1125
Kanyebwa	0	2121	1865	1565	2022
	40	2763	2363	2156	1481
K131	0	1756	1624	1503	1630
	40	1048	1754	1625	1416
$LSD_{0.05}$		379.5			
CV (%)		23.9			

N.B. The other parameters measured were not significant

High altitude zone: Kabale site

Table 5: Effect of P and Rhizobia Inoculum on climbing bean yield

Variety	P (kg P ha^{-1})	Rhizobia Inoculum			
		Nairobi Uni.	Biostacked	Makerere Uni.	Control
Land race	0	66.5	90.5	190.8	74.5
	40	94.6	104.3	258.5	109.6
NABE10c	0	184.2	107.8	144.1	87.9
	40	240.1	135.9	104.9	270.6
NABE12c	0	136.3	129	69	93.3
	40	142.1	99.8	115.5	76.2
$LSD_{0.05}$		40.23			
CV (%)		32			

Table 6: Effect of treatment on nodulation potential of climbing beans at Kabale (high altitude) site in Uganda

Variety	P (kg P ha^{-1})	Rhizobia Inoculum			
		Nairobi Uni.	Biostacked	Makerere Uni.	Control
Land race	0	1.7	1.3	1.0	3.7
	40	1.7	3.7	4.3	4.3
NABE10c	0	3.0	1.3	5.0	1.7
	40	8.0	5.0	5.0	4.0
NABE12c	0	3.3	3.3	3.3	3.3
	40	1.3	1.3	7.3	1.3
$LSD_{0.05}$		3.6			
CV (%)		65.7			

Table 7: effect of P and Rhizobia inoculation on 100 seed weight

P (kg P ha^{-1})	Rhizobia Inoculum			
	Nairobi Uni.	Biostacked	Makerere Uni.	Control
0	22.11	28.1	27.8	23.05
40	30.68	28.29	25.92	29.21
$LSD_{0.05}$	3.69			
CV (%)	22.3			

Table 8: Effect of Rhizobia inoculum on variety 100 seed weight

Variety	**Rhizobia Inoculum**			
	Nairobi Uni.	**Biostacked**	**Makerere Uni.**	**Control**
Land race	13.47	31.34	28.92	32.35
NABE10c	28.48	27.53	23.73	26.44
NABE12c	37.24	25.72	25.75	21.8
$LSD_{0.05}$		4.51		
CV (%)		22.3		

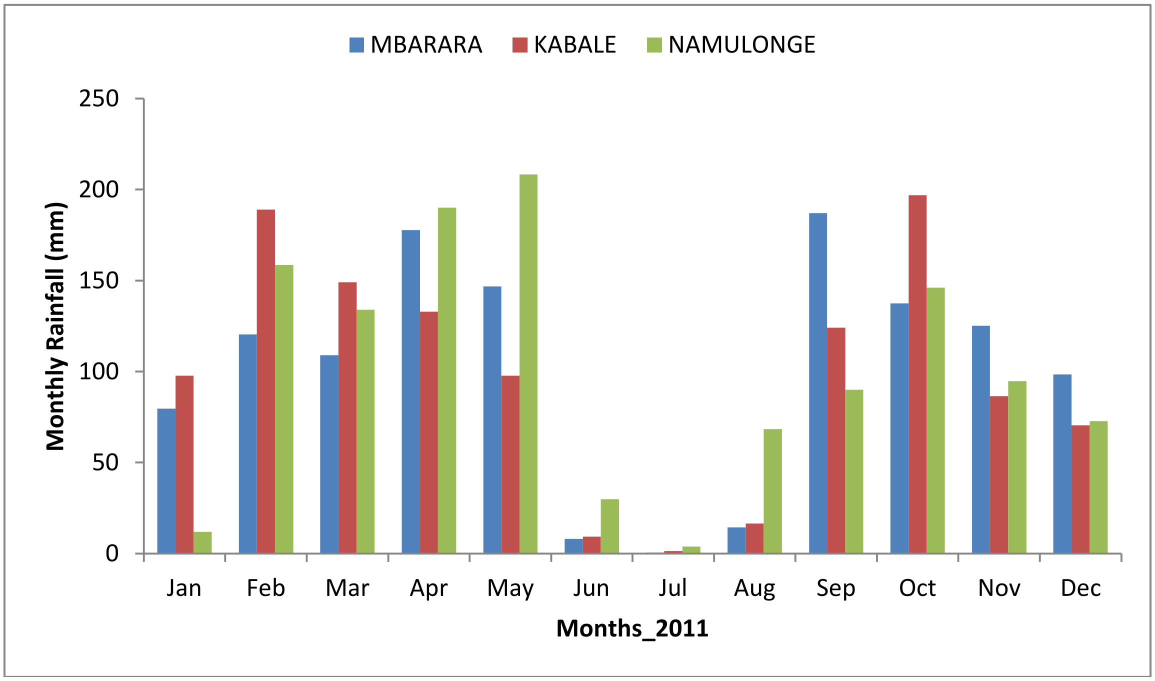


Figure 2: Monthly Rainfall for 2011

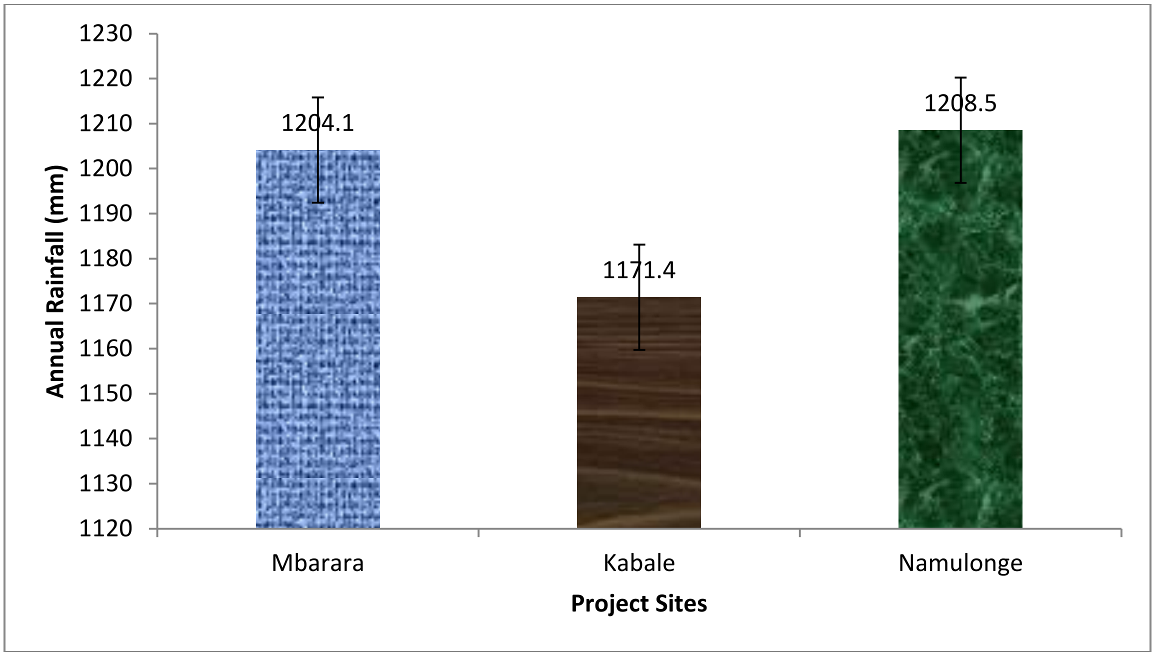


Figure 3: Annual Rainfall 2011

Data from Tanzania field trials

Table 6. ARUSHA BNF Experiment 2012

Yield (kg/ha)

		INOCULANT				
	Varieties	**BIOFIX**	**NAIROBI**	**NITROSUA**	**NO RHIZOBIA**	**Mean**
P-	Bilfa-4	1117	1040	1292	757	**1052**
	Jesca	1363	759	1347	1021	**1123**
	Kablanketi	748	533	786	628	**674**
	Rojo	790	607	1115	837	**837**
	Mean	**1005**	**735**	**1135**	**811**	**921**
P+	Bilfa-4	815	913	987	1254	**992**
	Jesca	1467	1194	1396	1072	**1282**
	Kablanketi	1036	1146	1325	1247	**1189**
	Rojo	822	919	820	694	**814**
	Mean	**1035**	**1043**	**1132**	**1067**	**1069**
	LSD				573	
	CV (%)				33.4	
-	SE	-	-	-	330.9	

Table 7. 100 seed weight (g)

		INOCULANT				
	Varieties	**BIOFIX**	**NAIROBI**	**NITROSUA**	**NO RHIZOBIA**	**Mean**
P-	Bilfa-4	28.0	27.8	27.7	29.6	**28.3**
	Jesca	47.7	42.1	46.6	46.6	**45.7**
	Kablanketi	43.4	36.8	38.1	35.3	**38.4**
	Rojo	34.1	39.0	33.6	35.7	**35.6**
	Mean	**38.3**	**36.4**	**36.5**	**36.8**	**37.0**
P+	Bilfa-4	27.1	32.3	27.2	27.9	**28.6**
	Jesca	44.2	46.8	46.6	46.5	**46.0**
	Kablanketi	43.4	49.3	39.9	38.9	**42.9**
	Rojo	36.8	35.1	34.8	33.7	**35.1**
	Mean	**37.9**	**40.9**	**37.1**	**36.7**	**38.2**
	LSD				7.83	
	CV (%)				11.5	
-	SE	-	-	-	4.3	

Table 8.
Pod/plant

	Varieties	INOCULANT BIOFIX	NAIROBI	NITROSUA	NO RHIZOBIA	Mean
P-	Bilfa-4	7	6	6	6	**6**
	Jesca	5	3	5	4	**4**
	Kablanketi	3	6	5	5	**5**
	Rojo	6	5	6	5	**5**
	Mean	**5**	**5**	**5**	**5**	**5**
P+	Bilfa-4	6	6	10	5	**7**
	Jesca	6	5	5	4	**5**
	Kablanketi	4	4	4	4	**4**
	Rojo	5	6	6	5	**6**
	Mean	**6**	**5**	**6**	**4**	**5**
	LSD				1.44	
	CV (%)				35.7	
_	SE	_	_	_	1.87	

Table 9.
Seed/pod

	Varieties	INOCULUM BIOFIX	NAIROBI	NITROSUA	NO RHIZOBIA	Mean
P-	Bilfa-4	4.1	4.9	4.5	4.7	4.6
	Jesca	3.6	3.1	4.0	4.2	3.7
	Kablanketi	4.6	4.1	4.1	3.4	4.1
	Rojo	4.8	4.3	4.4	4.5	4.5
	Mean	4.3	4.1	4.3	4.2	4.2
P+	Bilfa-4	5.0	5.1	4.7	4.5	4.8
	Jesca	3.9	4	3.8	3.8	3.9
	Kablanketi	3.7	4.1	3.9	4.4	4.0
	Rojo	4.8	4.4	4.4	4.2	4.5
	Mean	4.4	4.4	4.2	4.23	4.3
	LSD				0.91	
	CV (%)				13.6	
_	SE	_	_	_	0.58	

Table 10. Shoot dry weight

	Varieties	INOCULANT BIOFIX	NAIROBI	NITROSUA	NO RHIZOBIA	Mean
P-	Bilfa-4	4.67	4.60	4.17	4.27	**4.43**
	Jesca	6.00	4.30	5.50	4.53	**5.08**
	Kablanketi	3.47	5.20	5.90	3.90	**4.62**
	Rojo	2.80	4.23	3.73	2.30	**3.27**
	Mean	**4.24**	**4.58**	**4.83**	**3.75**	**4.35**
P+	Bilfa-4	4.80	4.90	5.93	2.80	**4.61**
	Jesca	4.60	3.03	4.60	5.30	**4.38**
	Kablanketi	6.33	4.10	4.07	4.47	**4.74**
	Rojo	5.47	5.63	5.13	6.30	**5.63**
	Mean	**5.30**	**4.42**	**4.93**	**4.72**	**4.84**
	LSD				3.66	
	CV (%)				44.6	
-	SE	-	-	-	2.05	

Appendix 2: Additional results from Genomics studies as MSU and WSU

Table 1: Traits related to BNF in a greenhouse screen of 100 RILs of BAT 477 x Dor 364 in East Lansing, MI in 2012.

Variable	Mean	Std Dev	Minimum	Maximum	Fold Difference
root wt. (g)	1.45	0.52	0.29	3.84	13
shoot wt. (g)	3.61	1.28	0.45	8.02	17
% N	2.39	0.36	0.74	3.26	4.4
% S	0.25	0.06	0.16	0.73	4.6
% P	0.32	0.07	0.18	0.66	3.7

Table 2: Pearson correlation coefficients among BNF related traits of 100 RILs of BAT 477 x Dor364 in East Lansing, MI in 2012.

	Root wt.	**Shoot wt.**	**%N**	**%S**	**%P**
Root Wt.	----	0.61 <.0001	-0.31 <.0001	-0.16 0.006	NS
Shoot Wt.		----	-0.48 <.0001	-0.3 <.0001	-0.11 0.06
% N			----	0.18 0.0017	NS
%S				----	0.46 <.0001

Rating	Estimated # of Nodules
0	None
1	≤ 20
2	20-50
3	50-100
4	100-200
5	200-400
6	≥ 400

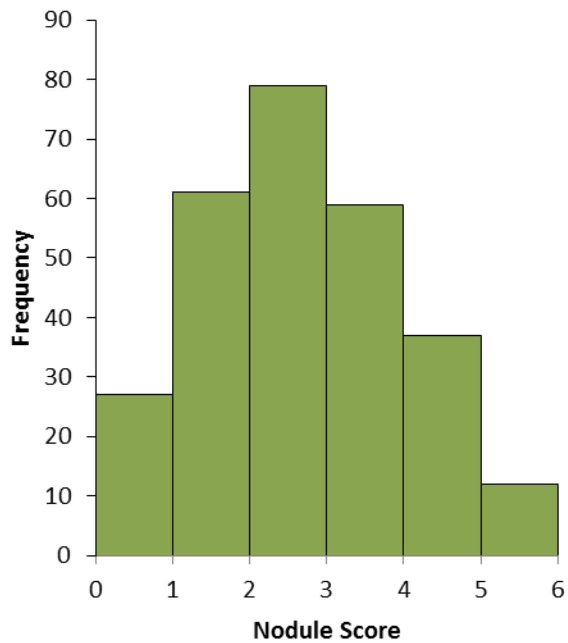


Figure 2: Nodule score rating chart and frequency distribution of nodule score of 275 lines of the Andean Diversity Panel grown in Entrican MI in 2012.

Table 3: Agronomic data on 275 lines of the Andean Diversity Panel grown in Entrican, MI in 2012.

ID	Genotype	nodule rating	growth habit	shoot wt. flw. (g)	days to flower	SPAD 35 DAP	Harvest index
Meso no nod	R99	0	2	64.6	.	40	.
no nod 1	G51496A nn	0	1	36	.	35.7	.
no nod 2	G51493A nn	0	1	35.4	.	35.9	.
no nod 3	G51495A	0	1	59.2	.	36.3	.
AF-6	Witrood	1	1	45.8	46.5	32.1	41.1
AF-12	Mishindi	1	1	27	47.5	40.6	51.7
AF-17	Uyole 96	1	2	52	45.5	31.6	43.7
AF-22	A483	1	1	38.5	49.5	38.4	48.6
CC-13	G 4499	1	2	43.6	37	39	45.1
PR-2	Colorado del Pais	1	2	45.3	39.5	38.9	38.4
BC-401	Dolly	1	1	45.3	49	32.4	32.7
AF-4	Bwana Shamba	1	1	50.3	44	34.8	52.5
AFV-15 (ADP110)	SUG 131	1	2	63.4	41	40.2	50.8
CAP100	K07921	1	1	25.1	33	35.6	39.6
CAP117	Fox Fire	1	1	65.6	32	38.9	47.2
CAP118	Lassen	1	1	54.3	38.5	40.7	38.8
CAP119	Sacramento	1	1	38.5	34	41	39.6
CAP252	Fiero	1	1	56.4	42	35.2	47

CAP256	USLK-1	1	1	44.4	39	34.6	50.8
CAP275	USWK-CBB-17	1	1	42.1	38.5	35.8	48.5
CAP318	Cran-09	1	1	35.6	47	35.8	48.5
CAP369	UCD 0405	1	1	43.4	30.5	33.8	45.4
CAP377	CELRK	1	1	35.6	46	34.6	48.6
CAP398	Pink Panther	1	1	37.3	43.5	34.8	45.1
CAP64	Isabella	1	1	57.3	45	40.1	0
Majesty	Majesty	1	2	29.2	45.5	39.2	0
CC-15	G 4644	1.5	1	30.3	47	37.7	45.9
TZ-27	Incomparable	1.5	1	37.9	47	34.2	48.6
CC-41	G 18356	1.5	1	30	45	37.6	21.6
CC-51	G 22455	1.5	2	49.6	46.5	35.8	40.5
PR-7	PR9745-232	1.5	1	43.3	42	38.2	48.3
PR-11	PC-50	1.5	1	36.9	39	44.9	32
PR-16	Larga Comercial	1.5	2	26.7	47	35	44.8
EC-1	INIAP 414	1.5	1	52.5	48	33	53.2
EAL-8	PI449430	1.5	1	31.8	35	37.6	49.4
AFV-23	Werna	1.5	2	29.3	43	37.1	49.7
CAP107	Taylor Hort.	1.5	1	65.6	33.5	35.1	37.4
CAP108	Cardinal	1.5	1	52.8	38	32.9	42.7
CAP171	UI-686	1.5	2	52.8	44.5	42	50.6
CAP262	USCR-7	1.5	1	49.6	45.5	35.2	43.2
CAP263	USCR-9	1.5	2	36.3	35.5	37.4	42.1
CAP264	USCR-CBB-20	1.5	1	53.1	35.5	33.9	41.2
CAP277	VA-19	1.5	1	56.7	41.5	35.5	53.2
CAP285	ICA Quimbaya	1.5	1	46.4	46	33.3	48.5
CAP376	Jalo EEP558	1.5	1	57.2	44	35.5	48.4
CAP503	H9659-23-1	1.5	2	52.6	34	32.8	0
TZ-10	CANADA	2	1	41.9	45	37.1	44.1
TZ-11	KIBOROLONI	2	1	30.8	33.5	35.1	49.2
CC-4	G 1375	2	2	41.6	41.5	32.1	50.9
CC-23	G 7930	2	1	39.9	34	39	41
TZ-30	RH No. 6	2	1	43.3	46.5	37	53.9
CC-52	G 22502	2	2	31.3	53	31.2	46.7
CC-56	G 23093	2	2	62.3	46.5	39.2	39
USC-1	PI 189408	2	1	31.7	45	36.7	35.8
PR-1	Badillo	2	1	26.6	66	37.7	45.8
PR-19	Chijar	2	2	28.7	65.5	39.9	37.3
EC-4	INIAP 422	2	1	53.1	46.5	35.6	38.8
EAL-21	PI527530	2	2	26.9	36	31.1	50.8
EAL-25	PI209815	2	2	42.1	50	36.1	35.6
TZ-5	KABUKU	2	1	36.9	38	39.3	53.5
AG-2	Fernando	2	1	31.2	45	41.4	41.7

AG-12	Katarina, Cela	2	2	33.2	40	34.8	46
BCV-505	TARS HT 1	2	1	31.7	66	31.7	52.6
TZV-67	NJANO	2	2	49.8	66	36.2	40.1
AFV-16	Uyole 98	2	2	44.1	48	35.5	42.5
AFV-17	Uyole 96	2	2	46.2	50	30.6	48.5
AFV-19	OPS-RS1	2	2	63.3	38	34.7	54.4
CAP149	Wallace 773-V98	2	1	30.6	45	32	48.8
CAP153	NY104	2	1	30.6	45.5	35.2	53
CAP154	NY105	2	1	38.5	42.5	35.5	42.1
CAP175	UI-51	2	1	46.7	41	35.2	45
CAP245	Kamiakin	2	1	48.7	42.5	30.7	56.2
CAP253	Royal Red	2	1	47.9	38	33.8	47.7
CAP254	Kardinal	2	1	47.9	35	31.7	48.3
CAP274	Silver Cloud	2	1	38.9	43.5	33.6	42.5
CAP338	Litekid	2	1	35.8	33	33	51.3
CAP344	OAC Lyrick	2	1	35	45	37.7	45.8
CAP347	Red Rider	2	1	46	45.5	34.2	50
CAP351	AC Elk	2	1	46.5	37	35.5	52.2
CAP396	Etna	2	1	41	45	33.3	52.3
CAP397	Hooter	2	1	43.5	45	33.9	58.1
CAP501	H9659-27-7	2	2	45.5	42.5	34.6	47.8
CAP502	H9659-27-10	2	2	54.9	39	33.2	0
CAP507	UC Red Kidney	2	1	58.5	36	38.7	0
CAP510	Clouseau	2	1	46.4	38	34.4	0
CAP58	Montcalm	2	1	33.6	43	37.2	0
CAP83	Beluga	2	1	53.6	39	36.6	0
AF-8	Pesa	2.5	1	40.4	46	36.3	42.5
AF-25	Tygerberg	2.5	2	40.5	48	37.8	47
CC-12	G 4494	2.5	1	35	46.5	32.5	49.4
CC-14	G 4564	2.5	1	32.4	66.5	37.1	38.7
CC-17	G 4970	2.5	1	30.7	31.5	36.8	43.8
CC-18	G 5034	2.5	1	32.9	44.5	39.3	44.5
CC-21	G 6239	2.5	2	48.7	47.5	37.4	56.1
CC-25	G 8907	2.5	2	28.3	42.5	45.5	47.1
TZ-25	RUHONDELA	2.5	1	30.9	48	37.5	28.2
TZ-28	Sisi	2.5	1	44	42.5	34.9	45
CC-38	G 14440	2.5	2	63	35.5	40.4	47.3
TZ-29	RH No. 2	2.5	2	29.8	49.5	36.8	25.3
CC-40	G 17913	2.5	1	36.2	45	36.4	46
CC-43	G 21210	2.5	1	25.1	39	35.5	41.6
USC-7	PI 310511	2.5	1	34.4	37	33.7	51.2
PR-9	RM-05-07	2.5	1	25.9	40.5	40.1	34.7
TZV-45	RH No. 12	2.5	2	26	48.5	34.9	47

EC-9	INIAP 430	2.5	1	24.3	44.5	30.4	55.3
EAL-2	PI331356-B	2.5	1	39.1	49.5	31.1	48.7
EAL-5	PI353534-A	2.5	1	27.9	36.5	38.9	50.7
EAL-24	PI209802	2.5	1	40.1	47	32	40
AG-11	Mantega blanca, Kibala	2.5	2	53	48.5	33.8	40.1
TZV-56	KABUKU	2.5	2	28	51	38.7	51
BC-76	Isles	2.5	1	36.2	36	35.5	46
BC-248	K-407	2.5	1	35.5	44	33.2	54.6
BCV-508	OAC Redstar	2.5	1	34	37.5	35.1	45.7
TZV-85	KABLANKETI	2.5	2	42.4	45.5	33.4	47.7
AFV-26	Kranskop HR-1	2.5	2	43.9	35	36.3	43
CAP148	Red Kloud	2.5	1	33.9	32.5	38.8	50
CAP152	1132-V96	2.5	1	59.2	45.5	35.5	49.3
CAP246	K-42	2.5	1	45.1	41.5	32.5	44.9
CAP247	K-59	2.5	1	54.3	46	34.1	40.8
CAP250	USDK-CBB-15	2.5	1	35.3	43	37.1	37
CAP261	Krimson	2.5	1	49.8	48	40.1	48.9
CAP265	G-122	2.5	1	34.8	45.5	36.6	50
CAP360	UC Nichols	2.5	1	45.7	38	38.7	41.2
CAP370	UCD 0801	2.5	1	36.7	40.5	31.1	52
CAP500	H9659-21-1	2.5	2	76.7	48	35.6	30.2
CAP81	Red Hawk	2.5	1	55.2	39.5	36	0
AF-28	Jenny	3	2	45.2	59.5	33.4	45.4
AF-29	Pesa	3	2	42.7	31.5	34.8	50.6
TZ-18	SODAN	3	1	34	49.5	34.8	40.5
TZ-19	KASUKANYWELE	3	1	17.4	43	34.1	47.5
CC-9	G 3452	3	2	41.6	48.5	36.1	41.2
TZ-22	KISAPURI	3	1	27.3	44.5	36	44.3
CC-20	G 5625	3	1	43.4	38	33.3	45.9
CC-27	G 9013	3	1	47.8	65.5	38	55.5
TZ-26	Black Wonder	3	1	31.3	46.5	35	42.1
TZ-32	RH No. 21	3	1	30.3	66	34.9	52
TZ-34	KIJIVU	3	1	25.8	51.5	33.9	56.7
USC-2	PI 203934	3	2	47	48.5	42.7	44.1
USC-4	PI 307808	3	1	29.7	47.5	33.3	52.2
TZV-42	MKOKOLA	3	2	32.3	36	33.8	49.9
PR-5	Gurabo 5	3	1	35.8	51	38.7	52.3
PR-12	46-1	3	2	54	47.5	44.6	36.2
EC-5	INIAP 424	3	1	39.8	38.5	33.2	48.5
EC-6	INIAP 425	3	1	37.9	45.5	33.6	42.1
EAL-1	PI331356-C	3	1	40.7	45	36	38.9
EAL-12	PI527508	3	2	42.5	38.5	31.5	43.4
EAL-16	PI527519	3	2	29.1	46.5	30	45.2

EAL-19	PI527512	3	2	44.5	38.5	31.1	42.6
EAL-23	PI449428	3	1	43.6	49.5	31.3	40.3
AG-13	Chumbo, Cela	3	2	46.3	51	35.7	38.4
TZV-72	NJANO-DOLEA	3	2	23.6	50	33.8	46.9
TZV-93	KABLANKETI	3	2	24.1	49.5	32.6	52.3
TZV-94	KASUKANYWELE	3	2	25.3	41	33.5	46.8
AF-1	Rojo	3	1	47	47	35.4	40.2
AF-3	Selian 97	3	1	44.3	59.5	36.6	48.3
CAP116	Camelot	3	1	39.6	39	37.8	50.4
CAP144	Myasi	3	1	46.8	43	33.4	41.1
CAP147	Red Kanner	3	1	55.9	33	36.7	47.2
CAP251	USDK-4	3	1	52	32	36.7	45.4
CAP255	Blush	3	1	57.2	37.5	31	48.8
CAP272	Indeterminate Jamaica Red	3	2	50.6	46	32.8	39.3
CAP276	USWK-6	3	1	32.2	43	36.9	43.9
CAP313	02-385-14	3	1	39.9	31.5	37.2	55.1
CAP315	ND061106	3	1	42.8	38.5	37.4	45.7
CAP359	CDRK	3	1	33	46.5	36.7	40.7
CAP504	OAC Inferno	3	1	54.1	39	37.2	0
AF-11	Zawadi	3.5	1	32	36	37.7	45.9
AF-16	Uyole 98	3.5	2	46	36.5	37	46.6
AF-18	OPS-RS4	3.5	2	37.4	52	37.6	47.3
AF-20	Bonus	3.5	2	37.1	51	38.7	35.4
TZ-14	KIANGWE	3.5	1	39.9	47	27	39.6
TZ-16	GOLOLI	3.5	1	46.1	63	34.9	43.1
TZ-21	MBULAMTWE	3.5	1	33.7	49	36	55.4
CC-16	G 4780	3.5	1	18.7	49.5	35.3	47.7
CC-31	G 12689	3.5	1	43.9	45.5	36.1	55.6
CC-36	G 13778	3.5	1	31.5	31.5	34.8	46
TZ-3	KIDUNGU	3.5	1	29.6	33	38.3	43.8
TZ-31	RH No. 11	3.5	2	32.4	43.5	32.6	39.1
TZ-33	KIJIVU	3.5	1	28.5	38.5	37.3	44
CC-55	G 23086	3.5	2	31.8	46	34.7	38.8
USC-5	PI 308894	3.5	1	44.7	44.5	35.9	41.5
TZ-4	KILOMBERO	3.5	1	39.4	47.5	35.3	41.7
USC-9	PI 451906	3.5	1	44.8	48.5	34.9	44.3
EAL-9	PI209808	3.5	1	34	48.5	34.7	45.8
EAL-18	Hutterite	3.5	1	51.5	45.5	38.1	41.5
TZV-52	RH No. 3	3.5	2	19.8	35	33.1	43.7
AG-8	Katarina, Kibala	3.5	1	23.6	61.5	32.4	52.1
BC-367	UCD 0906	3.5	1	26.8	34	33.3	42.9
TZV-65	W6 16500	3.5	2	45	36.5	32.3	41.8

AF-2	Bilfa 4	3.5	1	36.2	46	39.5	51.3
CAP249	Lisa	3.5	1	48.3	48.5	35.7	43.1
CAP34	Badillo	3.5	2	40.2	45	33.6	49.1
CAP365	UCD 0704	3.5	1	44.9	52	34.9	46.7
CAP506	TARS-HT2	3.5	1	59.9	45	36.9	.
CAP509	Red Rover	3.5	1	50.7	36.5	37.5	.
CAP57	Charlevoix	3.5	1	34.9	43	35.6	.
AF-13	Njano	4	2	27.2	50	34.9	45.2
TZ-15	W6 16495	4	1	35.3	32	28.3	57
TZ-24	YELLOW	4	1	35.9	36	32.9	42.5
CC-32	G 13092	4	1	35.1	31	34.6	43.9
TZ-35	Kokola	4	1	34.8	66	31.6	38.2
CC-54	G 23070	4	2	54.7	43	38.4	50
TZ-38	Moono	4	1	46.5	49.5	33.5	55.9
TZ-39	Rozi Koko	4	2	28.4	47	34	50.1
USC-6	PI 309701	4	2	33.7	59	34.2	50.3
TZV-41	MRONDO	4	2	27.1	46.5	33.5	49.7
PR-3	PR9920-171	4	2	35.6	47	33.3	46.3
PR-4	PR1013-3	4	2	50.9	42.5	30.9	43
EC-3	INIAP 420	4	1	40.6	66	37.2	48.6
EC-12	INIAP 483	4	1	34.1	41.5	30.3	45.8
TZV-48	MSOLINI	4	2	32.8	43	36.8	45.5
EAL-17	PI319706	4	2	35.2	47.5	35.2	38.8
AG-5	Ervilha	4	1	40.9	66	37.7	41.7
AG-14	Cebo, Cela	4	1	37.8	45	34.7	47.5
AG-16	Canario, Cela	4	2	29.7	46	41.2	42.6
TZV-58	KIJIVU	4	2	33.9	47	38.6	52.2
TZV-62	Maulasi	4	2	27.1	45.5	36	35.5
TZ-8	Nyayo	4	1	47.9	43.5	35.3	47
TZ-9	Maalasa	4	1	35.4	45.5	36.9	52.5
TZV-95	W6 16560	4	2	38.3	46	34.7	48.1
TZV-96	MORO	4	2	19.9	43.5	31.9	46.3
AFV-14	Kablanketi	4	2	38.1	47	35.7	51.9
CAP283	Pompadour B	4	1	40.3	38.5	35.9	42.9
CAP366	UC Canario 707	4	1	35	37.5	36.6	38.1
CAP374	UCD 9623	4	2	38.6	37.5	44.6	47.3
TZ-1	ROZI KOKO	4.5	1	37.1	45.5	32.9	40
AF-10	Sewani 97	4.5	2	42.4	43	36	50.2
AF-14	Kablanketi	4.5	2	22.6	46.5	34.6	58.5
AF-23	Werna	4.5	2	51.5	60.5	39.6	38
AF-30	NABE 4	4.5	2	25.4	38	34.9	40.7
TZ-17	W6 16529	4.5	1	34.2	44	33.3	28
CC-3	G 1368	4.5	2	41.2	45.5	33.1	41.6

CC-7	G 2377	4.5	2	57.7	35	38.6	42
TZ-37	W6 16488	4.5	1	38.8	43	31.8	51.7
PR-6	PR0637-134	4.5	2	25	47	38.8	49
EAL-10	PI527538	4.5	1	31.1	38.5	34.4	54.4
EAL-11	PI527521	4.5	1	33.3	38	31.1	41.9
EAL-22	PI209804	4.5	1	29.1	45.5	33.5	46.6
AG-6	Canario	4.5	2	37.9	48.5	38	44.8
TZV-73	MASUSU	4.5	2	26.7	48	31.3	40.8
TZV-74	MASUSU	4.5	2	35.7	59	34.2	52.6
TZV-84	KABLANKETI	4.5	2	38.5	42	35.2	43.6
TZV-98	LUSHALA	4.5	2	34.9	44	34	51.6
AFV-18	OPS-RS4	4.5	2	76.7	48	37.4	51.8
CAP82	Chinook 2000	4.5	1	53.5	39	36.7	0
AF-24	A193	5	2	31.4	45.5	30.4	41.6
TZ-13	KIBUMBULA	5	1	47.6	46.5	33.2	50.5
TZ-20	KIGOMA	5	1	29.4	45	35.5	43.2
CC-19	G 5087	5	2	23	43.5	35.7	41.5
CC-22	G 6415	5	1	61.2	52	36.2	49.3
TZ-36	Lyamungu 85	5	1	33.3	48	30.7	42.5
PR-8	PR0737-1	5	1	36.6	49	35.6	33.3
PR-17	Vazon 7	5	2	40.6	52.5	41.5	41.2
EC-10	INIAP 480	5	1	54.9	38.5	36	44.8
TZ-6	W6 16465	5	1	46.5	39	32.1	47.2
BC-378	UCD 0701	5	1	26.2	41	35.9	41
BC-499	Micran	5	2	29.5	37.5	39.5	41.8
TZ-7	BUKOBA	5	1	63.3	44.5	37.9	44
AF-5	EG 21	5	1	38.6	45	38.3	44.8
AFV-13	Njano	5	2	44.1	50	32.4	55.7
AFV-21	A-800	5	2	30.6	36	39	50.7
CAP345	AC Calmont	5	1	55.9	42.5	35.2	50
TZ-2	W6 16444	5.5	2	31.7	54	35.4	35.3
TZ-23	MSHORONYLONI	5.5	2	45.6	41	38.3	39.9
CC-35	G 13654	5.5	2	50.2	47	41.8	47.1
PR-10	JB-178	5.5	1	35.1	52	37.3	40.5
TZV-44	KIJIVU	5.5	2	21.3	67	34.9	25
PR-14	49-2	5.5	2	38.6	67	39.1	39.5
BC-399	Drake	5.5	1	32.7	50.5	33.6	45.2
CAP150	1062-V98	5.5	1	44.4	35.5	34.5	45.4
AF-7	Jesca	6	1	32.3	41	33.4	45.7
AF-9	Wiamwngu	6	1	28.9	48	35.9	44.2
TZ-12	W6 16489	6	1	29.8	59.5	30	38.2
AG-15	Amarelo, Cela	6	2	65.7	43	37.5	53.3

MEAN	**3**	**.**	**40.1**	**44.4**	**35.6**	**45.5**
CV	**37**	**.**	**34**	**8**	**9**	**11**

Table 4: Pearson correlation coefficients among agronomic and BNF related traits of 275 Andean Diversity Panel lines grown in Entrican, MI in 2012.

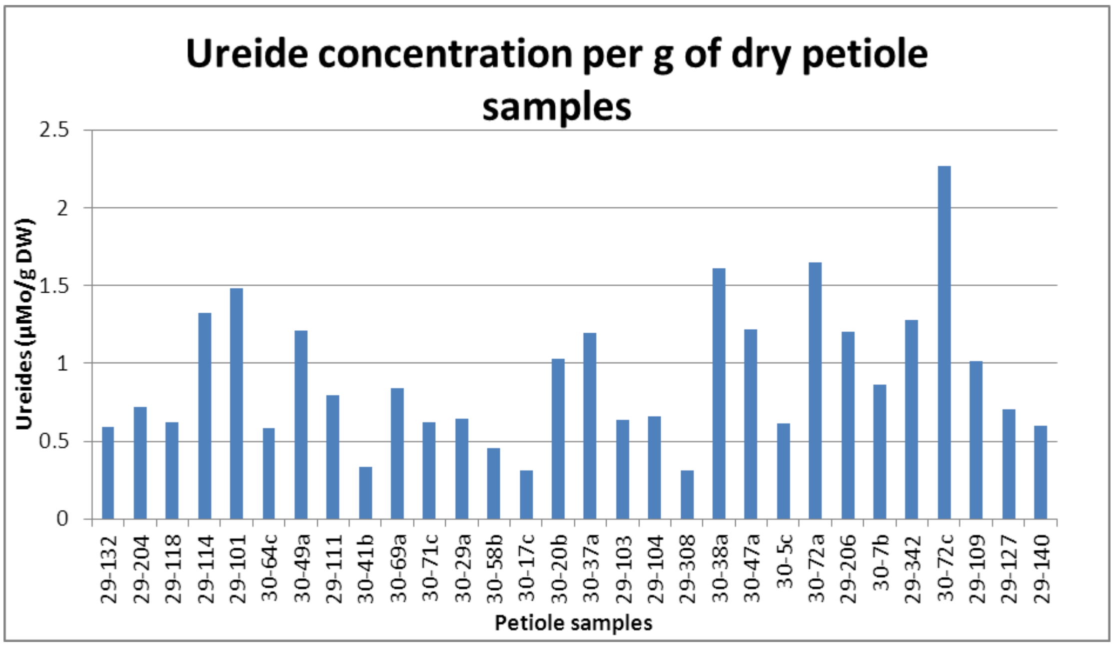
	nodule rating	**growth habit**	**shoot wt.**	**days to flower**	**SPAD 35 DAP**	**Harvest index**
Nodule rating	-------	0.12 (p=.006)	-0.11 (p=.009)	0.17 (p<.0001)	NS	-0.12 (p=.009)
Growth habit		-------------	NS	0.25 (p<.0001)	NS	NS
Shoot Wt.			------------	NS	NS	NS
Days to flower				------------	NS	-0.38 (p<.0001)
SPAD 35 DAP					-------------	0.11 (p=.02)

Appendix 3. Supplemental Ureide Analysis of parental lines and selected diversity panel lines conducted at ISU.

Common bean samples from WSU/MSU

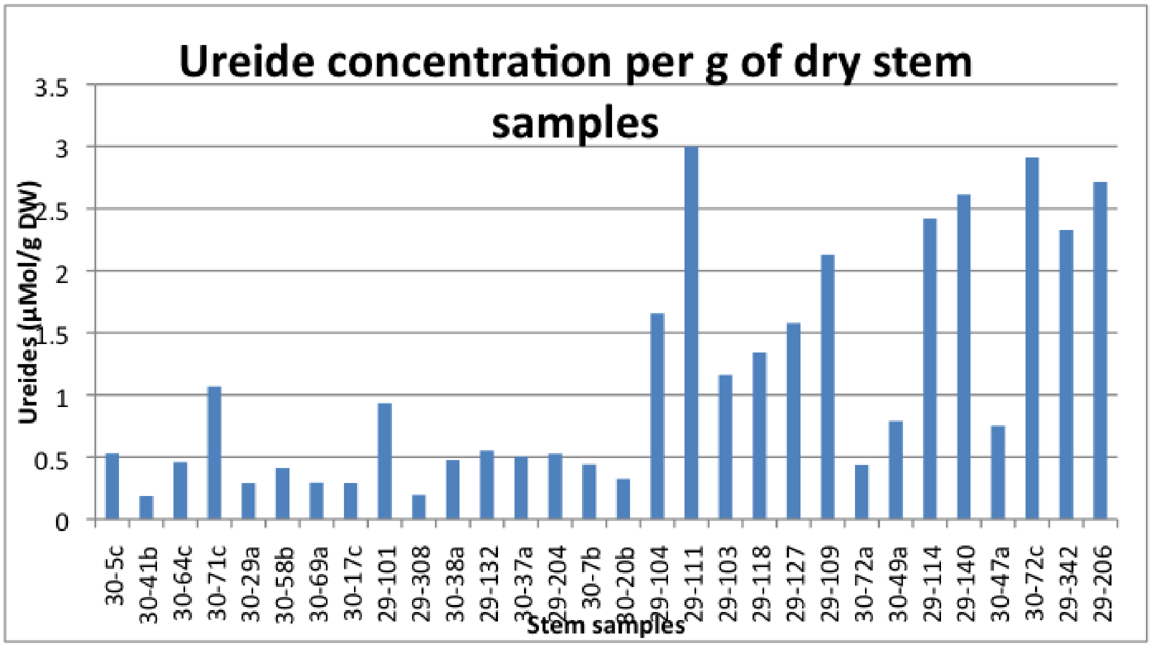
Ureides (allantoin and allantoic acid) are the principal forms of nitrogen (N) transported in common beans, which originate predominantly from N2 fixation. As such, the level in tisues is an indirect indicator of the extent of N2 fixation in by the nodules. The variation among plant tissues, genetics, and environmental effects, however, make it difficult to relate tissue level to N2 fixation directly. In this study, we extracted ureides from plant tissues (petioles, stem, leaves and pods) and measured relative levels spectrophotometrically against an allantoin standard. The objective was to deterimine which plant tissue, if any, provided a consistent relationship between ureide concentrations and total plant N and biomass accumulation.

Table 1. Variation in ureide concentration in petiole tissues of selected common bean lines. Data are expressed as allantoin equivalents on a dry weight basis. Values are the mean of three replicate samples.



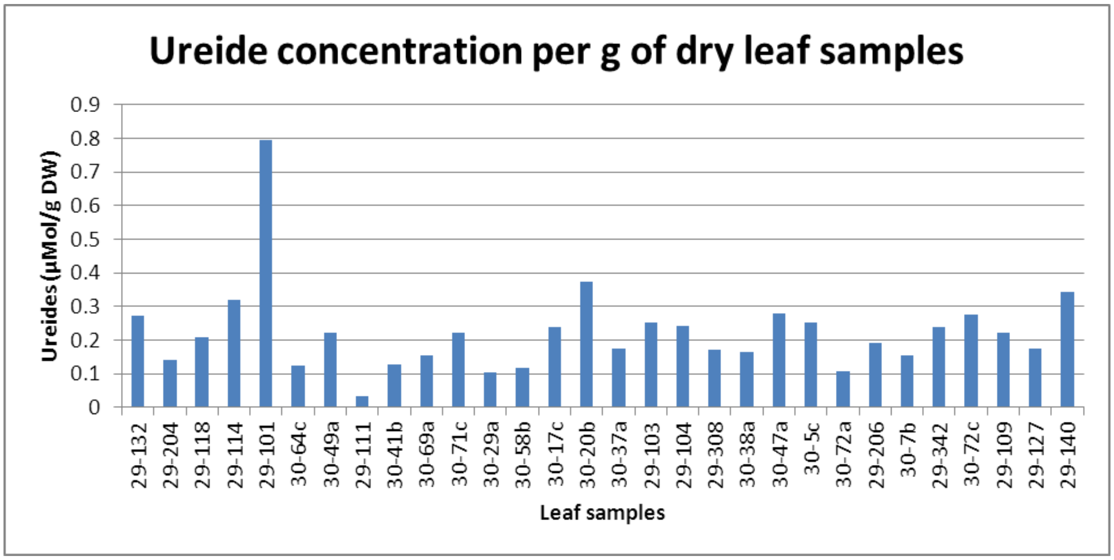
Ureide concentrations of individual samples varied between 0.1 and 2.8 µMol/g dry weight in the petioles. Petioles from cultivar 30-72c had the highest level of ureide concentration while petioles from cultivars 29-308, 30-17c and 30-41b had the lowest ureide concentration levels.

Table 2. Variation in ureide concentration in leaf tissues of selected common bean lines. Data are expressed as allantoin equivalents on a dry weight basis. Values are the mean of three replicate samples.



Ureide concentrations in individual leaf samples varied between 0.1 and 0.8 µMol/g dry weight. Leaves typically exhibited the lowest levels compared to values observed in stems pods or petioles. Leaves from cultivar 29-101 had the highest level of ureide concentration, while leaves from cultivar 29-111 had the lowest ureide concentration level.

Table 3. Variation in ureide concentration in stem tissues of selected common bean lines. Data are expressed as allantoin equivalents on a dry weight basis. Values are the mean of three replicate samples



The ureide concentrations measured in this study varied between 0.1 and 3 µMol/g of dry weight in stems. Stems had the second highest levels of ureide concentrations. Stems from cultivar 29-111 had the highest level of ureide concentration while stems from cultivars 30-41b and 29-308 had the lowest ureide concentration levels.

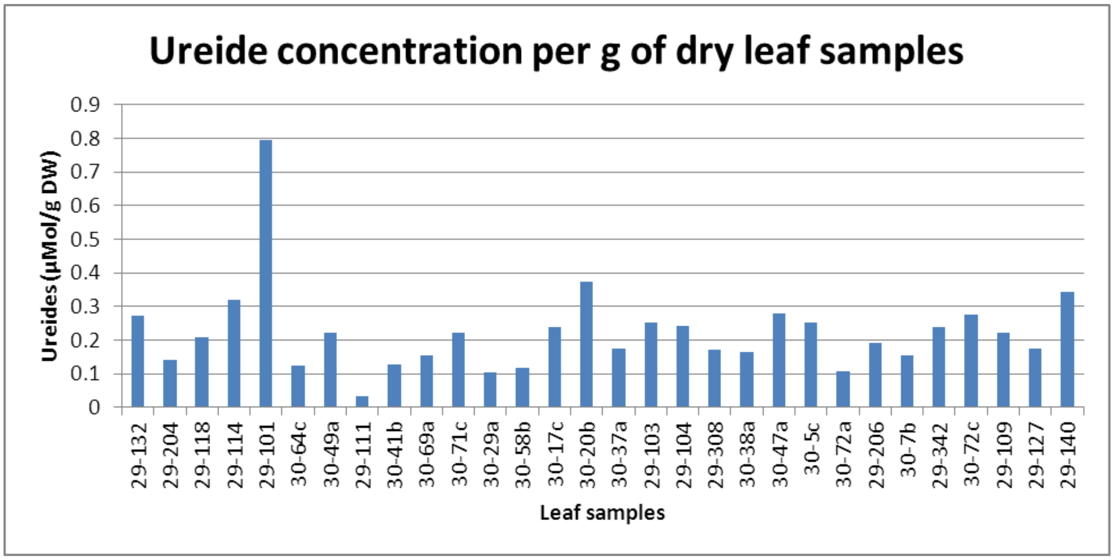
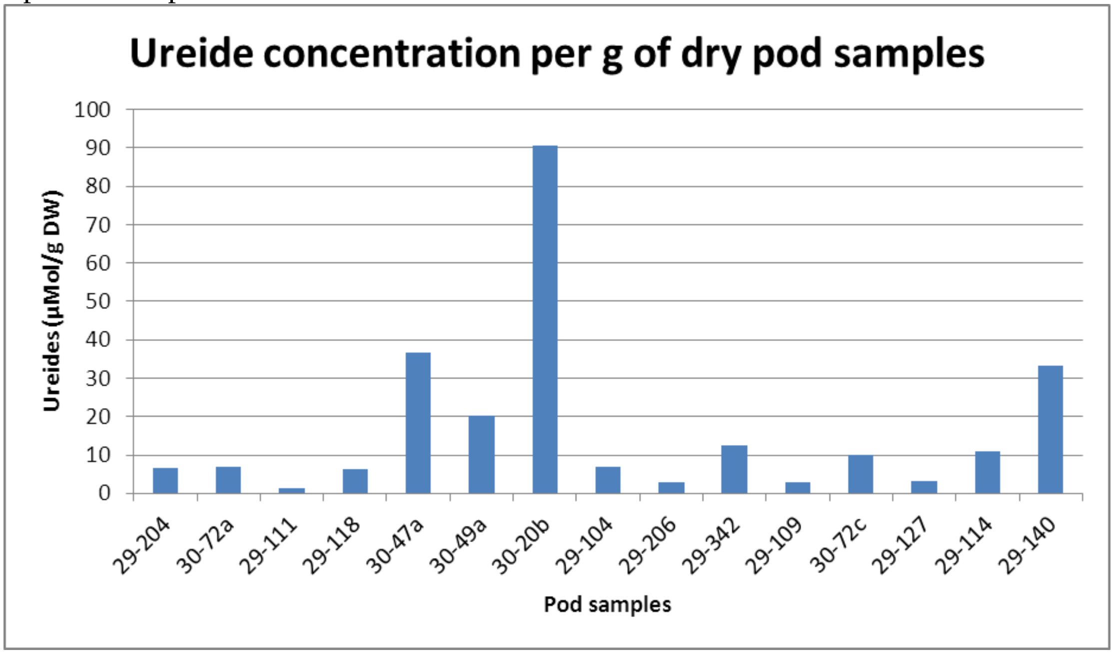


Table 4. Variation in ureide concentration in pod tissues of selected common bean lines. Data are expressed as allantoin equivalents on a dry weight basis. Values are the mean of three replicate samples



The ureide concentrations in pods varied between 1 and 90 µMol/g of dry weight in pods. Of all the tissues, pods had the highest levels of ureide concentrations. Pods from cultivar 30-20b had the highest level of ureide concentration while pods from cultivars 29-111 had the lowest ureide concentration level.

These results show that ureide levels differed dramatically in different plant tissues and across lines in the same tissue. Pods accumulated the highest concentrations of ureides followed by stems, then petioles and lastly leaves. Ureide concentration levels in plant tissues correlated with sample (petioles, leaves, stems and pods) biomass. Analyses are underway to relate total N and biomass accumulation with these tissue values of ureide concentration.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2011 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

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	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***	**9/30/2012**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																							
Objective 1																								
1.Field Trial 2 established at HC locations																								
2.Test common bean varieties in high/low N treatments (HC locs)													x	x		x	x		x	x		x	x	
3.Quantified yield advantage of inoculation for second HC field season													x	x		x	x					x	x	
4.Held workshop for graduate students on research results																								
5.Attend Bean Improvement Cooperative Workshop																								
6.Analysis of soil/weather data completed	x	x											x	x		x	x		x	x		x	x	
7.Confirmed phenotypic and yield responses to inoculant X Gen X Env.	x	x		x			x						x	x		x	x		x	x		x		x
8.Confirmed indigenous rhizobia levels related to environmental conditions	x		x	x			x												x		x			
9.Confirm soil rhizobia populations and strain diversity							x																	
10.Root/nodulation study initiated	x	x		x			x																	
11.Initial studies on strain x host interaction completed (WSU)							x																	
12.Identified most effective genotype-inoculant combinations for each eco-zone													x	x		x	x		x	x		x	x	
13.Determined economic return for inoculation treatments at all yield levels													x		x	x		x				x		x
Held BNF-CRSP team meeting																								
Objective 2																								
14.Increased seed of BNF diversity panel lines																								
15.Completed initial greenhouse screening of 50 selected lines for BNF response							x	x																
16.Evaluated correlative response of BNF phenotype characteristics	x	x		x			x	x					x	x		x	x					x	x	
17.Confirmed nodule rhizobia occupancy on selected lines							x		x							x	x							
18.Tested subset of BNF panel lines in low N soil +/- inoculants in HC				x			x	x					x	x		x	x					x	x	
19.Characterized soil rhizobia populations and strain diversity at field sites							x		x															
20.Confirmed season 1BNF response phenotyping for selected CAP & SA lines				x			x	x																
21.Conducted initial SNP analysis on bean CAP and SA Core collection				x			x	x																
22.Completed initial list of candidate genes for BNF response				x			x	x																
23.Advanced selected RILs to F3				x			x	x																
Objective 3																								
24.Established format for field demonstrations at HC stations																								
25.Included information on N2Fixation and inoculation at demonstration sites																								
26.Conducted field days in each HC to sensitize farmer on BNF										x	x		x	x		x	x					x	x	
27.Conducted on-farm trials with selected farmer cooperators										x	x		x	x		x	x					x	x	
28.Created training materials to disseminate through PELUM network	x		x							x	x		x	x		x	x		x	x		x	x	
30.Incorporated research results into extension training programs, farmer advocacy meetings, and PELUM network website										x		x	x		x	x		x	x		x	x		x
31.Determined potential for engaging international funding agencies to expand current technology transfer efforts	x	x								x	x		x	x		x	x		x	x		x	x	
32.Conducted advocacy meetings with farmer groups and agribusiness interests										x	x													
Objective 4																								
Graduate students identified	x	x		x			x	x								x	x		x	x				
Graduate research programs initiated	x	x		x			x	x								x	x		x	x				
Undergraduate student interns identified										x	x											x	x	
Undergraduate student projects intiated										x	x											x	x	
Name of the PI responsible for reporting on benchmarks	Westgate			Cichy			Miklas			Musoke			Ugen			Nchimbi			Tenywa			Musoni		

Signature/Initials:

Date: 10/1/2012

Signature **Date**

Dry Grain Pulses CRSP
PERFORMANCE INDICATORS/TARGETS for FY 12
(October 1, 2011 -- September 28, 2012)

Output Indicators	PIII-ISU-2 2012 Target	2012 Actual (Oct 1 2011-Sept 28, 2012)	
Degree Training: Number of individuals who have received degree training			
Number of women	4	6	
Number of men	3	6	
Short-term Training: Number of individuals who have received short-term training			
Number of women	200	470	Greater number of farmer groups participated in field
Number of men	200	422	demonstrations of inoculant use and benefits than anticipated
Technologies and Policies			
Number of technologies and management practices under research	1	10	New combinations of inoculant, improved seed, and soil fertizer
Number of technologies and management practices under field testing	1	9	were tested on farm, and at regional research centers.
Number of technologies and management practices made available for transfer	1	5	Inoculant from five labs were tested and made available for
Number of policy studies undertaken	0	1	field demonstrations
Beneficiaries:			
Number of rural households benefiting directly from CRSP interventions - Female Headed households	3000	2210	
Number of rural households benefiting directly from CRSP interventions - Male Headed households	2000	2140	
Number of agriculture-related firms benefitting from CRSP supported interventions	3	8	
Number of producer organizations receiving technical assistance	3	7	
Number of trade and business associations receiving technical assistance	3	3	
Number of community-based organizations receiving technical assistance	3	92	
Number of women organizations receiving CRSP technical assistance	3	2	
Number of public-private partnerships formed as a result of CRSP assistance	3	5	
Number of HC partner organizations/institutions benefiting	3	13	Capacity improvements at each HC university as well as
			local seed companies and farmer organizations who attended
Developmental outcomes:			trainings and field demonstrations.
Number of additional hectares under improved technologies or management practices	5000	4300	

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

Four hundred and forty one HIV-infected children and adolescents from 2 to 15 years of age are receiving one of three food supplements in two locations in Tanzania. The supplements contain 100% of the US Daily Recommended Intake for vitamins and minerals, maize and one of three protein rich foods: common dry beans, cowpeas, or small fish (sardines). The supplements are pre-cooked and are prepared by suspending the supplement in water and boiling for five minutes. Each child or adolescent is provided with 130 g of dry supplement per day. The study will determine if bean or cowpea is more efficacious in promoting growth and immune function than the supplement containing fish. This a single-blinded, community based, longitudinal study; the investigator compiling and evaluating the data is blind to subject treatment and therefore treatment differences cannot be evaluated at this time.

Treatment with highly active anti-retroviral (HAARV) drugs is expensive ($8 to $10 USD per day) and is crippling national economies. A previous study showed that feeding the bean-maize supplement improved the immune system (based on CD4 cell counts) and the children were not placed on HAARV treatment because their CD4 cell counts improved when the supplement was consumed. Food supplement cost is approximately $0.75 per day and represents a reduction in treatment costs of about $7 to $9 per day. Thus the potential savings are great!

HIV-infection damages the mucosal lining of the intestine and promotes development of inflammation in the intestinal mucosa with resulting poor absorption of nutrients. Studies with rodents demonstrated that repair of damaged intestinal mucosa is more effective when a bean-based diet is fed. These results confirm previous results and we believe the bean-based supplement enhances immune response and growth in HIV-infected children in the absence of HAARV by promoting greater integrity of the intestinal mucosa.

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 and improve the immune system (increased CD4 counts) even though the children were not receiving highly active antiretroviral (HAARV) drugs. This is an extremely important finding since 50% of HIV+ people do not have access to HAARV drugs and consuming the bean based supplement could be an important stop gap until more people are able to obtain HAARV drugs. Children receiving HAARV treatment also benefited from the bean-based supplement in a second study we have done and so, the bean-based supplement would also be useful to children that have access to HAARV medicine. 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.

Results, Achievements and Outputs of Research

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. Purchase ingredients, cook and package food supplements, transport and distribute food supplements to 400 subjects.
2. Every three months collect and analyze blood samples from approximately 400 subjects; therefore 1,660 blood samples will be analyzed for CD4, CD8, CD3 and total lymphocyte counts.
3. Train two M.S. students to assist in research.
4. Provide field practical training in community nutrition and health for 10 undergraduates.

Results and Outputs Achieved

At the beginning of FY12, 73 children were receiving food supplements. As the study progressed and expanded, a number of challenges required modification to our planned methodology. These modifications have both positive and negative aspects. The first and greatest challenge related to analysis of the blood samples. The original plan was to transport the blood samples from the communities to SUA for analysis. However, it quickly became apparent that the membranes of red blood cells from HIV-infected children are considerably more fragile than red-blood cells (RBC) from non-infected children. Transport of the blood samples collected at the Centers for Treatment and Counseling (CTC) to Sokoine University (a 100 to 550 km trip over bumpy roads) caused hemolysis of some of the RBC which interfered with the determination of CD4, CD8, CD3 and total lymphocyte counts. RBC hemolysis was not encountered during method development and testing, presumably because the samples were transported only 5 km from a local CTC. After much discussion, it was decided that the various CTCs would determine the CD4 cell counts in collaboration with SUA researchers. All of the CTCs are part of the Tanzanian HIV surveillance program and they routinely determine CD4 cell counts as a component of the clinical management of HIV-infected individuals. One positive outcome is that the CTCs now bear most of the cost for determining the CD4 cell counts as part of their routine surveillance program and the PIII MSU-3 project only provides miscellaneous supplies and reagents which had often previously limited the CTCs capability to perform their analyses. Thus, both the CTCs and the PIII MSU-3 project benefit from this arrangement. A second positive aspect is that the benefits of the supplemental feeding will be immediately obvious to the front line group handling HIV-infected individuals. We expect that local support from the CTCs will greatly assist us in our efforts to influence national and international policy related to care of HIV-infected individuals.

Sharing the responsibility for determining CD4 cell counts with the CTCs makes the PIII MSU-3 project much more a “community-based study” and a type of “participatory research” than originally planned. On the negative side, the CTCs are not capable of determining CD8, CD3, and total lymphocyte counts which would have been determined of the blood analyses could have been done at Sokoine University. While CD4 cells are the primary immune cell destroyed by the virus, having CD8, CD3, and total lymphocyte counts would have provided a more complete picture of immune response than what will now be available from just CD4 cell counts. A second negative aspect is the CTCs per national policy determine CD4 cell counts every 6 mo rather than every 3 mo as we had planned.

Our goal was to have 540 subjects complete the study in the absence of HAARV. The reality is that the availability of HAARV drugs in Tanzania is rapidly increasing and HIV-infected individuals are given HAARV drugs per physician recommendations which are based on clinical symptoms along with CD4 cell count. It would be unethical to ask subjects to refrain from taking HAARV drugs if their physician so recommends. An external reviewer of the PIII MSU-3 project recommended a cohort of subjects that were receiving HAARV drugs be included in the study. Initially, we could not take on this recommendation; however, as more and more of the HAARV-naïve children and adolescents were placed on HAARV by their attending physician, we were forced to accept the reviewer’s recommendation or risk failure of the study due to subject dropout. M. Bennink was a co-PI of a study conducted in Botswana that showed that HIV-infected children and adolescents receiving HAARV therapy had a significant improvement in immune response and growth compared to a control group ingesting a supplement that did not contain beans. Therefore, we still expect the group consuming the bean-maize supplement (and perhaps the group consuming the cowpea-maize supplement) will have a greater immunological and growth response than the control group consuming a fish-maize supplement.

Initiation of HAARV drug therapy during the course of study will add another level of complexity in data analysis. For anthropometric measurements, we will utilize statistical tools to adjust for initiation of HAARV drug therapy. We have gathered data from a group of subjects that are not receiving nutritional support and this group will become our "negative control" group and the data from the negative control group will be utilized to statistically adjust for initiation of HAARV drug therapy. We will still test the hypothesis that HIV-infected children fed a bean-maize supplement or a cowpea-maize will have greater immune and growth improvement in HAARV-naïve patients and reduce the need for HAARV therapy compared to the group consuming a fish-maize supplement.

We currently have 441 subjects in the study. Approximately 300 of the subjects reside in the northern rural areas of Rombo and Kilema and they are approximately 550 km from Morogoro. The other 141 subjects come from rural areas around Turiani, which is about 100 km from Morogoro. We had planned to have about 200 subjects from Morogoro Rural District. However, some of the CTCs in Morogoro Rural District did not have the capability to determine the CD4+ cell counts and the blood samples from these centers were handled by the regional government hospital. Access to the data produced in the regional government hospital was slow and difficult (restricted). Because of this, the Kilema CTC, which is located in the northern study site area, was included in the study instead of the Morogoro Rural District. The Kilema center provides 100 subjects.

Approximately 2 metric tons of pre-cooked and dried supplement is packed into 13,250 packages every month for distribution. Fuel and university vehicle rental costs have skyrocketed during the past 30 mo. However, the savings in reagent cost from not doing the CD4 analyses at SUA partly compensate for the increased transport costs. Data continues to be collected and is best to not break the diet code until more data is collected.

Three M.S. students in Human Nutrition received research training while assisting in work related to Objective 1. Two B.S. graduates from the Food Science and Technology department received practical training related to safe preparation of cereal foods. Fourteen undergraduates in the nutrition major at SUA received field-practical training for a five week period in June and July, 2012.

Objective 2: Determine the relative costs of three dietary treatments compared to HAARV drug treatment (Note: this completes the data gathering begun in FY10).

Collaborators
Jerry Makindara, Sokoine University of Agriculture

Approaches and Methods

1. Determine the costs associated with cooking beans, cowpeas, and sardines in a pot and for preparing Ugali (corn based local food).
2. Determine costs associated with preparation of the extruded (pre-cooked) bean-maize and cowpea-maize supplements and thin porridge from the supplements.
3. Determine costs associated with preparation of the fish-maize supplement and thin porridge from the supplement.

4. Determine costs associated with HAARV drug treatment.

Results and Outputs Achieved

1. The costs associated with cooking beans in a pot and preparing stiff porridge (Ugali). Data were collected from a sample of 100 randomly selected women as follows:- Rombo (30), Kilosa (15), Kimamba (11), Turiani (35) and Mtibwa (9). The subjects reported the amount of money used in buying the food ingredients including the maize flour, beans, cooking oil, onions, tomatoes, salt and other spices. The amount of time spent in cooking was determined and valued in monetary form based on the government payment rates for casual laborers per day (TShs 6000.00). The value of the fuel (charcoal, firewood) used to prepare the ugali with beans was determined. Transport costs were taken into account whenever the subject paid money for transport when buying the food and non-food materials. The total cost for preparing the equivalent of 130 g of dry ugali plus beans was computed since 130 g is the weight of pre-cooked supplement provided to each subject each day. (see Table 1).

2. The costs associated with cooking sardines in a pot and preparing stiff porridge (Ugali). Data were collected from a sample of 91 randomly selected women as follows:- Rombo (21), Kilosa (19), Kimamba (8), Turiani (33) and Mtibwa (10). The subjects reported the amount of money spent in buying food ingredients including the maize flour, sardines, cooking oil, onions, tomatoes, salt and other spices. The amount of time spent in cooking was determined and valued in monetary form based on the government payment rates for casual laborers per day (TShs 6000.00). The value of the fuel (charcoal, firewood) used to prepare the ugali with beans was determined. Transport costs were taken into account whenever the subject paid money for transport when buying the food and non-food materials. The total cost for preparing the equivalent of 130 g of dry ugali plus sardines was computed (see Table 1).

3. The costs associated with cooking cowpeas in a pot and preparing stiff porridge (Ugali). Data were collected from a sample of 86 randomly selected women as follows:- Rombo (20), Kilosa (22), Kimamba (10), Turiani (25) and Mtibwa (9). The subjects reported the amount of money spent in buying food ingredients including the maize flour, cowpeas, cooking oil, onions, tomatoes, salt and other spices. The amount of time spent in cooking was determined and valued in monetary form based on the government payment rates for casual laborers per day (TShs 6000.00). The value of the fuel (charcoal or firewood) used to prepare the ugali with beans was determined. Transport costs were taken into account whenever the subject paid money for transport when buying the food and non-food materials. The total cost for preparing the equivalent of 130 g of dry ugali plus cowpeas was (see Table 1).

4. Cost involved in the preparation of the extruded, fortified maize-beans/cowpeas/ sardines composite supplementary foods. Data were collected from six, 1000 kg batches of food materials that were bought at different seasons to reflect the market price fluctuations. For each batch of 1000 kg, the following information was collected. Cost of food materials – maize, beans/cowpeas/sardines, sugar, salt, bicarbonate, vegetable oil and minerals/vitamins pre-mix. Overhead costs collected were dehulling, milling, extruding, electricity, labor charge, transportation of raw materials and delivery of products and packaging materials. For each batch of 1000 kg food materials processed, the number of 130 g sachets yielded was determined. The total cost for each 1000 kg batch (cost of food ingredients + labor +

overheads) was thereafter divided by the total number of 130 g sachets obtained from the batch. The average cost of each 130 g sachet was then established.

5. Cost involved in anti-retroviral drugs or syrup (HAART). Data were collected from various pharmacies and from Tanzania Pharmaceutical Industry (TPI), which manufactures the anti-retroviral therapies. A total of 15 retail pharmacies were visited: Morogoro (4), Dar es Salaam (6), and Moshi (5). Retail prices for a 30-day dose were obtained from each of the pharmacies visited. Visits were also paid to the Medical Store Department (MSD) (sole distributor of essential medicines in Tanzania) in Morogoro, Moshi and Dar es Salaam where wholesale prices were recorded. A visit was also paid to the factory (TPI) that manufactures antiretroviral therapies in Arusha. Industrial-gate prices were also recorded. From the average retail price of a 30-day dose, the cost for one-day dose of antiretroviral drugs or syrup was then established.

Discussion for Objective 2

The food costs presented in Table 1 are based on the amount of energy that is required for a 5 year old child. The costs would be doubled for a 15 year old. Costs are for foods prepared over an open fire and for foods prepared via extrusion. The data in Table 1 are based on comparable dry weights and include the cost of vitamins and minerals. The costs associated with preparing ugali and cowpeas or ugali and beans (equal amounts of protein) are similar. Preparing a similar amount of protein with ugali and sardines instead of cowpeas or beans cost about 5 – 7% more. Preparing a pre-cooked flour increased the cost of the food supplements 20 – 22% compared to preparing similar foods in a pot over a fire.

Direct comparisons for managing HIV-infected children through diet versus drug treatment cannot be made since the two treatments don’t achieve the same results. However, a daily savings of $7.25 – $10.00 USD is achieved if the child can be managed with the food supplements used in this study instead managing the infection with drugs. A child managed with one of the food supplements will achieve better growth and development than a child that simply receives HAARV. Moreover, drug treatment causes deleterious side effects and drug effectiveness often declines due to development of drug resistance. If governments desire more normal physical and mental development in their children treated with HAARV, they should provide a nutritional supplement and that would increase the treatment differential to at least $8.00 per day. How long and how effectively a HIV-infected child can be managed with diet alone remains to be determined.

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.

Collaborators

Dr. Elizabeth Ryan, Colorado State University

Approaches and Methods

1. Analyze approximately 800 dried blood samples shipped from Tanzania for HIV load, selected pro-inflammatory cytokines, and R16s (a marker of bacterial translocation).

2. Develop a rodent model to study bacterial translocation from the intestine into tissues and blood. A bean based diets is expected to reduce bacterial translocation and release of pro-inflammatory cytokines. The effectiveness of cowpeas will also be tested in this model.
3. Correlate changes in pro-inflammatory cytokines, and R16s in the human feeding study with the changes observed in the rodent model to help establish a mechanism of how feeding beans (maybe cowpeas) can improve immune status of HIV-infected children.

Results and Outputs Achieved

Activities related to objective 3 are secondary to the activities for objectives 1 and 2.

1. Blood samples were collected from the subjects and dried blood spot samples were prepared and are in storage at Sokoine University. The analytes we are interested in are stable for years when the blood spots are properly prepared and stored. These samples, which are biohazardous due to the presence of HIV, require special clearance for international shipping. Once we have approval from the Center for Disease Control to ship these samples from Tanzania to the U.S., the samples will be analyzed as planned.

2. The intestinal mucosal barrier, comprised of goblet cell-derived mucin and reinforced by tight junctions, normally limits passage of bacteria and other luminal antigens through the epithelium and into the lamina propria and deeper tissues. Since the intestinal barrier is not perfect, immune cells destroy bacteria and luminal antigens that do get into the lamina propria and deeper tissues. The human immuno virus destroys CD4 and other immune cells and seriously compromises the ability of the immune system to prevent bacteria from gaining entrance into the circulatory systems. Bacteria and bacterial products that are not inactivated by immune cells cause inflammation in the intestinal wall resulting in poor absorption of nutrients and greater permeability of the intestinal mucosa. From previous research regarding diet and colon cancer, we have observed that eating beans improves the colonic mucosal barrier following mucosal damage.

   It would be unethical to obtain intestinal biopsies from our subjects, so we performed two experiments with rats. The experiments were designed to further document that eating beans promotes greater mucosal integrity and reduces inflammation. Rats are not susceptible to the HIV, so a chemical toxin (azoxymethane) was injected to impair mucosal integrity and to promote inflammation in the intestinal wall. Control rats were injected with saline rather than the toxin. Three months following toxin injection, mucosal integrity in the small intestine was evaluated. Immido black, a dye that does not permeate healthy mucosa was infused into the lumen of the intestine. Histology showed that mucosal damage by the toxin had long term effects on mucosal integrity regardless if rats were fed a control diet or a diet containing beans. Rats injected with the toxin and fed a control diet had the greatest mucosal permeability to the dye (Table 2). Rats injected with the toxin and fed beans had reduced mucosal permeability compared to rats injected with the toxin and fed the control diet. Rats injected with saline had minimal permeability of the dye past the epithelial layer; however, rats feed beans had slightly less dye permeability than rats fed the control diet. Histology showed the presence of immune cells in the lamina propria paralleled dye permeability. These results are qualitative, but the study did show that eating beans caused better recovery of the intestinal mucosa following mucosal damage than eating a control diet that did not contain beans.

The second rat study followed the same protocol as study 1except mucosal integrity and inflammation was assessed by measuring expression of key genes involved in innate defense and immunity. RT-PCR detected a significant increase in expression of the anti-microbial genes (lysozyme, *Pla2g2a*, and neutrophil (NP) defensin 3 (*RatNP-3)*) and innate immune genes (toll-like receptor 4 (*Tlr4*) and *Dmbt1*) in the toxin-injected controls compared to the saline injected controls. Expression of these genes was also induced by toxin treatment in bean-fed animals, but to a significantly less extent than in the toxin injected rats fed the control diet. Expression of these genes in the bean-fed, saline-injected rats was slightly lower (trend, but not statistically significant) than in saline-injected rats fed the control diet. *Pla2g2a* and *RatNP-3* exhibit antimicrobial activity, and together with other proteins play an important role in mucosal epithelial defense. *Pla2g2a* is a multifunctional protein induced in a variety of inflammatory conditions. Decreased expression of the genes *Tlr4* and *Dmbt1* further suggest that eating beans reduces microbially-induced inflammation . A lower expression of these genes in bean-fed rats suggest that translocation of bacteria and other antigens from the intestinal lumen is reduced by eating beans. Taken together these 2 studies strongly suggest that eating beans improves mucosal barrier function and reduces inflammation in the intestinal mucosa and lamina propria.

3. Activity 3 cannot be completed until activity 1 is completed and we expect to complete both in FY13.

Objective 4: Institutional Capacity Building

Degree Training

Trainee # 1
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: May, 2013
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

Ms. Hooper continued her thesis research (characterization of bean starch) during the summer semester and will likely graduate in May 2012.

Trainee # 2

First and Other Given Names: Rosemary
Last Name: Marealle
Citizenship: Tanzanian
Gender: Female
Degree: MS
Discipline: Human Nutrition
Host Country Institution to Benefit from Training: Tanzania
Training Location: Tanzania
Supervising CRSP PI: Theobald Mosha
Start Date of Degree Program: September 2010
Program Completion Date: September 2011
Training Status during Fiscal Year 2012: Graduated in November, 2011
Type of CRSP Support (full, partial or indirect): Partial

Activities for Trainee # 2
Ms. Marealle completed her thesis work and graduated in November 2011.

<u>Trainee # 3</u>
First and Other Given Names: Amos
Last Name: Nyangi
Citizenship: Tanzanian
Gender: Female
Degree: MS
Discipline: Human Nutrition
Host Country Institution to Benefit from Training: Tanzania
Training Location: Tanzania
Supervising CRSP PI: Theobald Mosha
Start Date of Degree Program: September 2011
Program Completion Date: September 2012
Training Status during fiscal year 2012: Active
Type of CRSP Support (full, partial or indirect): Partial

Activities for Trainee # 3
Ms. Marealle completed her thesis work and will graduate in Nov, 2012.

<u>Trainee # 4</u>
First and Other Given Names: Sarah
Last Name: Johnson
Citizenship: Tanzanian
Gender: Female
Degree: MS
Discipline: Human Nutrition
Host Country Institution to Benefit from Training: Tanzania
Training Location: Tanzania
Supervising CRSP PI: Theobald Mosha
Start Date of Degree Program: September 2011

Program Completion Date: September 2012
Training Status during fiscal year 2012: Active
Type of CRSP Support (full, partial or indirect): Partial

Activities for Trainee # 4
Ms. Johnson completed her thesis work and will graduate in Nov, 2012.

Short-Term Training
Type of Training: HACCP
Description of Training Activity: Food safety - Hazard Analysis Critical Control Points
Status of this Activity as of September 30, 2012: Completed
When did the Short Term Training Activity occur?: December 2011
Location of Short Term Training: MSU
If Training was not completed as planned, provide a rationale: NA
Who benefited from this Short Term Training Activity? SUA Faculty
Number of Beneficiaries by Gender: Male – 2
FeMale – 0
Total – 2

Explanation for Changes
Objective 3, activity 1, involves international shipment of biohazardous materials (HIV contaminated dried blood spots) and requires approval from various regulatory agencies. We are awaiting approval for international shipping from the Center for Disease Control. Once we have approval, we will ship the dried blood spots and conduct the analyses as planned.

Networking and Linkages with Stakeholders
During the FY 2012 collaboration was made with several institutions dealing with food processing and management of HIV/AIDS. These included:

1. *Tuboreshe Chakula* - USAID funded project dealing with rural food fortification and social markeing of micronutrients. Mosha assisted them initiate their project.
2. *Mwanzo Bora* – USAID funded project dealing with management of HIV/AIDS cases in rural communities. Mosha provided nutritional training for their personnel.
3. *World Bank* country office – focusing on rural fortification of foods. Laswai and Mosha served as technical experts to the government and NGOs in their efforts to launch staple food fortification initiatives in Tanzania.
4. TechnoServe– USAID funded NGO that hopes to develop large scale food extrusion and fortification. Mosha provided food extrusion and fortification training to their personnel.

Leveraged Funds
Name of PI receiving leveraged funds: *Mosha, Laswai, and Bennink*
Brief description of leveraged project and purpose: A high-energy, bean-based paste will be used to rehabilitate moderately malnourished children in a community intervention approach. The study is slated to start 11/10/2012.
Dollar Amount: $91,948
Funding Source: Heinz Company Foundation

Scholarly Activities and Accomplishments

Rondini EA, Bennink MR. 2012. Microarray Analyses of Genes Differentially Expressed by Diet (Black Beans and Soy Flour) during Azoxymethane-Induced Colon Carcinogenesis in Rats. J Nutr Metab. 2012;2012:351796. Epub 2012 Feb 8.

Rondini EA, Barrett KG, Bennink MR. 2012. Nutrition and Human Health Benefits of Dry Beans and Pulses. In: Siddiq M, Uebersax MA (editors), *Dry Beans and Pulses – Production, Processing and Nutrition.* Ames, IA: Wiley-Blackwell Publishing (*in press*).

Bennink, M.R., Mosha, T.C.E., Laswai, H. and Jackson, J. Impact of Food Supplements on Malnutrition and CD_4 Cell Number in HIV Infected Children in Tanzania and Botswana. Heinz symposium Series 20, 2012.

Tables/Figures

Table 1: Cost comparison for the various foods/supplementary foods and the antiretroviral therapies.

S/N	TYPE OF PRODUCT	COST (USD)[1] PER DAY	COST RANGE PER DAY
1	Ugali with beans	$0.60	0.57 – 0.64
2	Ugali with sardines	$0.63	0.62 – 0.70
3	Ugali with cowpeas	$0.60	0.56 – 0.65
4	Extruded/fortified Bean-based supplement	$0.72	$0.70 – $0.77
5	Extruded/fortified Cowpea-based supplement	$0.72	$0.69 – $0.77
6	Extruded/fortified Sardine-based supplement	$0.77	$0.71 – $0.80
7	Antiretroviral therapies[2] 1. Drugs 2. Syrup	 $2.62 $1.98	 $2.45 – $3.25 $1.81 – $2.77
8	Antiretroviral therapies[3] 1. Drugs 2. Syrup	 $10.48 $7.92	 $9.80 – $12.98 $7.23 – $10.40

[1] USD = approximately 1,550 Tanzanian Shillings per $1 USD
[2] Cost to patient; patient pays 25% and government pays 75% of the costs through Essential Drugs Program
[3] Total (unsubsidized) cost of drugs

Table 2. Qualitative evaluation of intestinal permeability in rats injected with saline or toxin and fed either the control diet or the diet containing beans.

Treatment	Control diet	Bean containing diet
Saline injection (negative control)	++	+
Toxin injection	+++++	+++

+ was less permeable and +++++ was most permeable

Literature Cited
None

Contribution to Gender Equity Goal
Four females received advanced degree training (1 PhD and 3 MS). One MS student graduated in November 2011 and is employed by an NGO in Tanzania. The other two MS students will graduate in November 2012. They will begin employment in Tanzania immediately. All four trainees will contribute to the pool of professionals in nutrition and food science to their respective countries (3 in Tanzania and 1 in Jamaica).

Progress Report on Activities Funded Through Supplemental Funds
Not applicable.

Dry Grain Pulses CRSP

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

(For the Period: October 1, 2011 -- September 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by October 1, 2012

Project Title: *Improving Nutritional Status and CD4 Counts in HIV-Infected Children Through Nutritional Support*

	Abbreviated name of institutions																	
	MSU			0			0			0			0			0		
	Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved		Target	Achieved	
Benchmarks by Objectives	**9/28/12**	**Y**	**N***	**9/28/12**	Y	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Prepare, package, distri-	0			0			0			0			0			0		
bute food supplement	0			72800	√		0			0			0			0		
Determine blood cell count	0			450	√		0			0			0			0		
Train M.S. student in research	0			2	√		0			0			0			0		
Provide practical training	0			10	√		0			0			0			0		
0	0			0			0			0			0			0		
0	0			0			0			0			0			0		
Objective 2																		
Determine relative costs of	0			0			0			0			0			0		
nutritional supplements vs	0			0			0			0			0			0		
ART	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 3																		
Analyze dried blood	0			0			0			0			0			0		
spots	900			0		√	0			0			0			0		
Conduct animal study	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 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				M. Bennink & T. Mosha														

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

Maurice R. Bennink	[illegible]
Signature	**Date**

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

Contribution of Project to Target USAID Performance Indicators

Dry Grain Pulses CRSP

PERFORMANCE INDICATORS/TARGETS for FY 12

(October 1, 2011 -- September 30, 2012)

	PIII-MSU-3	
	2012 Target	2012 Actual
Output Indicators	(Oct 1 2011-Sept 30, 2012)	
Degree Training: Number of individuals who have received degree training		
Number of women	4	4
Number of men	0	0
Short-term Training: Number of individuals who have received short-term training		
Number of women	0	
Number of men	2	2
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 from CRSP interventions - Female Headed households	150	150
Number of rural households benefiting directly from CRSP interventions - Male Headed households	100	100
Number of agriculture-related firms benefitting from CRSP supported interventions	2	2
Number of producer organizations receiving technical assistance	2	2
Number of trade and business associations receiving technical assistance	1	1

Number of community-based organizations receiving technical assistance	3	3
Number of women organizations receiving CRSP technical assistance	0	0
Number of public-private partnerships formed as a result of CRSP assistance	0	0
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
Richard Bernsten, Michigan State University, USA (co-PI)
Eric Crawford, Michigan State University, USA (co-PI)

Collaborating Scientists
Jim Beaver, University of Puerto Rico, Haiti
Juan Carlos Rosas, EAP, Haiti
Aurelio Llano, INTA,
Francisco Pavon. INTA,
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
Barry Pittendrigh, University of Illinois at Urbana–Champaign, USA
Julia Bello-Bravo, University of Illinois at Urbana–Champaign, USA
Malick Ba, INERA, Burkina Faso
Maurice Bennink, Michigan State University, USA
Theobald Mosha, Sokoine University of Agriculture, Tanzania
Henry Laswai, Sokoine University of Agriculture, Tanzania

Abstract of Research Achievements and Impacts

In FY12, the project team focused on completing the ex post impact assessment study on cowpea improvement research in Senegal. The survey results indicate that total adoption rate of improved varieties (IV) as reported by farmers in the three major cowpea growing regions was 44%. Adoption rate of the three CRSP varieties specifically identified by their names (Melakh, Mouride and Yacine) was about 22%. About 46% of the sampled farmers were growing at least one of the CRSP varieties. Comparison of the reported adoption rates of the CRSP varieties with those found from the 2004 study reveals that the adoption of CRSP varieties has increased rapidly since 2004—from about 4% in early 2000s to 22% in 2010. This is in part a reflection of the efforts in the past 4–5 years by the government, FAO, NGOs and farmers organizations (and recently by the CRSP) in the multiplication and dissemination of seeds of Melakh and Yacine in major cowpea growing regions in Senegal. The results of the economic analysis indicate that past investments by the CRSP and ISRA have produced an internal rate of return of about 18.6% and a net present value of $18.6 million. The program was further found to be profitable under every sensitivity analysis scenario.

A meta-analysis of ex post impact assessments of research on dry grain pulses was initiated in FY12. The goal of this exercise is to assemble a pool of studies that report economic benefits from pulse crop research and then use that data to conduct a meta-benefit-costs analysis to identify generalized patterns from case observations and estimate an overall rate of return to research investments in pulse crop research. After reviewing and filtering for eligible studies, the final pool for inclusion in the meta-cost-benefit analysis includes 17 studies. Currently, yearly data on benefits and costs are being systematically collected from these studies with the plan to conduct the meta-analysis based on these 17 studies.

To implement an integrated impact evaluation strategy as part of the CRSP project design, the project team collaborated with several Phase 1 and Phase 3 project teams to conduct baseline assessment, design impact evaluations, and conduct in-depth case studies to better understand sustainable models of dissemination of agricultural technologies. Research studies initiated in FY12 towards this objective include 1) Baseline assessment of the economic effects of pest problems on cowpea growing areas in Burkina Faso; 2) Impact evaluation to test the effectiveness and impacts of methods of extension to disseminate materials for IPM of cowpea pests; 3) Benefit/Cost (B/C) analysis of the bean-based nutrition intervention in Tanzania; and 4) Case study of the bean seed multiplication and distribution system in Central America. As of the end of September 2012, two surveys in Burkina Faso, and three surveys in Nicaragua were completed. Some more data collection efforts are underway in Burkina and Tanzania. The data analysis and report writing will be completed in the coming months as part of the no cost extension phase.

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. 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

<u>Objective 1:</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.

In FY12, the project team focused on completing the West Africa impact assessment study on cowpea improvement research and initiated the meta-analysis of ex post impact assessments of research on dry grain pulses in general and of CRSP research in particular. The progress under each of these two activities and emerging results are reported below.

Objective 1a. Benefits of genetic improvement of cowpea in Senegal and West Africa

The general objective of this study was to perform an ex post economic impact assessment of B/C CRSP investments in cowpea varietal development in Senegal. The investment by the CRSP in Senegal has led to the development and dissemination of three determinant, short-cycle varieties: Melakh, Mouride and Yacine.

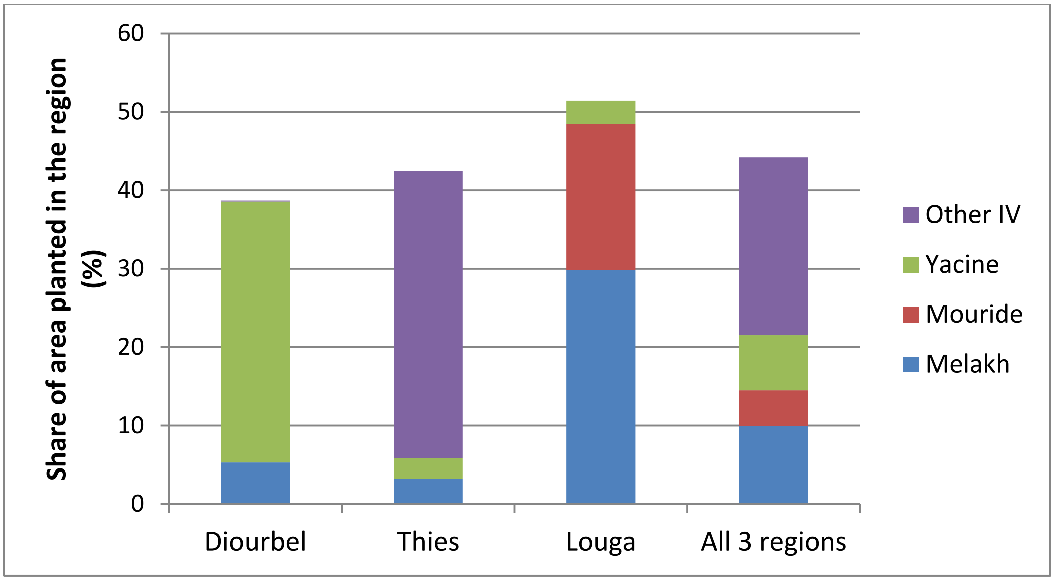
To assess the adoption and economic impact of these improved varieties (IV), a survey was conducted in the Thiès, Louga and Diourbel regions of Senegal. The survey was a supplement to a national survey conducted by the Directorate for Analysis and Prediction of Statistics (DAPS) in 2010. Two groups of farmers were surveyed: (1) farmers interviewed during the 2010 nationwide DAPS survey who indicated that they grew cowpea; and (2) an additional sample of households drawn randomly from the same survey enumeration districts, sufficient to give a total of 7 households per local enumeration area. Of the total intended sample of 1,365 households, 1,257 households remained in the data file after cleaning. The sample was weighted to account for proportional representation, and data were analyzed using Excel and SPSS software.

The total adoption rate of improved varieties as reported by farmers in the three regions was found to be 44%. Adoption rate of the three CRSP varieties specifically identified by their names (Melakh, Mouride and Yacine) was half of this reported area under IV adoption (about 22%). About 46% of the sampled farmers across the three regions were growing at least one of the CRSP varieties. In terms of area, the adoption of improved varieties is found to be highest is Louga (51%), followed by Thies (42%) and Diourbel (39%). The preliminary report on the cowpea seed system by Diatta (2012) indicates a significantly higher quantity of IV seed grown and disseminated in Louga by farmer organizations, possibly contributing to the higher adoption rate observed in this region.

Almost all of the unnamed ‘other improved varieties’ reported by farmers is in Thiès region (36% of cowpea area in that region). Personal communication with the cowpea breeder in Senegal (Dr. Cisse) suggests that if these are indeed improved varieties, then they are likely to be CRSP varieties. However, to be on the conservative side, the economic analysis conducted to estimate the rates of return excluded other improved varieties reported in Thies.

Comparison of the reported adoption rates of the CRSP varieties with those found from the 2004 study based on a survey of farmers from the same regions (Boys et al. 2004) reveals that the adoption of CRSP varieties (and IV in general) has increased rapidly since 2004—from about

4% in early 2000s to 22% in 2010. This is in part a reflection of the focused efforts by the government, FAO, NGOs and farmers organizations (and more recently by the CRSP) in multiplication and dissemination of breeder seeds and certified seeds of Melakh and Yacine in the last 4-5 years. This certainly explains the higher adoption rates observed in this survey.



Source: DAPS survey 2010 and CRSP survey 2011

Figure 1. Share of improved varieties in total area planted to cowpea in the Diourbel, Thiès and Louga regions of Senegal

The yields of cowpea grain for the three CRSP varieties and traditional varieties (TV) based on the survey results are presented in Table 1. As reported, the yield of traditional varieties ranged from 130 kg/ha in Thies to 175 kg/ha in Louga. Reported yields of CRSP varieties are consistently higher than traditional varieties across all the regions. However, the yields of three CRSP varieties varied significantly between regions, with the lowest reported yield difference between TV and IV in Diourbel, and highest in Louga (Table 1).

Table 1. Median grain yields by variety (kg/ha), 2010 season

	Melakh	Mouride	Yacine	Traditional (a)
Diourbel	229.44		215.06	159.69
Thiés	460.65		140.35	129.91
Louga	403.33	711.57	417.77	175.04

Source: DAPS survey 2010 and CRSP survey 2011

a. Reported in the survey as 'traditional varieties'

Adoption rates from this survey and the 2004 study (Boys et al. 2004) were used to project adoption curves for each variety within each region. Using these adoption curves as well as yield gains from improved varieties, economic benefits generated from the adoption of higher yielding Melakh, Mouride and Yacine were estimated and compared with the value of research investment in cowpea breeding by the B/C CRSP and the Senegalese Agricultural Research Institute (ISRA). The results of this analysis indicated that past investments by the CRSP and ISRA have produced an internal rate of return of about 18.6% and a net present value of $18.6 million. The program was further found to be profitable under every sensitivity analysis scenario.

In FY12, a report was also produced by Josiane Diatta, an intern hired by ISRA to shed more light on the cowpea sector and the seed production and distribution system in Senegal. A survey was developed and administered to 11 of the largest cowpea producer organizations in Louga, Diourbel and Thiès, as well as the main actors working in cowpea seed multiplication and distribution at ISRA. The results of this study (Diatta 2012) are complementary to this objective and help understand and interpret the results of the farm survey and the economic analysis reported here. These are summarized below.

Summary of findings from Diatta's survey of the seed system in Senegal: Her study found that improved varieties in Senegal are largely grown in monoculture, with traditional varieties more likely to be grown in intercropping arrangements, as farmers value the TVs more for their taste and leaf production (i.e. fodder). Currently, Melakh and Yacine are the focus of extension efforts in Senegal, replacing earlier IVs, including Mouride. This explains why adoption of Mouride was reported by very few farmers in 2010 growing season in the CRSP farmer survey. While farmers value Melakh and Mouride largely for their drought resistance and green pod yield, Yacine is favored for its brown color and taste. These varieties are determinant varieties and thus are more focused on producing higher green pod and dry grain yields, at the expense of producing animal fodder. For this reason some farmers still prefer to grow traditional varieties that have lower yields.

Before a variety is released, it is tested both at the ISRA research station as well as in on-farm trials is different parts of the country. After being evaluated through these on-farm trials, the variety is sent to the Institute of Food Technology (ITA) to determine its nutritional make-up. An identity card for the variety is produced and the variety is sent to the Department for Plant Protection (DPV) for approval.

Breeder seed for released varieties is produced through ISRA, and then provided to outside organizations through contractual arrangements to produce certified seed. Currently ISRA only produces breeder seed for Melakh and Yacine, as well as two forage varieties, 5574 and 6635. ISRA also provides training on seed production to seed growers. Demand for seed exceeds its supply. According to Diatta (2012), ISRA is able to produce enough breeder seed to meet only around 80–85% of the demand. This is largely due to lack of technical staff and funding.

Producer organizations (PO) have been formed to meet the demand for quality seed at the local level. Many of the POs were initially formed to produce peanut seed, but are now also producing cowpea seed as a way to diversify their crop mix and demand for quality seed as increased as cowpea has become a valuable cash crop. The POs are not only serving as a way to train farmers in seed production but also act as an intermediary between farmers and international actors. These organizations range from a diversified group of individual farmers with a loose/informal arrangement, to community based organizations that pool resources together. They also vary in terms of whether the seed is produced only for organization members, or sold in the market as certified seed. There are significantly more POs producing IV cowpea seeds in Louga than in Thiès and Diourbel.

The seed is only certified if the farmer producing the seed follows the recommended production practices. Farmers growing seeds for the POs do not strictly follow the recommended practices, and thus the seed produced does not meet the certification standards and is not certified. However, the seed is still better than grain and is still sold/used as seed and becomes part of the 'informal' seed system. Because of this, the informal seed sector is fairly large, and there are no real official outlets where farmers can buy and sell quality but 'uncertified' seed of cowpea. Traders will often buy the seeds wholesale from POs, and store the seeds until they can be sell them in times of shortage. Additionally, the seed that goes through this channel (i.e., traders) is not always sold as seed; it may end up as grain in the market.

The inadequate quantity of breeder seed from ISRA was reported to be a major constraint faced by the POs in producing IV seed. Additionally, the breeder seed is often not received in time by the PO, which was cited as one of the reasons for lower seed yields. Seed growers are also often not trained enough on all aspects of how plants should be protected against some common pests, thus contributing to lower yields. Another problem, ironically due to the shorter duration for maturity of IVs is that farmers may not have adequate facilities to dry harvested seeds in the middle of the rainy season, leading to seed rot and other problems that deteriorate the seed quality. Additional training for farmers is needed to not only produce higher seed yields, but also to increase the quality so that the amount of seed that can be certified is increased. Thus, an expansion of the formal seed sector requires closer collaboration between the government and POs, specifically better access to inputs and a more flexible regulatory environment in terms of seed certification.

Objective 1b. Meta-analysis study

Towards this study, a thorough literature review was conducted to identify all the research impact studies (CRSP and non-CRSP) related to beans, cowpeas and other dry grain pulses. The goal of this exercise was to assemble a pool of studies that report economic benefits from pulse crop research and then use that data to conduct a meta-benefit-costs analysis to identify generalized patterns from case observations and estimate an overall rate of return to research investments in pulse crop research following the approach used by Maredia and Raitzer (2010).

Sixty nine studies were identified and some minimum information on each of these studies was entered in a database. A quick review of the abstract/summary and methodology section led to the elimination of many studies that were either duplicates, were not empirically based aggregate level ex post impact assessment studies. In the case of duplicative studies published in different venues, the more rigorous publication (e.g. peer reviewed) was included and all other versions were excluded from the review pool. The final pool of studies for inclusion in the meta-cost-benefit analysis includes 17 studies.

Currently, yearly data on benefits and costs are being systematically collected from the published reports or requested from authors if these data are not included in published outputs. In the coming months, the dataset needed for the analysis will be finalized, the meta-analysis will be conducted, and a paper targeted for publication and an Impact Brief based on the findings of this study will be developed.

<u>Objective 2:</u> Investigate opportunities to integrate baseline data collection and impact evaluation strategies as part of the CRSP project design

Objective 2a. Baseline assessment of the economic effects of pest problems on cowpea growing areas in Burkina Faso.
This is a joint activity with the UIUC-INERA PII-UIUC-1 project team. To address the field insect pest problems like legume pod borer, bruchids, and pod sucking bugs for which conventional breeding has not been effective, the PII-UIUC-1 project has developed alternative strategies for control of these insect pests, in order to reduce the levels of pesticides used on cowpea crops. One of the strategies developed is to implement a comprehensive biocontrol program. This CRSP research by the UIUC–INERA team is expected to generate following long-term impacts on cowpea growers in the region: 1) Health and environmental benefits from the reduction in the use (and misuse) of pesticides. 2) Economic benefits resulting from increased productivity (due to reduction in crop losses) and increased profitability (due to reduction in input costs) to cowpea growers in the region. The realization of these impacts of the biocontrol research being conducted by the PI-UIUC-1 project, critically depends on the following realities—1) the movement and spread of biocontrol agents in relation to where the pest population is present; and 2) the pest control strategies practiced by farmers to control the pests in the absence of biocontrol agents.

To estimate the long term benefits of this type of research requires three types of data/information: 1) a better understanding of the pest population (that are targeted by this research) in terms of its spatial distribution, 2) tracking the movement and spread of biocontrol agents over time, and 3) the change in farmers' pest control practices and/or productivity outcomes as a result of the introduction of biocontrol agents in the environment. The PI-UIUC-1 project has collected (and collecting) data towards the first two types of information that will be useful to conduct an ex post impact assessment of this CRSP project in the future. As part of this project's workplan, in FY12, a baseline household level data was collected towards the third type of information that will be needed to assess the impact of biocontrol research after several years of cumulative efforts by the UIUC–INERA team in Burkina Faso. The following activities have been carried out to date towards this study.

Meeting with collaborators during the DGP CRSP Global Meeting in Rwanda, February 2012. The UIUC–INERA PII-UIUC-1 and PIII-MSU-4 project teams held the first meeting to coordinate activities to be carried out under this project. The PIII-MSU-4 team developed two questionnaires for use during baseline data collection. The PII-UIUC-1 team provided feedback on these questionnaires and the final versions were translated into French. Excel templates were developed for data entry.

The village-level questionnaire included questions about the general characteristics of the villages, location-specific characteristics, access to basic services, and agricultural-related information at the time of the survey. The household-level questionnaire included questions related to general information on the respondent, field characteristics, use of varieties, and cowpea production during the 2011 season, cowpea sales during the 2011 season, the use of labor and other inputs during the 2011 season, importance of the cowpea crop as a source of income and food security, pesticide sources of information, pesticide management, and health effects due to pesticide use, infrastructure owned and access to services, and socioeconomic characteristics of the household (e.g., assets, composition).

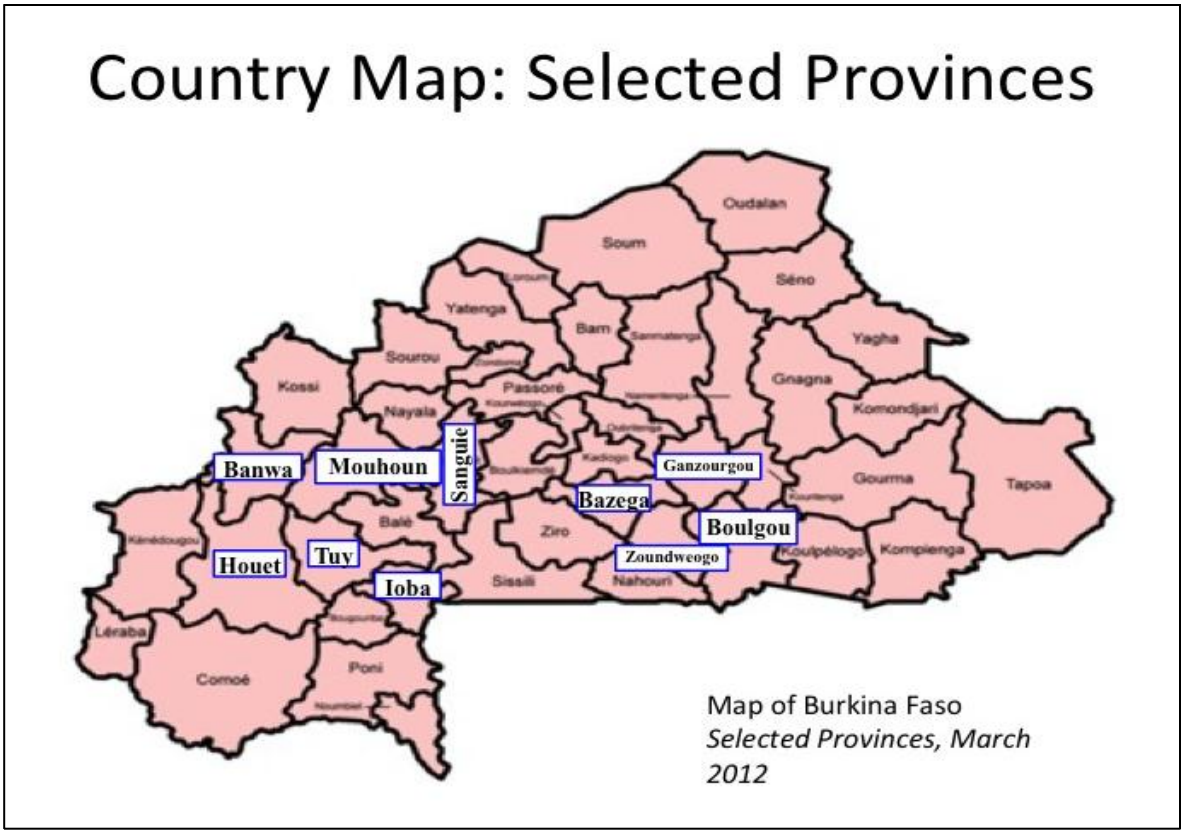


Figure 2. Selected provinces for baseline data collection, Burkina Faso, 2012.

Visit to Burkina Faso by Byron Reyes, March 2012. The main purpose of this visit was to participate in the training of the enumerators who were going to collect the baseline data, randomly select the villages to include in the study, and train the staff who were going to enter the data into Excel. Ten enumerators and two supervisors were trained. The supervisors were also in charge of entering the baseline data into Excel.

The household-level instrument was pretested and a revised version was generated based on the pretesting experience. Four farmers were invited to INERA to participate in the pretesting activity because it was easier to move these four farmers to INERA than to move the 12 enumerators/supervisors plus researchers to the field, and because of the limited time available. One of the four farmers was a woman. Due to the limited number of farmers available, the pretesting was carried out in groups of 2–3 enumerators.

Prior to this visit, the UIUC–INERA PII-UIUC-1 and PIII-MSU-4 teams selected ten provinces to include in this study, which were distributed in two parallel horizontal lines across the south and central regions of the country (Figure 2). This was done because the biocontrol agents will be released in the south region and are expected to move from south to north. Therefore, this design allows us to evaluate the effects of these biocontrol agents in provinces closer to/in the release area (south region) and in provinces farther from the release area (central region). The selected provinces were Houet, Tuy, Ioba, Zoundweogo, and Boulgou in the south region, and Banwa, Mouhoun, Sanguie, Bazega, and Ganzourgou in the central region. Within these provinces, 56 villages were randomly selected.

Further, within each village, ten households were randomly selected for interview using the steps described in Table 2. For this, it was assumed that all farmers within each village produced cowpea in 2011, a reasonable assumption since the provinces were also selected due to their high cowpea production.

Table 2. Steps to follow to randomly select ten farmers per village for baseline data collection, Burkina Faso, 2012.

Step	Instructions	Example
1	Ask the president of the Village Committee for Development to provide the total number of households in the village.	Total number = 38
2	Divide the total number of households in the village by 10. If this number is a decimal below 0.5 (for example 7.49) round this number down. If this number is a decimal equal to or above 0.5 (for example 8.5) round this number up. This number will be used as a fixed interval to select the households.	38 / 10 = 3.8 Round up to 4.0 (use this number)
3	The fixed interval from Step 2 will be used to select the households distributed throughout the village. Select the first household randomly (choose any household).	Choose any household. This will be your first interview.
4	From the selected household, use the fixed interval from Step 2 and count from the first household selected. From this new household, count again and select another household. Repeat this for all other households.	Count 4 households. This will be your next interview.
5	Repeat *Step 4* for all other households until you have 10 households in the village. Mark them in a map of the village (draw one by hand) for you to follow (if possible).	Repeat until you have 10 households
6	Start the interviews. You should know already which households you will interview.	
7	If a household can't be included in the study (because responsible of cowpea production was not available or didn't want to be included in the study), select a household next to the one you just selected but KEEP the original order. Do not count with the fixed interval from this new household!	House # 4 not available? Choose house 5. House 8 will be next (not house 9).

Baseline data collection, tabulation, data cleaning, and selected descriptive statistics. A total of 560 households were interviewed across 56 villages in March–April 2012. Although the analysis is in progress, selected descriptive statistics are presented in Table 3.

From the sample, approximately 95% of respondents were the head of the household (HHH), about 3% were the spouse of the HHH, and 2% of respondents were related differently to the HHH. Further, 98% of households were male headed and, on average, respondents indicated that they have lived in the village for 43 years. The average household size was almost 12 members. On average, each household planted 1.3 cowpea fields and the number of cowpea fields per household ranged from one field (74% of households) to five fields (0.2% of households). Approximately 95% of the households planted between one and two cowpea fields (Table 3).

The use of inputs varied by the type of input. While 54% of households applied chemical fertilizer to at least one of its cowpea fields, only 40% of households applied organic fertilizer (e.g. manure) to at least one of its cowpea fields. In contrast, 78% of households applied chemical or organic insecticides and 65% of households applied fungicides to their cowpea fields. Further, almost 43% of households purchased cowpea seed and spent an average of CFAs 3,866 on these seed (Table 3).

Table 3. Selected descriptive statistics of the 2011 production season baseline data. Burkina Faso, 2012 (*N=560*).

Variables	Total
General characteristics	
Respondent's relation to the HHH (%):	
Self	95
Spouse	3
Other relation	2
Gender of household head (% male)	98
Average number of years living in the village	43
Average household size	12
Average number of fields planted per household	1.3
Households growing 1–2 cowpea fields (%)	95.4
Households growing more than 2 cowpea fields (%)	4.6
Use of inputs in the 2011 season	
HH applying chemical fertilizer in at least one of its cowpea fields (%)	54
HH applying organic fertilizer in at least one of its cowpea fields (%)	40
HH applying insecticides (chemical or organic) in at least one of its cowpea fields (%)	78
HH applying fungicides in at least one of its cowpea fields (%)	65
HH purchasing cowpea seed (%)	43
Average expenses on cowpea seed among farmers who bought seed (CFAs)	3,866
Cowpea as a source of income and food security	
Share of HH income that comes from cowpea grain sales (% of HH):	
A quarter or less	38
Between one quarter and half	24
Between half and three quarters	25
More than three quarters	6
Do not know	7

Share of HH yearly consumption satisfied by own production (% of HH):	
A third or less	31
Between one third and two thirds	34
More than two thirds	24
Do not know	11
Length of time that food grain reserves of cowpea last after harvest (% of HH):	
Less than one month	1
1–3 months	9
3–6 months	20
6–9 months	16
Until harvest in the following season	53
Do not know	<1

Source: Baseline survey, 2012.
HH = household.
HHH = household head.

As expected, the cowpea crop is an important source of income and food security. Sixty two percent of farmers reported that grain sales represented 50% or less of their HH income. Additionally, for most households (34%), their own production satisfied between one third and two thirds of their annual cowpea consumption. Surprisingly, more than 50% of the households reported their food grain reserves of cowpea last until the following harvest (Table 3).

When farmers (*N=452*) were asked about their knowledge of the existence of beneficial insects and viruses, only 7.3% of respondents knew about beneficial insects and 2.6% knew about beneficial viruses. This suggests that efforts will be needed to make farmers aware of the existence of these organisms so they can implement practices to favor their populations. This is confirmed by the fact that only 14.6% of respondents said that they or someone in their household have received training on integrated pest management (IPM) in the past. Since most farmers (95%) consider that pesticides are toxic for their health, it was no surprise that only a small share (6.6%) of farmers re-use pesticide containers after they are empty. This awareness may have been given by the fact that a high share of farmers reported someone they knew has died (40%) or have been sick (42%) due to pesticide poisoning.

In the coming months, the plan is to finalize the baseline report and publish it as a MSU AFRE Staff Paper.

Objective 2b. Impact evaluation to test the effectiveness and impacts of methods of extension to disseminate materials for IPM of cowpea pests.

This is a joint activity of the UIUC–INERA PII-UIUC-1 and PIII-MSU-4 project teams and is partially funded through FY12 supplemental funds. After several interactions through conference calls and e-mails, the team has developed a randomized field experiment and is in the process of implementing the field activities with the goal of collecting all the data before the end of December 2012. We briefly describe the field experimental design and give an update on what has been accomplished to date.

Field experiment. The field experiment planned in Burkina Faso will address the following two research impact questions:

1. How effective is the animated educational video in inducing 'learning' about the postharvest cowpea drying and storing technologies among low-literate farmers?
2. Does learning induce the adoption of technology if availability is not a constraint?

The field experiment plans to test the effectiveness of two animated videos in inducing 'learning' among cowpea farmers in Burkina Faso. These two animated videos were developed with partial funding from the USAID funded Dry Grains Pulses Collaborative Research Support Program (CRSP) and describe 1) a solarization technique for killing cowpea bruchids before the seeds are stored, and 2) the triple bagging technique to store the grain for a long period of time without bruchid damage. Both these videos can be downloaded from the Internet (on You Tube) and are available in French and many local languages spoken in West Africa (e.g., *Moore and Dioula* spoken in Burkina Faso).

The advantages of these two techniques are that they are a) low-cost, simple and quick; b) effective when properly used; c) easy to explain and to disseminate, and d) there is a possibility of reusing the materials. Additional benefits of triple bagging include e) no use of pesticide; f) the grains are ready to be consumed when the bags are opened; g) good for storage of small and large quantities of cowpea; and h) the bags can be stored in homes.

Experimental design. As part of the collaborative CRSP research project, UIUC and INERA plan to pilot test the deployment of these two animated videos in selected villages in Burkina Faso using the government extension system. We use this opportunity to design this pilot initiative as a field experiment based on the principle of randomization in the assignment of the 'treatments' defined in Table 4. The experiment will consist of two treatments (labeled 1 and 2) to address research question #1 (how effective is the animated educational video in inducing 'learning' about the postharvest cowpea drying and storing technologies among low-literate farmers?), and two treatments (labeled A and B) to address research question #2 (does learning induce the adoption of technology if availability is not a constraint?). So in total there will be four treatments as described in Table 4. Note that for research question 2, the focus is only on the triple bag technology, which is expected to have more demand than solar heating technique.

The extension agents will be key in implementing these four types of treatments and they will be well trained on the experimental aspects of this research, the importance of consistency in adhering to the design elements of each treatment (and not mixing them), technical aspects of the two postharvest technologies, the use of animated videos, how to use cell phones to share videos, and baseline data collection of training participants. Each extension agent will complete a survey questionnaire as part of his/her training that will collect information about his/her background and characteristics that may be used to explain any variation in the results of the experiment. Each extension agent will be assigned the same number of treatment villages across the four groups to control for any systematic bias introduced by the extension agent himself/herself in the implementation and outcome of the treatments.

Table 4. Definition of treatment groups in the field experiment

	Treatment 1A	Treatment 1B	Treatment 2A	Treatment 2B
Dissemination of the information on storage technology (solar treatment and triple bag) to farmers	1 Extension agent visits the village (03–11 November) and gives a presentation/demonstration/training to farmers using the animated videos in a group setting (if shown on a big screen or TV) or one-on-one (if shown on cell phones). Installs the video in all handsets with video capability, identifies a leader farmer and leaves behind 'equipment' (DVDs and cellphones) for the village community to use		2 Extension agent visits the village (03–11 November) and gives training to farmers using the traditional method (i.e., practical exercise on how to use the bags to store cowpea).	
Availability of bags & record of sales	A Project leaves 100 sets of triple bags with the assistant in the village who sells these materials to interested farmers (for CFA 11/set of triple bag). Information of buyers (e.g. name, village, # bags, etc.) is recorded. The project collects the money and remaining bags at the end of the project	B Project only provides to the participants information that the bags are available for purchase from the extension agent's office. Interested farmers are sold the bag at the same price (CFA 11/set)	A Project leaves 100 sets of triple bags with the assistant in the village who sells these materials to interested farmers (for CFA 11/set of triple bag). Information of buyers (e.g. name, village, # bags, etc.) is recorded. The project collects the money and remaining bags at the end of the project	B Project only provides to the participants information that the bags are available for purchase from the extension agent's office. Interested farmers are sold the bag at the same price (CFA 11/set)

Sample design. The experiment includes 3 districts each from two provinces—Passore and Sourou. These six districts are Yako, Samba and Arbolle from Passore and Toeni, Tougan and Kiambara from Sourou. Each district is under the leadership of one extension agent. Eight villages will be randomly selected from each of the 6 districts and then 2 villages per district will be randomly assigned to Treatment 1A, 1B, 2A and 2B. The number of villages included in the experiment and their assignment to different treatments is given in Table 5.

Table 5: Number of villages and its distribution across treatment groups

Province	Districts selected	Extension Agent In-charge	Number of villages (see the list in Annex 1)				Total number of villages
			TR 1A	TR 1B	TR 2A	TR 2B	
Passore	Samba	Zongnaba Camille	2	2	2	2	8
	Arbole	Sawadogo Yacouba	2	2	2	2	8
	Yako	Kabre Michel	2	2	2	2	8
Sourou	Tougan	Yelemou Christine	2	2	2	2	8
	Kiembara	Ouattara Sie Victor	2	2	2	2	8
	Toeni	Dakuou Manasse	2	2	2	2	8
		Total	12	12	12	12	48

Questionnaires/forms for data collection. The PIII-MSU-4 team has developed the questionnaires/forms for use during training of extension agents and farmers, and during data collection. The PII-UIUC-1 team provided feedback on these instruments and the final versions of 11 of the 12 questionnaires have been translated into French.

To measure the treatment effects in terms of indicators that measure effectiveness in inducing 'learning' and adoption of the two technologies being promoted, farmer-level data will be collected using standard instruments. Baseline data on the pretreatment' prior knowledge about the storage techniques will be collected from 20 randomly selected participants who attend the training session in each village. A follow-up impact evaluation survey will be conducted for a sub set of 15 farmers per village to be selected randomly from the list of 20 farmers who attended the training/demonstration sessions (i.e., those who received the treatment) and had completed the pretreatment knowledge module. This data will be collected towards the end of November to early December.

Training of extension agents. The PII-UIUC-1 collaborator provided the training to the extension agents in October 2012. The training emphasized the objectives of the project, the importance of the treatments, how to play videos in the cell phones, and how to use the questionnaires/forms. The PIII-MSU-4 staff was available via cell phone/e-mail during this training to clarify any doubts the extension agents could have during their training. The extension agents also completed a pretraining questionnaire to record their knowledge about the two technologies they will be disseminating.

Next steps. Following activities will be carried out in the coming months (as part of the no cost extension phase):

- Visit to INERA by Byron Reyes in November 2012. The main purpose of this visit is to train the enumerators who will collect the village- and household-level data and to train the data entry staff.
- Revise and translate the household-level questionnaire into French.

- Develop Excel/STATA templates for data entry for all questionnaires/forms.
- Data collection, tabulation, and cleaning.
- Project report and development of a research paper based on the results

Objective 2c. Benefit/Cost (B/C) analysis of the bean-based nutrition intervention in Tanzania. The following activities have been carried out to date towards the conceptualization and planning of this study.

Meeting with collaborators during the DGP CRSP Global Meeting in Rwanda, February 2012. The PIII-MSU-3/SUA and PIII-MSU-4 project team members met to explore the feasibility of addressing the policy relevant question of cost-effectiveness of the proposed food-based approach being implemented in Tanzania and to gauge mutual interest in doing this study jointly. Given a encouraging and positive discussions at Rwanda, a follow-up meeting between campus based MSU-3 and MSU-4 teams took place in April 2012 to lay out the next steps of the project and develop a concept note as a guideline for SUA to follow in terms of the collection of appropriate data to conduct this analysis. Here we present the main elements of this concept note and the plan for types of data collection that needs to occur as part of the implementation of the nutrition intervention in Tanzania.

Background on the intervention, experimental design and sample selection. The research conducted by PIII-MSU-3 team involves testing three dietary supplements to improve the immune status of children and adolescents (2–15 years old) infected with HIV in rural Tanzania: (1) bean-maize, (2) cowpea-maize, and (3) fish-maize. This study includes 540 individuals receiving one of the dietary supplements and who were not receiving ARV (antiretroviral) drug at the time of enrollment. Once the individuals get too sick and need to be given ARV drug, they are excluded from the study. Although because of ethical reasons the study does not include a "true" control group, i.e., individuals receiving no treatment, it is possible to obtain indicators of health for years prior to the study for individuals who currently do not receive HIV treatment and use this information as a "control."

The individuals included in the study were randomly selected from a Government of Tanzania (GOT) list of HIV-infected individuals in two regions located 100 km and 600 km from Morogoro, respectively. After an informational meeting and after obtaining their consent, individuals were randomly assigned to one of the three dietary groups. However, siblings infected with HIV who belonged to the same family were assigned to the same treatment (i.e., dietary supplement).

The following hypotheses are being tested by this feeding trial:

1. The bean-maize supplement will be more effective and cheaper than the other alternatives in increasing the indicators of health and nutrition among HIV-infected children.
2. The supplements in general will delay the time when HIV-infected children and adolescents reach the threshold level after which they are automatically given the ARV drug.

Although it would be ideal to estimate the overall lifespan of children consuming each of the dietary supplements, this will not be feasible since the study will last only 30 months. Thus, the main objective is to demonstrate the cost-effectiveness of different diets in preventing/delaying the use of ARV drugs among HIV-infected children and adolescents.

The three dietary supplements are prepared by SUA staff from supplies procured from the market. The process involves extrusion and addition of minerals and vitamins to meet daily nutritional requirements. The end product is a precooked flour (like an instant porridge mix), which is distributed in 130 g bags. Each bag represents one serving per day or a dosage, which, as recommended, should be consumed as a mid-afternoon snack (so other meals are not displaced). Health workers visit the households of recruited subjects every month. During these visits, each infected individual is given enough dosages to last for one month (i.e., 30 dosages or until the next visit) and the adults in the household receive instructions on how to feed the supplement to the children.

Although the supplements are prepared following food safety regulations (HACCP guidelines) and have a one-year shelf life, once prepared there is no further monitoring of the quality of the supplements. Thus, controlling for potential variations in the quality of the supplements will not be possible.

Data collection plan. Data about the following indicators of health are being collected: CD4, CD8, CD3, viral and total lymphocyte counts (from blood samples), stunting and wasting (based on height and weight), and other physical growth indicators (i.e., upper arm circumference). Blood tests and physical growth indicators (i.e., anthropometric measures) are assessed every three months, except for children under five years of age for whom these tests/measurements are performed monthly. It is known that there is an inverse relationship between viral counts and CD4 counts. Thus, it is expected that if the supplements have a positive nutritional impact, CD4 counts will increase while viral counts will decrease.

Food consumption data for the individuals who are the subjects of this study are also being collected to get a picture of the quantity and quality of the overall diet. However, potential bias in this data may arise because they are based on recall data. It is possible that respondents will "tell us what we want to hear" and give misleading information.

Collection of hygiene-related data was not part of the original research design. However, because hygiene has a direct effect on an individual's health, it was proposed by the MSU-4 team to collect some hygiene-related information, such as the "WASH" indicators (see http://www.hip.watsan.net/page/4148). The recommendation was to collect information on at least some of the "essential" indicators. This could be done during the trimonthly visit when health data is collected.

Design of cost-effectiveness analysis. Once the data collection is completed by the MSU-3/SUA team, cost-effectiveness (C/E) ratios will be calculated for each of the three dietary supplements by the MSU-4 team. Cost-effectiveness analysis will be used rather than benefit-cost analysis because the benefits of the dietary supplements cannot be adequately expressed in monetary terms. However, costs can be determined and impacts can be expressed in terms of physical indicators.

The two parts of the C/E ratio will be determined as follows:

1. Costs will include those for buying, preparing, and delivering the supplements. Specifically:
    a. Costs of raw materials at the time of purchase by SUA. For items such as grain whose prices fluctuate over time due to seasonality, the price should be recorded at the time of each purchase or at critical times during the year, in order to allow estimating an "average" price. If the supplement will be prepared at home, the cost of purchasing raw materials by household members would need to be collected.
    b. Cost of preparing the supplements (inputs, labor, electricity)
    c. Transportation cost (for the inputs used in producing the supplements and for transporting the supplements themselves)
    d. Cost of the usual/regular diet consumed in the household
    e. Cost of preparing the supplement directly at the household, following SUA's instructions.
    f. Cost of ARV drug treatment and any other medical treatments required by children who get sick due to causes related to their HIV status.
2. Based on the statistical analysis of data from the dietary supplement trials, the effectiveness (impact) of the treatments will be evaluated using the following indicators:
    a. Extension of time during which children remain healthy, i.e., below the threshold at which they must be treated with ARV drugs.
    b. CD4, CD8, CD3 levels, which are measures of immune status used to determine when an individual must start ARV treatment.
    c. Viral and total lymphocyte counts, used in the same way as CD4, CD8, and CD3 measures.
    d. Stunting and wasting measures, which indicate general nutritional status.
    e. Upper arm circumference measurements, indicating general nutritional status.

Potential analytical challenges. Once C/E ratios have been calculated, they must be evaluated, which involves several potential complications:

1. In general for cost-effectiveness analysis, the "best" option is the one that is most cost-effective, i.e., has the lowest C/E ratio. However, it is generally important to evaluate whether the "best" option is acceptable in terms of absolute level of cost relative to the impacts achieved.[3] This can be done by reference to literature on other similar interventions, or by comparing the cost of the three dietary supplements with the cost of the typical household's diet in the zone studied, or to the cost of treating HIV-infected children with ARV drugs.
2. The use of multiple measures of effectiveness means that multiple C/E ratios will be calculated for each dietary supplement. It is possible, therefore, that no single dietary supplement will be most cost-effective in terms of all impact indicators being analyzed. In that case, in order to select the "best" supplement, an index that encompasses impacts with respect to all indicators would need to be calculated, or the trade-offs among the three dietary supplements assessed subjectively.
3. If the dietary supplements do not differ substantially in cost, it may be worth using a somewhat more expensive supplement than the one with the lowest C/E ratio, if the supplement with the next highest C/E ratio gives a significantly greater impact. This will also involve some judgment.

[3] If impacts could be expressed in monetary terms, one could simply determine whether monetary benefits exceed monetary costs.

4. Lastly, it will be important to assess and report qualitative or intangible factors that may differentiate the three dietary supplements, so that they may be considered along with the results of the quantitative C/E analysis.

Current status and next steps. We have been informed by the MSU-3 team that data collection to determine the relative costs of three dietary treatments compared to HAARV drug treatment has been completed by the SUA economist. However, data on other aspects of this analysis (e.g., food consumption data, cost of preparing dietary supplements by the project, data on WASH indicators) still remain to be collected. Funds for such data collection are currently not budgeted under either MSU-3 or MSU-4 project. Hence the proposed plan is to continue the remaining data collection and analysis efforts in the next phase of the CRSP project by specifically including this activity in the impact assessment project budget.

Objective 2d. Case study of the bean seed multiplication and distribution system in Central America

Under this activity, the project team has completed three surveys: a) A survey of 153 Community Seed Banks (CSB) in Nicaragua, b) a survey of 480 Nicaraguan farmers who received bean seed in 2011, and c) the cost of production record keeping by the Nicaraguan CSBs during the *Primera* planting season 2012.

The survey of Community Seed Banks (CSB) in Nicaragua was designed to gain insight into the CSB formation, how they are structured and what are the design elements that define them as a COMMUNITY seed bank. The socioeconomic conditions and the governance mechanism in which the CSBs operate, and the demographics of CSB members were also captured in the survey. The survey was carried out in coordination with the five regional offices of the national bean research program (INTA). In each region, INTA extension staff and CSB representatives were trained to fill out the surveys in March 2012. The surveys were completed and the database was developed in August 2012. A total of 153 CSBs participated in the survey. The preliminary analysis of this survey data indicates that the average CSB was formed by 7 members and had 21% female participation. Insight was also gained into the various types of CSBs. In 29 communities, a single farmer acted as the CSB by multiplying and disseminating seed to his or her community. In another region, a group of seven experienced seed producers formed a centralized seed multiplication and dissemination effort for six neighboring communities.

In August 2012, 480 Nicaraguan farmers were surveyed who were the beneficiaries of the seed distribution efforts of the Bean Technology Dissemination (BTD) project in 2011. The survey focused on the perceptions of the operations of the CSB as a seed multiplication and dissemination source in their community. The survey also asked about the quality of seed produced by the CSBs. The field work was carried out through NITLAPAN of the *Universidad Centroamericana* (UCA) in Managua. Staff of NITLAPAN supervised field work and data entry activities. The databases from the Nicaraguan farmer survey are in the final revision stage.

During the *Primera* planting season 2012, the seed production costs were recorded for each Nicaraguan CSBs. The record keeping data will be used to estimate the cost of a CSB operation, and in combination with the other two surveys, it will contribute towards conducting a benefit/cost analysis of the CSB model. The data from this record keeping exercise have not been entered yet and thus they have not been made available to the campus team. It is expected that production costs from 130 CSB will be included in the final database, which is being compiled by INTA staff.

CSBs plant high quality "registered" seed (produced by INTA) to multiply bean seed for dissemination. "Registered" seed is the same seed used to multiply commercial "certified" seed, which is sold at a very high price but considered to be of high quality. The CSB seed does not incur the cost of certification through INTA or the Nicaraguan Ministry of Agriculture, which means there is no monitoring of process of producing the seed and the quality standards of the seed produced. INTA records commercial "certified" seed production costs, which are expected to be much higher than the *apta* (or quality declared) seed produced by CSB. Forthcoming comparison of CSB production costs and "certified" seed production costs vis-à-vis their benefits in terms of seed quality will reveal the relative net benefits gained from the CSB model in Nicaragua.

Two additional complementary studies are planned for April 2013 in Honduras and Guatemala. Farmers will be surveyed regarding their impressions of seed quality and the seed dissemination methods used in each country. As noted in the FY12 Workplan, these activities are extended beyond FY12 through the 'Bean Technology Dissemination' (BTD) project currently being implemented through an Associate Award to the Pulse CRSP. In May 2012, the project team gave a presentation to representatives of the national programs from Nicaragua, Guatemala, Honduras and Haiti at the Second Regional Meeting of BTD. Plans for and methodology of the Guatemala and Honduras studies were shared at that meeting and input sought from country leaders in the data collection activities planned in those countries.

<u>Objective 3:</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. Ben Megan, a citizen of USA
    c. David deYoung, a citizen of USA
    d. Henry Akaeze, a citizen of Nigeria
4. In addition, the project hired Byron Reyes as a postdoctoral fellow (formal job title was "Specialist, Extension") from January 2, 2012 to help execute some of the field activities and data analysis of this project.

Networking and Linkages with Stakeholders

Mywish Maredia and George Norton (Impact assessment PI for the IPM CRSP) were the co-organizers of a Symposium at the 28th International Conference of Agricultural Economists held in Brazil, August 18–24, 2012. The symposium was titled "Assessing the Impacts of Agricultural Research and Development in a Global Bio-Economy" and included speakers representing five CRSPs—IPM, Peanut, BASIS, INTSORMIL and Dry Grain Pulses. The symposium presented case studies on how investments in agricultural research by the U.S. Agency for International Development (USAID) through the Collaborative Research Support Programs (CRSPs) have improved the productivity, profitability and sustainability of global agriculture. It also highlighted examples of methods and results of assessing the impacts of public goods science in improving human well-being. The Symposium was attended by more than 25 conference participants, mostly economists, representing diverse groups of stakeholders and researchers. The Symposium provided a good opportunity to highlight the accomplishments of CRSPs to an international audience and discuss some of the methodological challenges in doing impact assessment of agricultural research.

Mywish Maredia was invited to participate in the planning and proposal development meeting of the CGIAR Research Program (CRP) 3.5 focused on legume crops. The meeting was organized by ICRISAT and held in Dubai in May and was attended by representatives from four CGIAR centers (ICRISAT, ICARDA, IITA and CIAT), two CRSP directors (Pulse CRSP and Peanut), U.S. universities, consultants, and the Bill and Melinda Gates Foundation. This meeting provided a good opportunity to network with researchers and economists from the CGIAR system working in the area of pulse crops and to learn about and contribute to the proposed research agenda (esp. social science) by the CRP over the next 5–10 years.

Leveraged Funds

$12,000: Masters International Fellowship from the College of Agriculture and Natural Resources, MSU for Ben Magen

Scholarly Activities and Accomplishments

Dissertations and Theses

Reyes, B. 2012. The Economic Impact of Improved Bean Varieties and Determinants of Market Participation: Evidence from Latin America and Angola. Ph.D. Dissertation. Michigan State University. 203 p.

Magen, B. 2012. An Ex Post Economic Impact Assessment of Bean/Cowpea CRSP Investment on Varietal Development in Senegal. Plan B paper towards M.S. degree. Department of Agricultural, Food and Resource Economics, Michigan State University (Draft).

Impact Briefs

Based on the research conducted by this project and past ex post impact studies, the project team has developed and published the following three Impact Briefs by the end of September 2012. The Impact Briefs will be a permanent feature of the Pulse CRSP's website. The idea is to more widely disseminate and convey the impact stories of USAID's investments in Dry Grain Pulses CRSP (and its predecessor Bean/Cowpea CRSP) through rigorous research based impact assessments.

Reyes, B.; Maredia, M.; and Bernsten, R. Improved bean varieties in Central America and Ecuador generate economic benefits to farmers. Impact Assessment Research Brief No. 1, July 2012. (English and Spanish versions available)

Reyes, B.; Bernsten, R.; and Maredia, M. Sustaining a steady flow of high yielding, improved bean varieties through the bean research network in Central America. Impact Assessment Research Brief No. 2, July 2012. (English and Spanish versions available)

Moussa, B.; Lowenberg-DeBoer, J.; Fulton, J.; and Boys, K. Farmers in West and Central Africa obtain economic benefits from enhanced cowpea storage technologies. Impact Assessment Research Brief No. 3, July 2012. (English version available)

Presentations and Posters

Bernsten, R. Reflections on Bean/Cowpea and Pulses CRSP Achievements in Socio-Economic Research and Wisdom for the Future. Presentation made at the Dry Grain Pulses CRSP Global Pulse Researchers Meeting. Kigali, Rwanda, February 2012.

Maredia, M. Global Pulse Production and Consumption Trends: The Potential of Pulses to Achieve ‘Feed the Future’ Food and Nutritional Security Goals. Presentation made at the Dry Grain Pulses CRSP Global Pulse Researchers Meeting. Kigali, Rwanda, February 2012.

Maredia, M. Refocusing and positioning the CRSP to achieve development outcomes: Lessons learned from past Bean/Cowpea and Pulse CRSP Investments in Research. Presentation made at the Dry Grain Pulses CRSP Global Pulse Researchers Meeting. Kigali, Rwanda, February 2012.

Reyes, B., Bernsten, R., Maredia, M., Crawford, E., and Kelly, J. *Ex-post* economic impact evaluation of improved bean varieties in four Central American countries and Ecuador. Selected Symposium Presentation, IAAE Triennial Conference, Foz Do Iguaçu, Brazil, August 2012.

Reyes, B., Bernsten, R., Maredia, M., Crawford, E., Kelly, J., and Rosas, J.C. New bean varieties and their Economic Impact: Evidence from Latin America. Poster presented at the Dry Grain Pulses CRSP Global Pulse Researchers Meeting. Kigali, Rwanda, February 2012.

Reyes, B., Bernsten, R., Maredia, M., and Crawford, E. Seed systems as a basis for achieving impacts from research investments in bean and cowpea breeding. Presentation made at the Dry Grain Pulses CRSP Global Pulse Researchers Meeting. Kigali, Rwanda, February 2012.

Honors/Awards

Richard Bernsten (co-PI of this project) was the recipient of the CRSP Professional Achievement Award conferred to him by the TMAC at the Global Pulse CRSP meeting (in February 2012) for his "lifelong scientific achievement in contributing to improving the livelihoods of smallholder pulse farmers in developing countries."

Literature Cited

Boys, K, Fulton, J, Faye, M and Lowenberg-DeBoer, J (2004) *Adoption and the economic impact implications of storage technology and improved cowpea varieties in the North Central Peanut Basin of Senegal*, Purdue University, Bean/Cowpea CRSP.

Diatta, J (2012) *Adoption des Semences Améliorées de Niébé dans la Zone Nord Bassin Arachidier du Sénégal,* CNRA–Bambey. ISRA.

Maredia, M.K. and David Raitzer (2010) Estimating Overall Returns to International Agricultural Research in Africa through Benefit-Cost Analysis: A “best-evidence” approach. *Agricultural Economics* 41: 81–100.

Progress Report on Activities Funded Through Supplemental Funds

Activity 2b included in this project’s workplan was partially supported through supplemental funds to INERA through PI-UIUC-1 project. The progress of this activity is reported under Objective 2, activity 2b.

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 positive results obtained in Year 2, we conducted additional profiling to determine the structure of major flavonoids in cowpea and associate the specific composition with bioactivity. Phytochemical composition and properties were measured using UPLC-MS^n. We then tested select lines for specific anti-inflammatory pathways relevant to immune response and oxidative stress reduction using non-malignant colonic myofibroblasts CCD-18Co cells. We also tested antiproliferative activity of select lines against human colon cancer cells *in vitro*. Heritability of cowpea polyphenols was found to be strongly associated with the expression of seed coat color as a phenotypic trait. We confirmed that light brown cowpea lines high in tannins were most effective oxidative stress inhibitors, whereas the black and red lines high in flavonols and anthocyanins were most effective against various anti-inflammatory markers. We also discovered that the chemical nature of the major tannin compounds specific to cowpea is such that they are less likely to interfere with bioavailability of essential micronutrients like zinc and iron than bioactive compounds common in other food plants. We also found that compounds in cowpeas can prevent processes relevant to intestinal inflammation. Thus cowpea has tremendous potential as a 'dual purpose' food crop that provides essential nutrition, and promotes health and disease prevention. Our findings lay the foundation for additional investigations that will uncover the specific health benefits of cowpea in human intervention studies. We believe the crop will feature prominently as a strategically important component of nutrition and health initiatives in Sub-Saharan Africa.

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 is linked to depressed immunity and 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 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

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

<u>Approaches and Methods</u>

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 was determined.

The bulk of this objective was accomplished in the previous year; most of the tests outlined here were selective and confirmatory in nature.

***Gross phenolic composition*.** Was used to confirm heritability of composition in progeny. The following analyses were used for the screening: gross phenol content, anthocyanin pigments, and tannins content. Ground samples were extracted in 0.12 mol/L HCl in methanol. Anthocyanin pigment content was measured by pH differential method, which is based on measuring absorbance in pH 1.0 and pH 4.5 buffers at λ_{max} using a scanning UV-Vis spectrophotometer, The Folin-Ciocalteu method was used to estimate gross phenols content, by measuring reactant absorbance at 600 nm using gallic acid as the standard. The vanillin-HCl method was used for condensed tannin assay; reactant absorbance (with blank subtraction to correct for non tannin pigments) was measured at 500 nm, catechin was used as standard. In addition, we established a new rapid method for screening breeding populations for gross phenolic content using the FT-NIR technology as described under Objective 3.

Flavonoids profiling. Sample extracts obtained as described above were washed through a C-18 column to remove sugars and other non-flavonoid constituents. Flavonoids were eluted using 70% acidified methanol, rotoevaporated and reconstituted in 10% methanol containing 10 mL/L formic acid and filtered through 0.45 μm membrane before analysis. A reversed phase C-18 column was used for separation; and an Agilent 1200 HPLC system was used for characterization. MS analysis was performed using a Thermo-Finnigan TSQ7000 triple-quadrupole mass spectrometer equipped with an API2 source, and an Electrospray Ionization (ESI) interface.

***Phenolic acid and phenolate esters*.** Free phenolic acids were measured in methanol extract whereas alkaline hydrolysis of residue was used to measure esterified phenolic acids. Reversed phase HPLC separation, with appropriate standards, was used to identify the compounds; LC-MS was used for structural determination when needed.

***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 were initially cooked by boiling in water for 30 - 75 min (until soft), 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 AOAC Method 975.44. In vitro protein digestibility was determined by multi-enzyme (i.e. pancreatic trypsin, chymotrypsin and peptidase) method.

Results

Flavonoid composition of cowpea

The emphasis this year was to confirm previous year's data and also identify some major flavonoid compounds we were previously unable to identify. Part of this work was published (Ojwang et al 2012), and part of it is under peer review.

1. **Anthocyanins.** We confirmed that black and green cowpea varieties accumulate 8 major monomeric anthocyanin compounds: 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 petunidin-3-*O*-galactoside. The relative proportions of these compounds did not change regardless of growth environment; samples obtained from University of California-Riverside and those grown in College Station had similar anthocyanin composition. This indicates that genetics is the major factor that controls anthocyanin synthesis in cowpea.

   We also identified the same anthocyanin compounds in a grey speckled cowpea variety we did not previously report in 2011, Mounge. The only difference between Mounge and the other cowpea varieties with anthocyanins (IT95K-1105-5, IT98K-1092-1, TX2028-1-3-1) was that in Mounge, malvidin-3-*O*-glucoside and petunidin-3-*O*-glucoside (both O-methylated anthocyanins) were the dominant compounds as opposed to the non-methylated anthocyanins (delphinidin-3-*O*-glucoside, cyanidin-3-*O*-glucoside) that dominate the black and green varieties. O-Methyl substitution can significantly impact bioavailability and bioactivity of phenolic compounds, and thus the nutritional implications of such compositional differences should be explored further.

2. **Flavonols.** The findings confirmed previous year's data that indicated major variability in flavonol composition of cowpea. Glycosides of quercetin dominated the flavonol profile of all cowpea lines tested; they accounted for about 80% of flavonols in red cowpea varieties, and over 90% in most of the other phenotypes. Myricetin and kaempferol were minor components. These proportions did not change regardless of growth environment, again confirming that genetics play a bigger role in determining flavonoid composition in cowpea. In general, we confirmed that the red cowpea lines contain the most flavonols followed by golden brown lines. The white cowpea lines had the lowest flavonol content. The detailed characterization of the flavonols was published in *Journal of Agricultural and Food Chemistry* (Ojwang et al 2012).

3. **Flavan-3-ols.** Due to the major impact tannins are known to produce on nutrient digestibility and micronutrient bioavailability, we were keen to understand the polymeric profile of the cowpea tannins we identified in the previous year. Among the key factors that determine biological effects of tannins are their molecular weight distribution and structure. Catechin and (epi)afzelechin were the major flavan-3-ol units that made up the tannin polymers of cowpea. Unusual composition was observed in all cowpea phenotypes with significant

degrees of glycosylation in the monomers and dimers. Monomeric flavan-3-ols were the largest group of tannins (36 – 69%) in cowpea (Fig 1 & 2), with catechin-7-*O*-glucoside accounting for most (about 88%) of the monomers. The oligomers with degree of polymerization (DP) 2 – 4 ranged from 0.41 – 1.3 mg/g (15 – 20%), whereas DP>10 polymers accounted for only 13.5% of the tannins. By contrast, in most other food crops, including legumes, oligomeric and polymeric tannins usually account for more than 97% of tannins. Given that the high molecular weight tannins are the ones that bind most strongly to protein and other nutrients thus reducing their bioavailability (Cheynier et al 1997), the composition of cowpea tannins is advantageous from a nutrient bioavailability perspective. As reported in the previous year, light brown cowpea lines had the highest tannin content regardless of growth environment. Follow up studies using animal and humans will be necessary to demonstrate if the unique tannin composition of cowpeas translates to beneficial effects in vivo.

Gross phenolic

Regardless of origin, the light brown cowpea varieties once more had the highest phenol content on average, likely related to their high tannin content previously reported. For example, 09FCV-CC27M and Lutembwe, grown in Texas and Zambia, respectively, had phenol contents of 14.9 and 17.2 mg GAE/g, respectively). By comparison, white Early Acre variety had phenol contents of 2.6 mg GAE/g. In general, the phenol content of cowpea varieties analyzed were confirmed to have the following trend: light brown > black > red > golden brown > green > white, confirming that cowpea phenolic composition is highly influenced by seed coat color.

Summary

From the results, it is apparent that seed coat color has a major influence on the type of phenolic compounds accumulated by cowpea. Once more we confirmed that 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)

Darker-colored grains have been shown to contain higher levels of phenolic compounds than lighter-colored grains (Chang et al., 1994). However, for cowpeas, the seed coat color is a good indicator of the type of phenolic compounds present but not their content.

Protein content and quality

In general protein content of cowpeas were very similar across varieties and environments. The major cowpea lines in Zambia, M'sandile, Bubebe and Lutembwe had protein contents of 23.5 – 25.6%. South African lines, Agrinawa, Agrigold, and Glenda had protein contents of 23.4 – 24.4%. The IITA lines maintained at Texas A&M and University of California Riverside tended to have higher protein content than East and Southern African lines (range 22.6 – 32.5%, average 26.5%). This is likely due to long term breeding and selection efforts. Lysine content and available lysine were also higher for the IITA lines (average 1.73% and 1.66% of cowpea seed by weight, respectively) compared to the East and Southern African lines (average 1.52% lysine and 1. 47% available lysine). The values are for cooked cowpea. The average protein digestibility of cooked cowpea was 79%; micronization process which significantly reduces cooking time had no deleterious effects on in vitro protein digestibility of cooked cowpeas (Table 1).

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

Approaches and Method

The goal was to establish how the phytochemical profiles affect the ability of cowpeas to influence metabolic, cardiovascular and chemoprotective health predictors *in vitro*. To support results reported in the previous year, enzymic digestion (simulating gastrointestinal conditions) of cooked cowpea samples was performed to better mimic what would happen in humans. The enzyme digests were compared to extracts obtained using standard procedures based on organic solvents. Additional pathways for anti-inflammatory properties of these compounds were also explored.

Hydroxyl/free radical scavenging properties protection against oxidative stress is an important component of chronic disease prevention. Antioxidant capacity of cowpeas and their fractions was measured by two widely accepted methods that involve hydrogen atom transfer (HAT) and single electron transfer (SET) that have been shown to correlate with biological oxidative status measures. Oxygen radical absorbance capacity (ORAC) was the HAT method. Ability of cowpea extract to protect fluorescein from free radical attack by AAPH was monitored for 90 min at 37^{o}C using a fluorescence spectrophotometer (excitation 485 nm, emission 528 nm). The Trolox Equivalent Antioxidant Capacity (TEAC) was used for SET assay. Samples were reacted with preformed $ABTS^{o}$ free radical, and ability of the sample to quench the free radical measured after 30 min by monitoring color at 734 nm. Trolox was used as standard in both assays.

***Inhibition of low density lipoprotein (LDL) oxidation*.** Oxidation of LDL leads to impairment in the regulation of cholesterol uptake. This potentially leads to development of artherosclerosis and cardiovascular disease. The ability of extracts from the cowpea/bean varieties to inhibit LDL oxidation was determined using the method described by Puhl et al. (1994) by monitoring formation of conjugated dienes at 234 nm.

***Glycemic properties*.** Procedures described by Goni et al (1997) was used to measure rate of *in vitro* starch hydrolysis in selected cowpea lines. Hydrolysis index and estimated glycemic index was 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 assays

Two strategies were used to assess how cowpea compounds can protect against cancer and also cardiovascular disease, two major chronic diseases:

Anti-cancer effects

1. **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 used 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 was used as a positive control; this compound is a potent natural phase II enzyme inducer.

2. **Anti-proliferation assays.** These methods measured how the various cowpea extracts affect growth of pre-formed cancer cells. We used 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) was used to measure viable cell population by established protocols. Double stranded DNA was measured using the PicoGreen Quant-iT assay kit (Invitrogen Inc, Carlsbad, CA) as described by Ahn et al (1996). Genistein was used a positive control in both assays. *Apoptosis* was assessed by analyzing in cells by analyzing PARP-cleavage as previously described (Chintharlapalli, Papineni et al. 2009).

Cardiovascular Disease

In order to determine the in vitro effects of phenolic extracts and fractions from cowpea on biomarkers for antioxidant properties and inflammation using human colonic myofibroblasts (CCD-18co), we measured:

1. **Biomarkers for inflammation** nuclear factor kappa B (NFκ-B), interleukins IL-6, IL-8, tumor necrosis factor TNF□□ and Nf-kB was determined by ELISA assays obtained from E-bioscience, San Diego, CA and Life Diagnostics, West Chester, PA, as previously performed (76, 77). These biomarkers are typically used to assess inflammation and cowpeas extract is expected to decrease LPS-induced inflammation in these cells.
2. **Antioxidant biomarkers.** As previously performed (71), cells were treated with different extract concentrations and antioxidant effects were determined after different incubation times with the ORAC assay as well as the generation of reactive oxygen species (ROS). Additionally, oxidative stress was induced with hydrogen-peroxide and the mitigation of pro-oxidant potential by different concentrations of cowpea extract was assessed. Oxidative DNA damage was assessed in the same manner; after the induction of DNA-damage with H_2O_2, the alleviating effects of cowpea was assessed with the ApoAlertTM DNA Fragmentation Assay (BD Biosciences) according to the manufacturer's protocol.

Results

1. **Antioxidant capacity.** The data obtained last year were largely confirmed, with gross phenol content strongly correlating with antioxidant activity measured by various methods. Thus the light brown cowpea varieties tended to produce the strongest antioxidant activity, followed by red and black varieties.

As reported in the previous year for other oxidative processes, cooking produced a modest decrease in the ability of cowpea extracts to inhibit low density lipoprotein (LDL) oxidation (Table 2). However, micronization significantly reduced the antioxidant capacities of all cowpea types against LDL oxidation. This observation was somewhat unusual, given antioxidant activity measured by other methods were not impacted by micronization by this magnitude. Additional work is needed to confirm the data.

2. **Anti-inflammatory properties**. Again as a follow-up to previous year's positive findings, we investigated additional inflammatory pathways relevant to immune response in the gastrointestinal tract. Reduction of mRNA expression of inflammatory biomarkers was dose-dependent. In general, the ability of cowpea extracts to reduce expression of interleukine-8 (Fig. 3) was most dependent on flavonol content; varieties with the highest level of flavonols (red cowpea) were most effective at the lowest concentrations tested (2 g/mL. Interleukine-8 is involved in initiation and amplification of inflammatory process. Similar results were observed for tumor necrosis factor (TNF), a cytokine involved in chronic inflammation and proliferative cell signaling. Coupled with previous year's results, it is apparent that cowpea is a promising source of compounds that would be beneficial in controlling chronic inflammation and improving immune response, especially in the gastrointestinal tract.

3. **Antiproliferation and phase II enzyme activity.** The ability of cowpea extracts to inhibit colon cancer cell proliferation was compared to that of enzyme digests; the digests were obtained by simulated gastrointestinal digestion using a combination of amylase and protease enzymes. Agrinawa (red) and Blackeye were used for this investigation. In general, a dose response was observed for cancer cell growth inhibition for both samples (Fig 4). Cooking samples modestly reduced the potency of the extracts, especially from the red Agrinawa sample, against cancer cell proliferation. This may be related to reduction in polyphenol content due to cooking as reported last year. The red cowpea extracts and digest were more effective against cancer cell proliferation than the black-eye variety. Enzyme digest more effectively inhibited cancer cell proliferation than organic solvent extract when compared based on original cowpea sample. This indicates that the standard organic solvent methods used to estimate bioactive properties of grains may be underestimating potential health benefits.

For phase II enzyme activity, cooked Agrinawa (red cowpea) produced the strongest induction of phase II enzymes; this may be related to the relatively high levels of flavonols in the red cowpeas. However, the overall effect was still modest (maximum inducer activity of 1.5 times relative to control) compared to other known phase II enzyme inducing grains (Awika et al 2009).

From this work, we have successfully identified important cowpea phenotypes that should be targeted in follow up in vivo studies using humans and animal models to confirm how the flavonoid composition of cowpea influence specific health benefits.

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

<u>Approaches and Methods</u>
Greenhouse experiments were conducted to study the inheritance of antioxidant activity in cowpea. As indicated below, a number of crosses were made between 10 different parents selected based on their polyphenol content/antioxidant activity as low parent with high parent. These were:

1. Parents with low antioxidant activity:

Early acre, (white with thin black hilum line)
TX 2028-1-3-1(green with black eye)
IT98K-205-8 (white with small black eye)
GEC (white with small brown eye)
Bambey 21(white)
CB-27(white with large blackeye)

2. Parents with high antioxidant activity
IT82D-889 (red self color)
IT97K-1042-3(red self color)
IT97K-556-4(light brown self color)
TVu 7778 (light brown self color)

3. The successful crosses made were:

- Early Acre (low antioxidant) x IT82D-889 (high antioxidant)
- TX 2028-1-3-1 (low antioxidant) x 1042-3 (high antioxidant)
- IT98K-205-8 (low antioxidant) x IT97K-1042-3 (high antioxidant)
- GEC (low antioxidant) x IT97K-1042-3 (high antioxidant)
- Bambey- 21 (low antioxidant) x IT97K-556-4 (high antioxidant)
- CB-27 (low antioxidant) x IT97K-556-4 (high antioxidant)
- Bambey -21 (low antioxidant) x TVu 7777-8 (high antioxidant)

The resulting F1 seeds were grown in the green house and F2 populations were generated for most of the crosses. In view of the significant association between seed color and antioxidant content, notes were also taken on seed phenotypic traits in F1 and subsequent generations. Various combinations of seed colors were observed in F2 and F3 seeds including complementary gene action for seed color in some crosses.

<u>Analytical methods for bioactive compounds</u>

Analysis of total polyphenols and condensed tannins using Fourier transform near infrared spectrophotometer (FT-NIR)

A nondestructive method was developed to estimate total polyphenols, and total condensed tannins in seeds of crosses. This was important given the time consuming nature of the wet chemistry methods, and the large number of samples generated by the crosses. A standard curve for total polyphenols, total condensed tannins and antioxidant activities was established using 60 diverse varieties that were analysed for these values using wet-chemistry. Originally these 60 samples were analysed in triplicates using UV-spectromeric method. The values from wet-chemistry were plugged in equations of FTNIR scans (spectral range of 4000-9999) to establish correlations. High correlations were observed between the FTNIR data and wet chemistry methods for polyphenols and tannins, i.e., 0.992 & 0.996, respectively. Antioxidant activity did not correlate with the scans. A set of 28 more samples was validated against the correlations to determine the performance index, which were found to be higher than 65, an indication of a good validation. This method is currently being used to scan seeds from the above mentioned crosses in order to determine the inheritance of polyphenols and tannins in cowpea.

HPLC method. Select samples were characterized by HPLC using methods described under Objective 1 to confirm association of seed coat color with flavonoid composition.

Results

The analysis of the genetic materials is in progress. Some interesting preliminary observations are presented below:

Analysis of flavonoids and anthocyanins

The F1 plants from the cross involving Bambey 21 (white selfed) and IT97K- 556-4 (light brown selfed) produced black seeds showing a complementary gene action for seed coat color (Fig. 5).

The results showed complete absence of anthocyanins in both parents but very high levels in the hybrid indicating gene complementation for anthocyanin accumulation. In addition, hybrid vigor in flavonol content was observed in the hybrid, where accumulation of quercetin derivatives increased compared to either parents (Fig. 6).
As previously reported, these results indicate that the amount of bioactive compounds is significantly correlated with the seed color (Table 3). Also, the genetic segregation for seed color seems to determine the genetic segregation for the bioactive compounds. Based on the current data above, there may be only 2-3 pairs of genes controlling these traits. Further analysis of more F2, and backcross populations are in progress and the results would provide further insight into exact nature of inheritance.

Thus, even though it is apparent that heritability of seed coat color in cowpea is complex, the fact that the seed coat color itself is a good indicator of the type of flavonoid compounds accumulated by the seed may be more important. This is because our findings demonstrate that the type of flavonoids present in cowpea seed coat correlate with indicators of specific bioactive properties.
Further studies involving the F2 and F3 populations are in progress.

Objective 4: Institutional Capacity Building:

Degree Training

PhD Student 1

First and Other Given Names: Twambo
Last Name: Hachibamba
Citizenship: Zambia
Gender: Female
Training Institution: University of Pretoria
Supervising CRSP PI: Amanda Minnaar, Gyebi Duodu, Joseph Awika
Degree Program for training: PhD
Program Areas or Discipline: Food Science
Host Country Institution to Benefit from Training: University of Zambia
Start Date: August 2010
Projected Completion Date: June 2013
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Full

<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: Eugenie
Last Name: Kayitesi
Citizenship: Rwanda
Gender: Female
Training Institution: University of Pretoria
Supervising CRSP PI: Gyebi Duodu, Amanda Minnaar, Riette de Kock
Degree Program for training: PhD
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: KIST
Thesis Title/Research Area: Micronization of cowpeas: Effects on sensory quality, phenolic compounds and bioactive properties
Start Date: 2010
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: Indirect (Student received a University of Pretoria Post-graduate Fellowship for 3 years)

<u>PhD Student 4</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): Completed
Type of CRSP Support (full, partial or indirect) for training activity: Partial

<u>PhD Student 5</u>
First and Other Given Names: Archana
Last Name: Gawde
Gender: Female
Training Institution: Texas A&M University
Supervising CRSP PI: Joseph Awika
Degree Program for training: PhD
Program Areas or Discipline: Molecular & Environmental Plant Science
Start Date: January 2009
Projected Completion Date: December 2012
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

<u>MS Student 1</u>
First and Other Given Names: Billy
Last Name: Kiprop
Citizenship: Kenya
Gender: Male
Training Institution: Egerton University
Supervising CRSP PI: Abdul Faraj
Degree Program for training: MS
Program Areas or Discipline: Biochemistry
Host Country Institution to Benefit from Training: Egerton
Start Date: January 2010
Projected Completion Date: December 2011
Training status (Active, completed, pending, discontinued or delayed): Active
Type of CRSP Support (full, partial or indirect) for training activity: Partial

<u>Short Term Training</u>
Type of Training: Short term workshop and hands on laboratory training
Description of Training Activity: Workshop explaining preliminary findings and what they mean to cowpea promotion strategy, discussions on way forward.
Status of this Activity as of September 30, 2012: completed
When did the Short Term Training Activity occur? June 1, 2012
Location of Short Term Training: Lusaka, Zambia
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 ZARI and UNZA
Number of Beneficiaries by Gender: Male – 10
FeMale – 11
Total – 21
Additional training provided to technicians at University of Zambia and local cowpea producers in Siavonga, Zambia: 1 female and 6 male

Type of Training: Short term hands on laboratory training and discussions on research strategies
Description of Training Activity: Explaining preliminary findings and what they mean to cowpea promotion strategy, discussions on way forward.
Status of this Activity as of September 30, 2012: completed
When did the Short Term Training Activity occur? June 8-9, 2012
Location of Short Term Training: Nairobi & Katumani, Kenya
If Training was not completed as planned, provide a rationale:
Who benefitted from this Short Term Training Activity? Academic and field staff of KARI-Katumani and Egerton University
Number of Beneficiaries by Gender: Male – 1
FeMale – 2
Total – 3

Networking and Linkages with Stakeholders
During the year, cowpea germplasm was supplied to Kenyan collaborators. Supply of seed to Zambian collaborators was delayed due to import permit problems. This will hopefully be resolved before the end of the year. Dr. Awika visited field plots in dry areas of Siavonga Province of Zambia, and met with local government extension agents as well as some successful and struggling local farmers. This was an eye opening experience where various constraints to adoption of improved cowpea cultivars as well as major post harvest loss issues were discussed. We also met with various key government representatives and policymakers in the areas of agriculture and nutrition in Lusaka Zambia, including National Institute for Scientific & Industrial Research (NISIR), National Food & Nutrition Commission (NFNC), Ministry of Community Development Mother & Child Health, among others. We had long and productive discussions on specific strategies necessary to make the next phase of the project successful. (The agreement was that data generated from in-country feeding trials, especially targeting school children would be critical to generate buy-in with top policy makers.)

Leveraged Funds
Name of PI receiving leveraged funds: Joseph Awika
Brief description of leveraged project and purpose: Currently we are working on two other projects on cowpea related to heat and drought stress and P-acquisition efficiency, as they relate to nutritional and end use quality. We have three graduate students are working with the PI on these cowpea projects that directly contribute to the CRSP project goal. 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: $285,000
Funding Source: Texas AgriLife Research, CoNACYT, McKnight Foundation, Howard Buffett Foundation

Scholarly Activities and Accomplishments

Manuscripts

L. O. Ojwang, L. Dykes, J. M. Awika. 2012. Ultra performance liquid chromatography-tandem quadrupole mass spectrometer profiling of anthocyanins and flavonols in cowpea (*Vigna unguiculata*) of varying genotypes. *Journal of Agricultural and Food Chemistry* 60, 3735–3744.

Scientific Presentations

Leonnard O. Ojwang; Liyi Yang; Susanne Talcott; Clint Allred; JOSEPH M. AWIKA. Cereal-legume synergy: Exploiting differences in polyphenolic composition of sorghum and cowpea to provide complementary health benefits. American Association of Cereal Chemists International Meeting, Hollywood, FL, October 2012.

J. AWIKA, Archana Gawde, Leonnard Ojwang, B. B. Singh. 2012. Identifying health attributes of cowpea. 72nd Southern Region of the American Society of Horticultural Science, Feb 4–7, Birmingham, AL.

Tables/Figures

Table 1. Effect of micronization and cowpea type on % in-vitro protein digestibility of cooked Agrinawa and Blackeye cowpeas

Treatment	Cowpea types		Overall treatment effect
	Agrinawa	**Blackeye**	
Cooked	77.9 (1.2)[1] a[2]	80.4 (0.8) bc	79.2 (1.61) a[4]
Micronized and cooked	79.0 (1.8) ab	81.8 (1.0) c	80.4 (2.01) b
Overall cowpea type effect	78.5 (1.6) a[3]	81.1 (1.1) b	

Table 2. Effects of micronization of preconditioned and cooked cowpeas on protective effect of their extracts (10 mg/ml) against copper-induced LDL oxidation

Sample	Antioxidant activity against LDL oxidation (µm TE/100 mg)
Blackeye	
Uncooked	0.7 (0.1)[d]
Unmicronized (cooked)	0.5 (0.0)[c]
Micronized (cooked)	0.1 (0.0)[a]
Bechuana white	
Uncooked	1.3 (0.1)[f]
Unmicronized (cooked)	0.9 (0.0)[e]
Micronized (cooked)	0.2 (0.0)[ab]
Glenda	
Uncooked	1.3 (0.0)[f]
Unmicronized (cooked)	0.9 (0.1)[e]
Micronized (cooked)	0.3 (0.1)[ab]
Dr Saunders	
Uncooked	1.5 (0.0)[g]
Unmicronized (cooked)	1.2 (0.2)[e]
Micronized (cooked)	0.4 (0.0)[b]

[abc] = mean values within a column with different letters differ significantly ($p<0.05$), Standard deviations are given in parentheses and results are expressed as micro molar trolox equivalent (TE) per 100 mg of the sample

Table 3. Results of the preliminary genetic studies involving different populations of the cross, IT82D-889 x Early Acre:

Population	seed color	Phenols	Tannins
IT82D-889	Red	9.96	13.43
Early Acre	White	2.02	0.55
F1	Lt.Brown	10.7	10.30
F2	Lt. Brown-8	7.6-9.22	7.7-12.49
F2	D.Brown-3	11.48-13.13	8.77-13.22
F2	Mixed color-24	0.39-7.07	0.39-9.36
F2	Red-1	7.95	10.1
F2	White-3	1.48-2.84	0.38-2.25

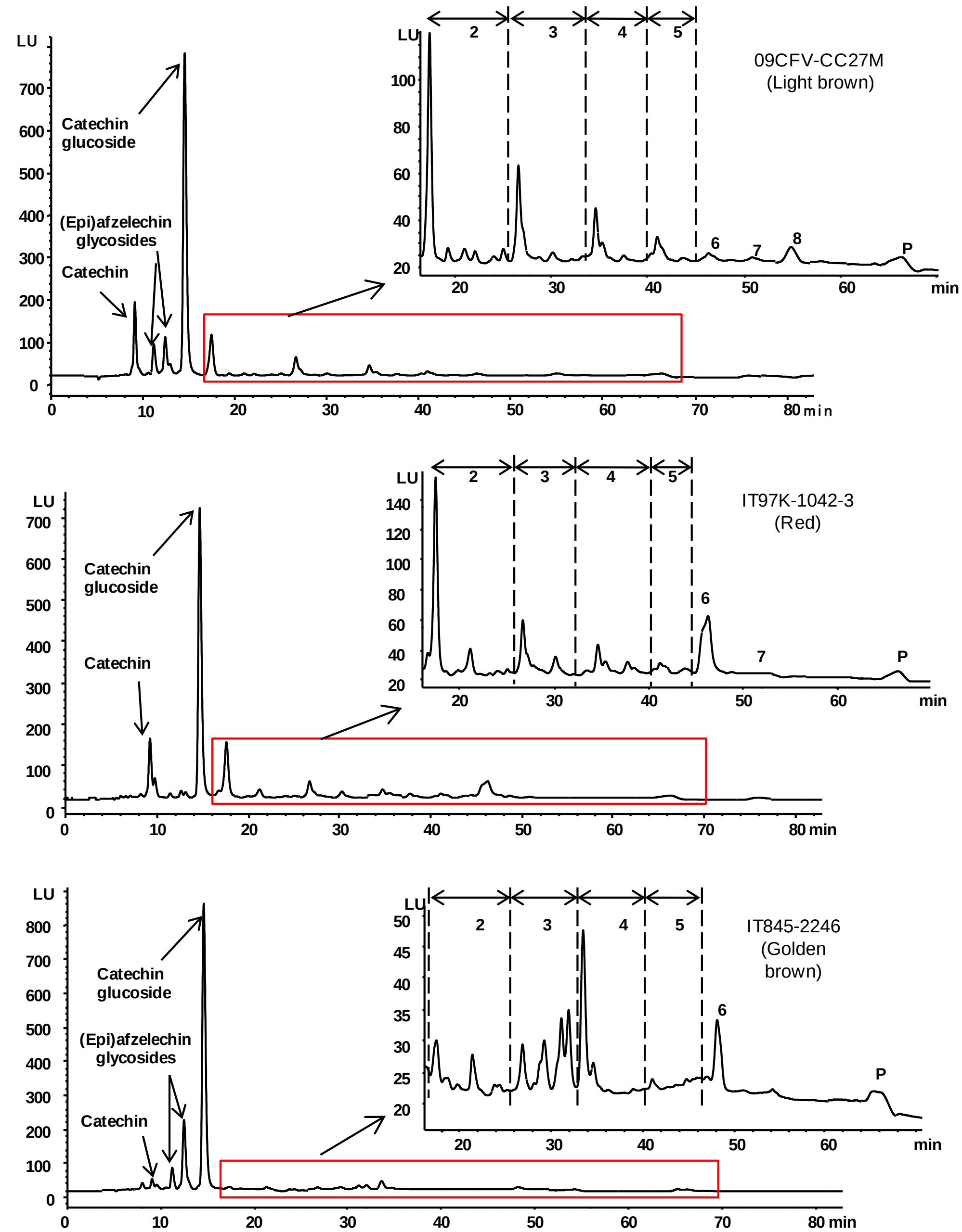


Figure 1. Representative normal-phase high performance liquid chromatography with fluorescence detection (HPLC-FLD) proanthocyanidin profiles of selected cowpea varieties. Numbers above peaks denote degree of polymerization; P = polymers with DP > 10.

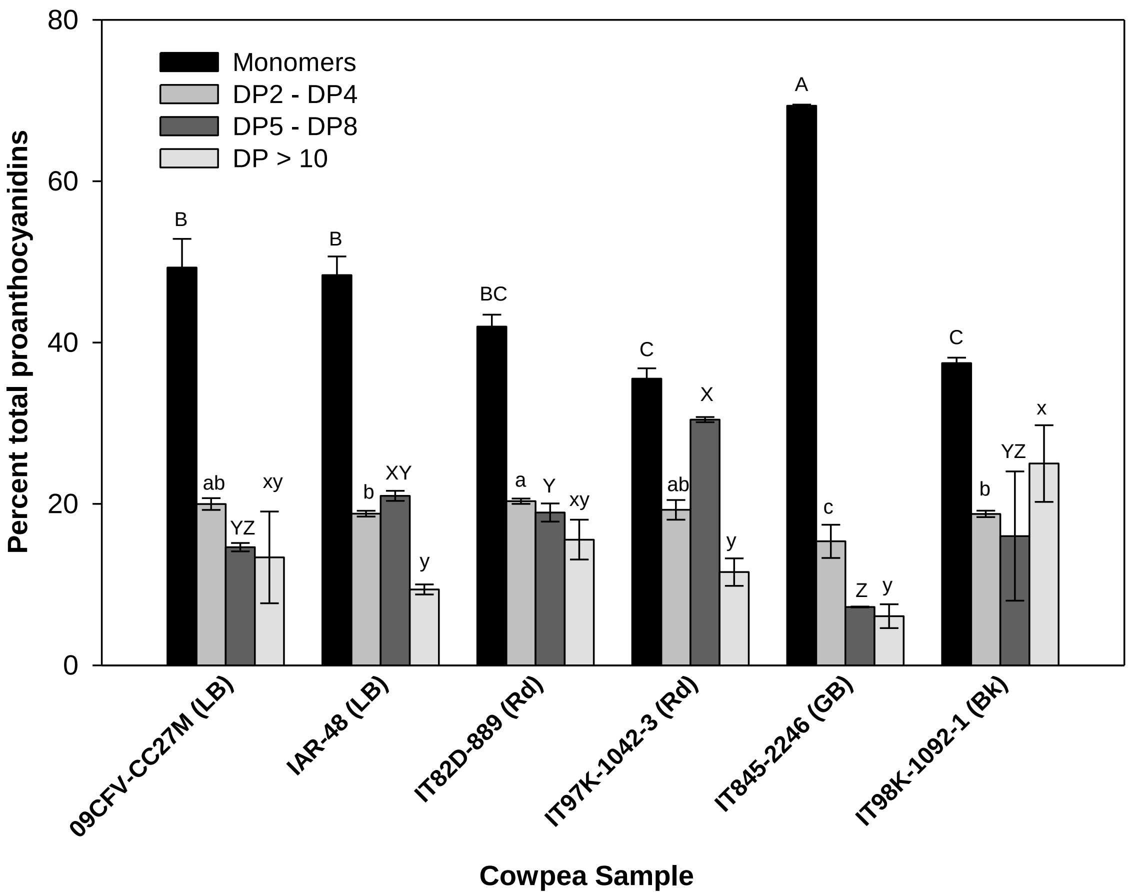


Figure 2. Relative proportions of proanthocyanidins of various molecular weight (MW) groups in the tannin-containing cowpea. Error bars represent ± sd; DP = degree of polymerization. LB = light brown, GB = golden brown, Rd = red, Bk = black. Bars with same letter within a MW group not significantly different ($p < 0.05$, Tukey HSD).

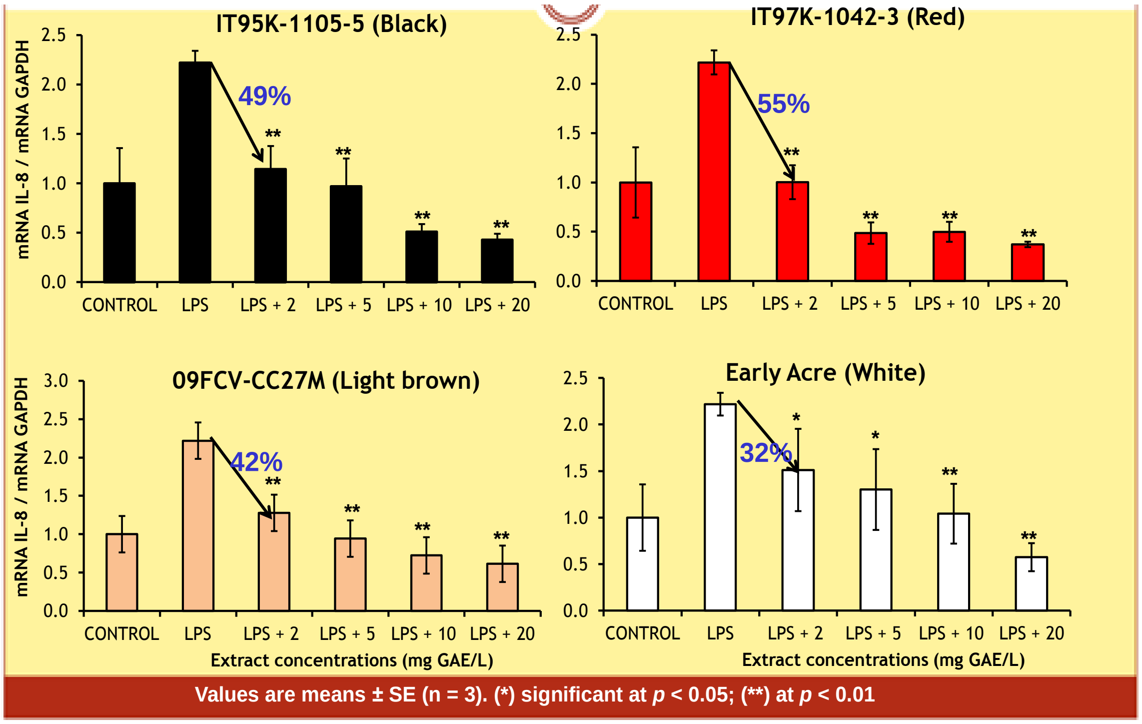
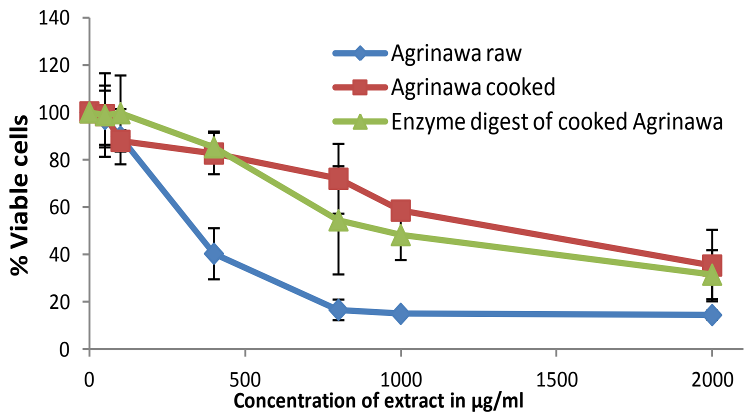


Figure 3. Non malignant colonic myofibroblast **(**CCD-18Co) gene expression of Interleukin-8. Cells were pre-treated for 3 hrs with cowpea extracts (2 – 20 mg GAE/L), then stimulated with LPS for 6 hrs; and analyzed by real time qRT-PCR as ratio to GAPDH mRNA. Values are means ± SE (n = 3); (*) $p < 0.05$, (**) $p < 0.01$.



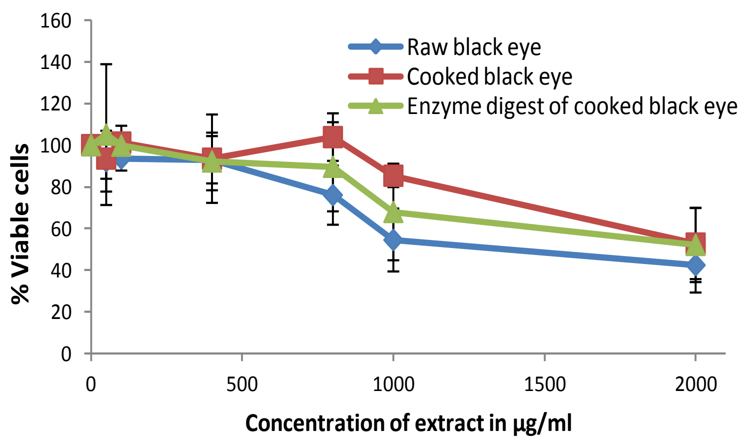


Figure 4. Effect of cowpea extracts and enzyme digest on *in vitro* Caco-2 colon cancer cell proliferation. Cells were incubated with extracts for 48 hrs and proliferation measured using the MTT assay.

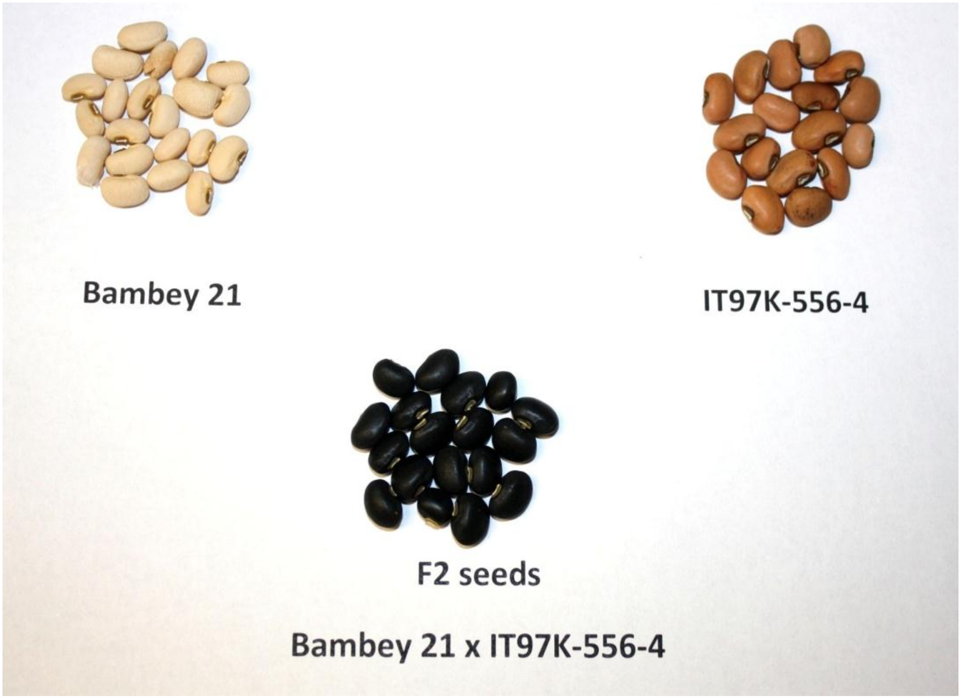


Figure 5: Parents (Bambey 21 and IT97K-556-4) and F1 hybrid or F2 seeds used for HPLC quantifications to elucidate inheritance of specific group of compounds.

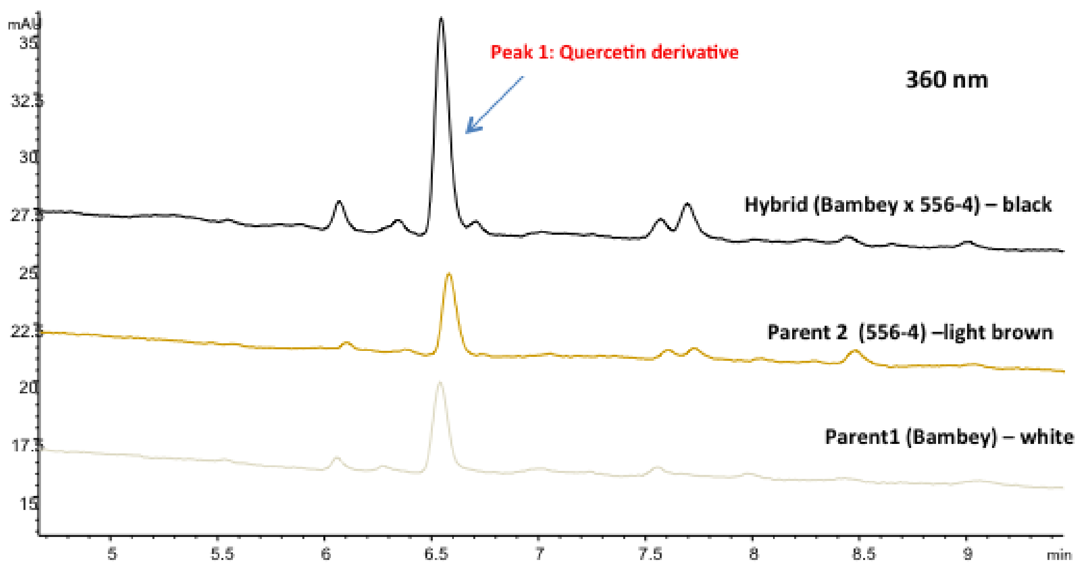


Figure 6: HPLC graphs of parents and hybrids at 360 nm showing hybrid vigor in flavonol content. Further studies involving the F2 and F3 populations are in progress.

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Contribution to Gender Equity Goal

Currently 2 females (from Kenya and Zambia) working on their PhD are directly funded on this project. In addition, of the 27 people who received short term training in Zambia this year, 12 were females.

We will continue to actively engage females throughout the project.

Additional Literature

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Dry Grain Pulses CRSP

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

(For the Period: April 1, 2012 -- Sept 28, 2012)

This form should be completed by the U.S. Lead PI and submitted to the MO by April 1, 2012

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	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**9/28/12**	**Y**	**N***	**3/31/12**	**Y**	**N***	**3/31/12**	**Y**	**N***
	(Tick mark the Yes or No column for identified benchmarks by institution)																	
Objective 1																		
Elite lines:																		
Screening tests													**0**			**0**		
Phenolic Profiling	x	x		x	x					x	x		**0**			**0**		
Protein content													**0**			**0**		
Protein quality and digestibility				x	x*					x	x		**0**			**0**		
													0			**0**		
													0			**0**		
Objective 2																		
SET & HAT assays													**0**			**0**		
Bile acid binding assay							X	x					**0**			**0**		
Inhibition of LDL oxidation										X	x		**0**			**0**		
Glycemic Index				X	x								**0**			**0**		
Phase II	X	x											**0**			**0**		
Anti-proliferation	X	x											**0**			**0**		
Inflammatory biomakers	x	x											**0**			**0**		
Objective 3																		
Perform relevant crosses													**0**			**0**		
Obtain F3 seed	x	x											**0**			**0**		
Conduct field trials	x	x		x	x								**0**			**0**		
Distribute F2 & F3 seed to HC	x	x											**0**			**0**		
													0			**0**		
													0			**0**		
Objective 4																		
Stakeholder workshops				x	**x**		x	**x**					**0**			**0**		
Prepare training manuals/brochures													**0**			**0**		
Final meeting of project PI's	x	x		x	x		x	x		X	x		**0**			**0**		
Graduate training (PhD)	x	x								x	x		**0**			**0**		
Name of the PI reporting on benchmarks by institution	J Awika			J Shindano			A Faraj			A Minnaar								
Name of the U.S. Lead PI submitting this Report to the MO	Joseph Awika																	

Joseph Awika — **Signature**

10/6/2012 — **Date**

* *This task was initiated by UNZA but completed at TAMU due to technical problems with equipment at UNZA*

Dry Grain Pulses CRSP		
PERFORMANCE INDICATORS/TARGETS for FY 12		
(October 1, 2011 -- September 30, 2012)		
	PIII-TAMU-1	
	2012 Target	**2012 Actual**
Output Indicators	**(Oct 1 2011-Sept 30, 2012)**	
Degree Training: Number of individuals who have received degree training		
Number of women	2	2
Number of men	1	1
Short-term Training: Number of individuals who have received short-term training		
Number of women	15	14
Number of men	15	17
Technologies and Policies		
Number of technologies and management practices under research	6	6
Number of technologies and management practices under field testing	1	1
Number of technologies and management practices made available for transfer	5	5
Number of policy studies undertaken	0	

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	0	0
Number of rural households benefiting directly from CRSP interventions - Male Headed households	0	0
Number of agriculture-related firms benefitting from CRSP supported interventions	0	0
Number of producer organizations receiving technical assistance	0	0
Number of trade and business associations receiving technical assistance	0	0
Number of community-based organizations receiving technical assistance	0	0
Number of women organizations receiving CRSP technical assistance		0
Number of public-private partnerships formed as a result of CRSP assistance		0
Number of HC partner organizations/institutions benefiting	4	4
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices	0	0

Pulse Value Chain Initiative—Zambia (PVCI-Z)

Principal Investigator
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Collaborating Scientists
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Mukwiti Mwiinga, University of Zambia, Zambia
Prisilla Hamukwala, University of Zambia, Zambia
Bernadette Chima, University of 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

Research Achievements and Impacts
The final year of operation was focused on completing data collection and analyzing data, testing hypotheses and envisaging implications of the results from the study towards the Feed the Future goals of reduced poverty and enhanced nutrition. This report provides an overview of the project's activities over the three years. The major accomplishments are the number of people trained under the institutional capacity building initiative was exceeded due to stewardship. Additionally, the project built enduring relationship with local institutions such as 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. Finally, the governance experiments started with a small group of producers has started yielding enduring results – reducing operations costs and increasing incomes.

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 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's objectives are:
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. Pilot at least one governance system to identify the factors and characteristics of participants influencing performance.
6. Based on the results from the foregoing, develop and deliver education and outreach programs targeting specific stakeholders and provide policy recommendations to facilitate solutions.

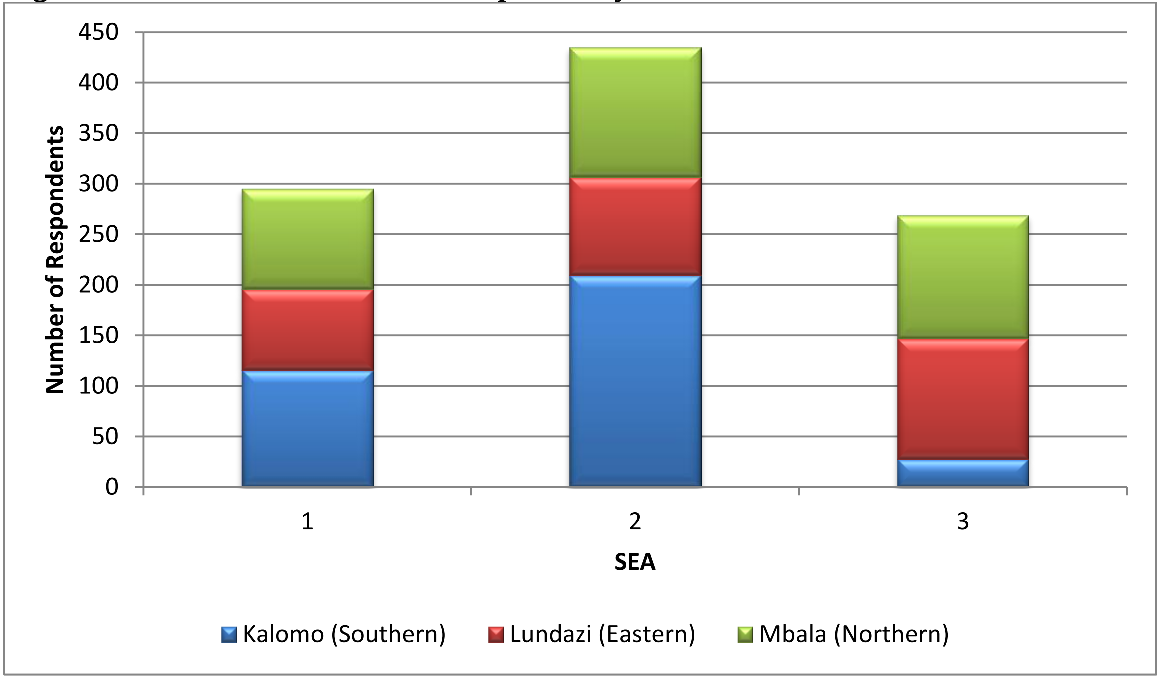
Results, Achievements and Outputs of Research
Primary data is used to achieve the objectives of the first category objectives described above. This study was conducted in three districts – Kalomo in Southern Province, Lundazi in Eastern Province and Mbala in Northern Province. These districts were selected on the basis of their relatively high levels of production of beans (Mbala and Lundazi) and cowpeas (Kalomo and Lundazi). Production estimates used in this decision were determined using data from the 2008 rural income and livelihood survey (RILS) by the Central Statistical Office (CSO), the Ministry of Agriculture and Cooperatives (MACO) and the Food Security Research Project (FSRP).

A two-stage cluster sampling strategy was used to select sample households from the three districts, a design that has been used by most large-scale studies around the world, including Living Standards Measurement Studies, LSMS (Grosh and Munoz 1996). The study's sample design used the Central Statistics Office's standard enumeration areas (SEAs) as primary sampling units at the first stage and the households in the selected SEAs as the secondary sampling units.

The survey was conducted between November 2011 and February 2012 and resulted in a total of 1,050 households being interviewed. After stringent data cleaning, a total of 1000 usable responses or 95.2% of the original dataset remained. Their distribution, presented in Figure 1 shows that the majority of respondents (435) were in SEA 2 while SEA 1 and SEA 3 accounted for 295 and 269 respondents each. However, the distribution across the three districts used in the study was as follows: Lundazi, representing Eastern Province (297); Mbala, representing Northern Province (349); and Kalomo, representing Southern Province (354). The figure shows that the cleaned data resulting in an underestimation of the optimal 350 sample size for Lundazi District by about 15% and overestimating Kalomo (Southern Province) by about 1%. Mbala District (Northern Province) was the only one statistically equal to the estimated optimal size. Because the appropriate sampling weights were applied in all the analyses, and because the sampling focused on centers of production concentration in the identified crops, confidence in the inferential power of the dataset is preserved despite these slight deviations from the optimal sample sizes per stratum.

Another preparation of the data was to identify *extreme outliers* with the possibility of unduly skewing the results. Given that the majority of the respondents were s smallholder farmers, total household cropland was determined to explain the extremeness of the outliers (Donald, 2001). Barnett and Lewis’ (1978) suggestion that responses that are three or more standard deviations from the mean was adopted in screening outliers. However, because the study was interested in smallholders of all sizes, the screening rule focused only on those respondents whose cropland holdings were three or more standard deviations higher than the estimated mean. This reduced the cleaned sample from 1,000 to 940, indicating that about 2.6% of the original usable dataset was “large enough” to possibly distort results. This small group of “large producers” have been grouped into a different category and not used in any of the analyses reported in this report.

Figure 1: Distribution of Usable Responses by Standard Enumeration Areas



The summary weighted demographic statistics for the respondents is presented in Table 1. It shows that the nearly all respondents (90.2%) indicated farming as their primary occupation, suggesting that the right group of respondents was identified in the sampling process. About 14.0% of the respondents were female and 86.5% were married. The table shows that nearly 68% of respondents indicated growing mixed beans compared to 52.5% for cowpea, and approximately 97% produced maize, Zambia's staple food Zambia (Amanor-Boadu, 2010; Mason, Jayne, Chapoto, & Donovan, 2011). A little over 27.0% of the respondents were shown to be located in Eastern Province and Southern Province respectively while 45.2% resided in Northern Province.

Table 1: Summary Statistics of Respondents' Basic Characteristics

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Gender (Female = 1)	939	70,066	14.00%	34.72%	0	1
Married (Yes = 1)	939	70,066	86.46%	34.24%	0	1
Farmer (Yes = 1)	939	70,066	90.16%	29.80%	0	1
Mixed Beans (Yes = 1)	940	70,127	67.91%	46.71%	0	1
Maize (Yes = 1)	940	70,127	96.91%	17.32%	0	1
Cowpea (Yes = 1)	940	70,127	52.51%	49.96%	0	1
Eastern (Yes = 1)	939	70,066	27.54%	44.70%	0	1
Southern (Yes = 1)	939	70,066	27.24%	44.55%	0	1
Northern (Yes = 1)	939	70,066	45.22%	49.80%	0	1
Education (Years)	939	70,066	6.18	3.35	0	18
Age (Years)	939	70,066	41.84	15.01	14	99
Cropland (ha)	940	70,127	8.25	6.73	0.30	37.00
Annual Income	867	64,303	3.13	6.42	0.01	72.00

The weighted sample average age was approximately 42 years, with a standard deviation of about 15 years. The average formal education was 6.2 years, with a standard deviation of about 3.4 years, implying that a typical respondent had only completed primary school. Weighted average cropland was about 8.3 ha with a standard deviation of 6.7 ha and ranged from 0.3 ha to 37.0 ha. This is higher than the less than 4 ha estimated average cropland holdings for smallholders in sub-Saharan Africa (Ellis, 2005). The average annual income of the sample was ZMK3.1 million with a standard deviation of ZMK6.4 million and had a range of almost ZMK72 million.[4] The World Bank estimated gross national income for capita (purchasing power parity approach) for 2011 was U.S.$1,490, equivalent to ZMK7.45 million. This would suggest that the average income of the sample is significantly lower than the national average income, an observation that is not surprising given that most rural people's incomes are below the national average. This measure also provides a benchmark for designing policy as the opportunities embedded in mixed beans and cowpeas are explored to enhance producer incomes and reduce poverty.

It is known that smallholders often undertake multiple cropping and this was found to be true in Zambia. The results from the survey shows that 189 households planted maize, mixed beans and cowpeas together but only three households planted both mixed beans and cowpeas. While only three households planted only cowpeas and maize, 402 households planted both beans and maize while 322 planted both cowpeas and maize. The correlation between maize and mixed beans acreage was positive (0.18) and significant at the 1% level while the correlation between maize and cowpeas was not significant. The correlation between mixed beans and cowpeas was, as expected, negative (-0.12) and statistically significant at the 1% level. The correlation between available cropland and the acreages of these thee crops was positive and statistically significant at the 1% level.

The issue of gender is important in development conversations because of overwhelming research showing the critical role females play in nutrition status of their families, education of children and agricultural production (Ransom & Bain, 2011; Zamani & Erfanirad, 2011). However, research shows that females tend to control less production resources in most communities, including smallholder agricultural communities (Chu, 2011). Therefore, the gender and regional differences in these summary statistics are evaluated to determine gender and regional disparities in the sample. The results, presented in, show that there was statistical difference between male and females in five characteristics: marital status; mixed beans; education, age; and income. There were about equal proportions of males and female in the different provinces and their cropland ownership was also about the same.

[4] The Zambian Kwacha (ZMK) was exchanging at about ZMK5,000 to U.S.$1.00.

Table 2: Summary Statistics and Difference Tests of Respondents' Basic Characteristics by Gender

Mean	Male	Female	Difference	t	P>t	Sig.
Married (Yes = 1)	96.12%	31.97%	64.15%	15.00	0.00	***
Farmer (Yes = 1)	91.72%	90.30%	1.42%	0.06	0.95	
Mixed Beans (Yes = 1)	69.26%	58.77%	10.49%	2.31	0.02	**
Maize (Yes = 1)	97.14%	98.84%	-1.69%	-1.10	0.27	
Cowpea (Yes = 1)	53.26%	54.08%	-0.82%	-0.25	0.80	
Eastern (Yes = 1)	28.08%	27.35%	0.72%	-0.16	0.87	
Southern (Yes = 1)	27.01%	26.11%	0.90%	0.11	0.91	
Northern (Yes = 1)	44.91%	46.54%	-1.62%	0.03	0.97	
Education (Years)	6.46	4.83	1.62	5.28	0.00	***
Age (Years)	40.02	47.11	-7.10	-5.90	0.00	***
Annual Income	3.34	1.69	1.65	3.34	0.001	***
Cropland (ha)	20.51	20.58	-0.07	0.59	0.55	

* ≤ 0.10, ** ≤ 0.05 and *** ≤ 0.01 level of statistical significance respectively.

Table 3 shows the weighted summary statistics of all crops survey respondents indicated planting in 2010. The largest average crop area was maize, which was unsurprising given the place of maize in Zambia's food profile. It received an average of 2.6 ha and ranged from about 0.2 ha to 22 ha. Mixed beans and cowpeas were the second and third crops with the largest areas, with mean areas of approximately 2.3 ha each. Eleven other crops had an average area of 2 ha or more but only ten crops had more than 100 producers reporting. For example, burley tobacco had an average area of 3.7 ha but only eight producers reported its production. Similar, the average area for millet was about 2.1 ha but only 68 producers reported producing the crop.

Table 3: Summary Weighted Statistics for Crop Area by Households in Hectares

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Maize	916	68,159	2.64	2.94	0.20	22.00
Mixed beans	612	49,811	2.35	2.48	0.10	16.00
Cowpeas	516	33,823	2.32	2.29	0.10	25.00
Groundnuts	453	32,410	2.11	2.58	0.10	24.00
Sunflower	202	14,167	2.02	2.74	0.10	16.00
Cassava	152	15,119	2.48	2.39	0.20	12.00
Seed Cotton	132	8,810	1.19	1.43	0.10	11.00
Sweet potatoes	104	8,784	2.47	2.39	0.10	16.00
Soya Beans	89	6,624	1.19	1.56	0.10	8.00
Millet	68	6,494	2.37	2.07	0.20	8.00
Virginia Tobacco	13	710	1.25	1.25	0.30	4.00
Irish Potatoes	12	1,187	3.10	2.15	0.20	8.00
Bambara nuts	10	607	1.43	1.27	0.25	4.00
Burley Tobacco	8	570	2.65	3.73	0.40	10.40
Sorghum	6	430	2.92	2.37	0.61	6.00
Peas	5	531	2.78	1.09	2.00	4.00
Rice	3	382	2.12	2.11	0.50	4.00
Tomato	3	245	0.43	0.56	0.10	1.21

Popcorn	2	148	2.00	-	2.00	2.00
Pumpkin	2	196	1.43	0.70	1.00	2.00
other use	2	199	1.28	0.42	1.00	1.60
Velvet beans	1	61	1.00	.	1.00	1.00

Thus, taking the crops that are planted by more than 100 producers, it is observed that mixed beans and cowpeas were in the top-five crops based on the average land allocation. However, raking by number of participating producers, it is observed that these two the second and third most-important crops to the producers. They are more important than cash crops such as groundnuts and seed cotton.

Table 4 presents the summary of weighted statistics of households' output for the various crops. The table, arranged in order of number of respondents, indicates that maize output was the highest among the food crops, with a weighted average in excess of 3,000 kg per household. For non-food crops, burley tobacco had the highest output, averaging 3,350 kg per household. However, unlike maize that had 914 households, burley tobacco involved only eight households. The average output per household for mixed beans and cowpeas was about 257 kg and 85 kg respectively.

Female rankings of production for maize, mixed beans and cowpeas were the same as for the total population, albeit lower averages (Table 5). For example, average maize output by females was 2,169.7 kg, about 39% lower than the estimated mean for the total average output for maize. Mixed beans average output was 141.3 kg, again lower than that of the average mixed beans output, but with a smaller standard deviation of about 187 kg. The table also shows that females did not produce a number of crops that were produced in Table 4, indicating that males produced those crops. The weighted summary output statistics for males is presented in Table 4. Because they dominate production in all the major crops, the rankings are the same as in in Table 4. Indeed, average maize production for males was about 3,152 kg with a standard deviation of about 6,053 kg. The average output for mixed beans and cowpeas was 273.2kg and 88.3 kg respectively.

Table 4: Summary Output Statistics of Respondents by Crop (in Kilograms)

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Maize	914	68,028	3,013.89	5,991.31	8.00	70,350
Mixed beans	541	44,827	257.21	397.15	2.25	3,240
Cowpeas	474	30,999	85.07	173.50	1.06	1,800
Groundnuts	387	28,265	168.17	210.48	3.00	2,175
Sunflower	153	11,115	212.34	249.46	2.10	2,100
Seed Cotton	99	6,777	1,514.05	7,396.09	12.00	67,200
Cassava	95	9,174	1,018.07	1,303.56	2.00	9,000
Sweet potatoes	89	7,616	761.17	937.19	35.00	9,500
Soya Beans	81	6,056	363.26	556.60	2.15	3,250
Millet	64	6,069	479.65	517.03	18.00	2,178
Bambara nuts	10	607	74.63	134.94	2.00	432
Irish Potatoes	10	976	566.41	815.78	25.50	2,850
Virginia Tobacco	9	502	467.72	417.29	50.00	1,700

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Burley Tobacco	8	570	3,350.97	5,619.92	43.00	15,480
Peas	4	426	15.41	10.51	2.00	24
Sorghum	4	338	459.11	131.84	166.00	552
Garden crops	3	143	13.57	6.21	6.00	19
Rice	3	382	271.71	317.63	66.00	735
Tomato	3	245	12.99	13.66	5.00	32
Popcorn	2	148	380.38	300.94	17.00	505
Pumpkin	2	196	4.59	4.20	2.00	8

Table 5: Summary Statistics of Female Respondents' Output (kg) by Crop

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Maize	120	9,406	2,169.69	5,558.37	8.00	48,300
Mixed beans	64	5,314	141.32	187.13	4.60	864
Cowpeas	61	4,281	65.09	185.40	2.25	1,530
Groundnuts	58	4,452	145.74	158.48	16.00	864
Sunflower	21	1,642	184.72	283.84	8.30	1,400
Soya Beans	14	979	195.28	311.52	7.60	1,350
Cassava	10	927	621.53	688.47	94.00	2,350
Sweet potatoes	9	712	379.31	289.09	104.00	950
Millet	8	695	302.60	432.03	18.00	1,188
Seed Cotton	6	440	305.56	261.67	50.00	1,000
Burley Tobacco	1	85	440.00	.	440.00	440
Rice	1	85	735.00	.	735.00	735
Sorghum	1	85	552.00	.	552.00	552

The importance of mixed beans and cowpeas cannot be just by their yield indicators above. For example, they do not feature among the top-10 crops in the table above based on the mean. However, evaluated on the basis of number of households producing the crop, then mixed beans and cowpeas take the second and third positions as found in the allocation of cropland in Table 3.

The cropland productivity for maize, mixed beans and cowpeas are presented in this section. Weighted average yield for maize was 1,660.6 kg/ha while mixed beans' and cowpeas' yield was 234.9 kg/ha and 147.7 kg/ha. On-farm cowpea yields in Africa have been estimated at about 240 kg/ha (Roberts et al. 2009), which is significantly higher than the average estimated for the most intensive cowpea-producing regions in Zambia. The principal rationale for this low yield may be because cowpeas are not as important in Zambia as they are in Nigeria and other West African countries. The average yield for mixed beans was estimated at 235.3 kg/ha. Similarly, the average mixed beans yield for the 2007 to 2010 period in neighboring Malawi and Zimbabwe was estimated at 568.8 kg/ha and 494.2 kg/ha respectively (FAOStat, 2012). Average maize yield for the three provinces included in the study was lower than the national average yield of approximately 2,587.1 kg/ha, which is not surprising given that the locations were selected for their mixed bean and cowpea production concentration.

Evaluating the average yields by gender shows that there are statistically significant differences between males and females for mixed beans and maize but not cowpeas. Average yield for maize, mixed beans and cowpeas for females was 73% that of males for maize, 63% for cowpeas and 58% for beans. Thus, the difference in performance between the genders was highest for mixed beans. Table 6 shows this by the fact that the statistical significance of the difference was highest for mixed beans, with t-value of 3.16, this difference was significant at the 1% level. The 95% confidence interval for this difference ranged from 39.4 kg/ha to approximately 169.3 kg/ha across the three provinces. Like mixed beans, the difference between males and females for maize yield was significant at the 1% level with a 95% confidence interval ranging from 134.7 kg/ha to over 808.0 kg/ha.

Table 6: Summary Weighted Statistics of Project Crop Yields (kg/ha) by Gender

	Mean	SE	95%CI		t	P>t
			Maize			
Male	1,728.43	62.83	1,604.80	1,852.07	2.75	0.006
Female	1,256.85	161.75	938.57	1,575.14		
			Mixed Beans			
Male	247.67	15.35	217.44	277.90	3.16	0.002
Female	143.32	28.62	86.94	199.69		
			Cowpea			
Male	155.24	28.22	99.59	210.88	1.29	0.199
Female	98.01	31.67	35.57	160.45		

Objective 1

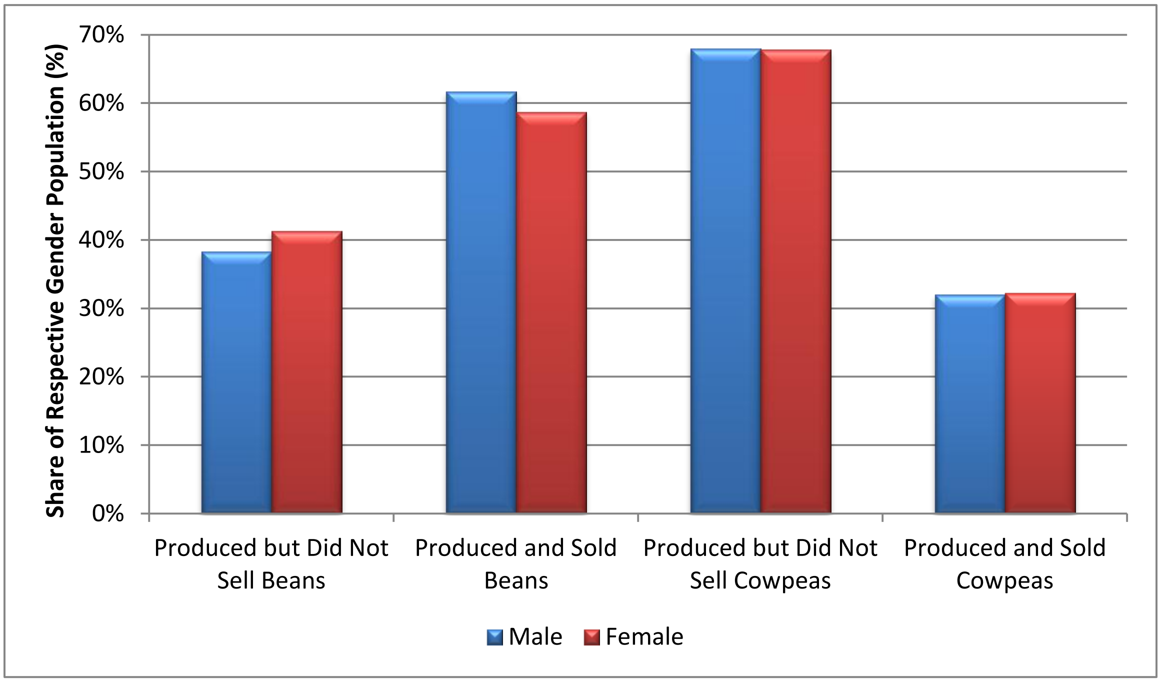
Market participation has been identified as critical in enhancing the performance of smallholder agricultural producers in developing countries (Alene, Manyong, Omanya, Mignouna, Bokanga, & Odhiambo, 2008). Alene et al.'s study shows that certain non-market factors, such institutional factors, influenced market participation more than prices. Yet, the extent of the influence of market and non-market factors, including transaction costs, pivots the focus point of the market participation decision on potential marketed surplus and the household's economic situation. For example, the household's cash needs balanced by its food needs would determine the extent of market participation for certain food crops, especially staples.

The distribution of responding households by the channels they were involved in started with identifying the intensity of market participation in the dataset. The data revealed that of the 538 households that produced dry mixed bean grains and 468 produced dry cowpea grains. Of the total number of households producing mixed beans, about 66% of them participated in some manner in the market, i.e., sold part or all of their production. The remaining 34% did not sell any of their production. This implies that for this group of 208 households, mixed beans production was solely for non-market use – home consumption, gifts, seed and in-kind payment for goods and services. About 32.7% of cowpea-producing households participated in the market, representing about 150 households. The remaining 67.3% used their production for non-market exchanges – home consumption, gifts, seed and in-kind payment for good and services.

Market participation intensity for cowpea producers was 32.7%, representing 150 of the 468 households that produced the crop.[5]

Evaluating the foregoing distributions on a gender basis shows that there were not a lot of proportional differences between the sexes with respect to market participation intensity (Figure 3). For example, while nearly 70% of both males and females produced but did not sell dry grain cowpeas, only about 38% of males and 41.3% of females produced but did not sell dry grain mixed beans in the sample. The figure shows that the market participation intensity for males producing dry grain beans was slightly higher than for females but there was virtually no difference between the market participation intensity for male and female cowpea-producing households.

Figure 3: Gender-Based Market Participation Intensity by Crop



The nodes in the supply chain are defined to encompass consumers, retailers, traders, and institutions. Traders include both local and foreign traders while institutions encompass hotels and restaurants, processors, brokers, non-governmental organizations, cooperatives and trade associations, schools, universities, hospitals and government agencies. Table 7 and Table 8 show the number of market participating households directly participating at each of the four supply chain nodes.

Table 7: Number of Mixed Bean Market Participants at Each Supply Chain Node

Nodes	Retailers		Traders		Institutions		Total Participants
	No	Yes	No	Yes	No	Yes	

[5] All proportions and other statistical metrics in this study are derived using sampling weights. Therefore, direct estimation of metrics may not reveal the weighted results.

Consumer	No	234	53	167	120	167	120	287
	Yes	73	5	74	4	69	9	78
Retailers	No			185	122	181	126	307
	Yes			56	2	55	3	58
Traders	No					115	126	241
	Yes					121	3	124

Table 7 shows that 78 mixed bean market participants sold directly to consumers while only 58 and 124 sold directly to retailers and traders. About 129 mixed bean market participants sold directly to institutions. This is equivalent to about 39% of all mixed bean market participants. The table also shows that five of these participants sold to both consumers and retailers while nine sold to both consumers and institutions. And while 122 sold to traders and not retailers, two sold to both nodes.

Table 8 shows that 57 cowpea market participants sold directly to consumers while only 22 and 67 sold directly to retailers and traders. The proportion of cowpea market participants selling directly to traders was estimated at about 45.6%. About 14 cowpea market participants (or about 10.3%) sold directly to institutions. The table also shows that only one of these participants sold to both consumers and retailers and to both traders and institutions. No-one selling cowpeas directly to retailers sold to institutions.

Table 8: Number of Cowpea Market Participants at Each Supply Chain Node

Nodes		**Retailers**		**Traders**		**Institutions**		**Total Participants**
		No	**Yes**	**No**	**Yes**	**No**	**Yes**	
Consumer	No	77	21	32	66	85	13	98
	Yes	56	1	56	1	56	1	57
Retailers	No			66	66	118	14	132
	Yes			21	1	22	0	22
Traders	No					75	13	88
	Yes					66	1	67

The total sample for this research has 86.1% males and 13.9% females. This provides a framework for assessing the gender effect on market participation. Table 9 shows that mixed bean market participation by gender was slightly off from this distribution of population by gender. The proportion of mixed bean market participants who were male mixed was about 88.5% compared to 11.5% who were female. Of all mixed bean market participants, about 18.6% sold directly consumers compared to 39% selling directly to institutions. Of the number selling to consumers, 89.7% were males and 10.3% females. This is equivalent to 17.3% and 1.3% respectively of all mixed bean market participants. Females were most active at the institutional node in the mixed bean market, accounting for nearly 5.6% of all market participants and almost 15% of those selling directly to institutions.

Table 9: Distribution of Mixed Bean Market Participants by Supply Chain Node and Gender

Nodes	**Male (%)**	**Female (%)**	**Total (%)**	**Number of Participants**

Consumer	17.3	1.33	18.63	78
Retailers	14.06	3.08	17.14	58
Traders	30.25	2.15	32.4	124
Institutions	33.54	5.55	39.09	129
All Nodes	88.47	11.53	100	364

Table 10 shows that the proportion of male cowpea market participants were was about 87.7% compared to 12.3% who were female. Off all mixed bean market participants, about 18.6% sold directly consumers compared to 39% selling directly to institutions. Of the 57 cowpea market participants selling directly at the consumer node, only compared to 12.1% of the 66 selling at the trader node. However, unlike mixed beans, the largest proportion of female cowpea market participation occurred at the trader node, with the institution node accounting the smallest participation over all.

Table 10: Distribution of Cowpea Market Participants by Supply Chain Node and Gender

Nodes	Male (%)	Female (%)	Total (%)	Number of Participants
Consumer	32.46	1.13	33.59	57
Retailers	10.22	4.851	15.07	22
Traders	40.12	5.142	45.26	66
Institutions	8.68	1.628	10.31	14
All Nodes	87.68	12.32	100	154

Objective 2

It has been shown in the foregoing that upon deciding whether to participate in the market, decision-makers then choose the supply chain nodes that they want to use. Do the characteristics of the producers influence their choice of supply chain node used to directly participate in the market, and if so, which ones are statistically significant in explaining choices among supply chain node?

A logistic regression model is used to determine the probability of different household characteristics influencing choice of market channels selected. The generic model is expressed as follows:

$$\theta_{kj} = \left.\begin{matrix} 0 \text{ if } j=0 \\ 1 \text{ if } j=1 \end{matrix}\right\} = \frac{\exp(\alpha + \sum \beta x_i)}{1+\exp(\alpha + \sum \beta x_i)} \quad (1)$$

where α = the constant of the model equation, β = the coefficient of the predictor variables and θ_j is the node choice where *j =1* implies the node is selected by the decision-maker and is zero if it is not. The alternative nodes, *k*, are Consumer, Retailer, Traders and Institutions. The independent variables of interest are gender, education, location (province), cropland (as an indicator of household wealth) and the proportion of that cropland allocated to the crop of interest, i.e., mixed beans and cowpeas. The presented results show percent change in the probability of choosing a particular supply chain node as a result of a percent change in any of the explanatory variables. This offers a response indicator akin to the traditional elasticity measure, making it a lot easier to explain the effects of these producer characteristics effect on producers' binary choice at each supply chain node.

Table 11 shows the logistic regression results for mixed bean market participants by chosen node. The results ask the question: What is the percentage change in the probability of choosing to participate at a selected node when there is a percentage change in the explanatory variable of interest? The results show that there is a 29% higher probability of selling mixed beans to consumers if the market participant is located in the Northern Province instead of in the Eastern Province and this effect is significant at the 5% level. Similarly, a percent increase in the proportion of cropland allocated to mixed bean production increases the probability of selling to consumers by 2.3%, significant at the 1% level. On the other hand, a percent increase in the total cropland owned by the household leads to a 5.3% decrease in the probability of participating at the consumer node in the supply chain. There seem to be no statistical difference between market participants selling to retailers and those not selling to retailers for all variables with the exception of location in the Southern Province (significant at the 1% level) and education, which was found to be significant at the 10% level. The table indicates that a percentage increase in the number of years of formal education decreases the probability of selling to retailers by 4.2%. Incidentally, this is the only node at which education proved to be statistically significant in explaining choice.

Table 11: Logistic Regression Results for Mixed Bean Market Participants by Node

Variables	Consumers		Retailers		Traders		Institutions	
	Elasticity	z	Elasticity	z	Elasticity	z	Elasticity	z
Gender	-0.099	-1.610	0.025	0.580	-0.131**	-2.290	0.012	0.370
Education	0.221	1.010	-0.427*	-1.700	-0.109	-0.690	0.149	0.950
Southern	0.104	1.320	-0.875***	-3.240	-1.129***	-4.120	-0.372*	-1.660
Northern	0.290**	2.390	0.100	0.800	-0.014	-0.170	0.882***	6.600
Cropland	-0.530***	-2.740	-0.081	-0.560	-0.058	-0.510	0.118	1.390
Bean Share (%)	0.235***	2.340	0.015	0.130	0.234***	7.970	0.179*	1.850
F-value	3.93		3.26		6.11		17.7	
Prob > F	0.00		0.0041		0.00		0.00	

* ≤ 0.10, ** ≤ 0.05 and *** ≤ 0.01 level of statistical significance respectively.

Gender is statistically significant at the 5% in explaining the selling to traders and shows that the probability of a female mixed bean market participant selling to traders is about 13.1% lower than males selling directly to the same supply chain node. Also, there is a 113% lower probability of selling mixed beans to traders if the seller is located in the Southern Province than in the Eastern Province. This is very understandable because the volume of mixed beans in the south is relatively small and traders tend to demand higher volumes of products from individual sellers in order to reduce their own transaction costs. But like the choice to sell to consumers, mixed bean share of total cropland was significant at the 1%, with a percent increase in it leading to 0.2% increase in the probability of selling to traders. Finally, location in the Northern Province increases the probability of selling to the "other" category of traders by more than 88% in comparison to being located in the Eastern Province. Thus, with the exception of Southern Province location variable, node choice exhibited inelastic responses to all variables.

The situation for cowpea market participants is different in certain ways. For example, Table 12 shows that females have about 23.4% lower probability of selling cowpeas to consumers but being located in the Southern Province increases the probability of selling to consumers by 14.4% while being located in the Northern Province decreased it by almost 54% relative to being located in the Eastern Province. Education, cropland and cowpea share were all not statistically significant in their explanation of whether a market participant sold cowpeas to a consumer. The table shows that females had a 12% higher probability of selling cowpeas to retailers but there was no statistical difference between the genders in selling to traders and others. However, being located in the Northern Province decreased the probability of selling cowpeas to retailers by almost 116% and to traders by 177% relative to being located in the Eastern Province, significant at the 5% and 1% levels respectively. On the hand, cowpea share of total cropland presented a positive effect on selling to secondary, tertiary and higher level nodes in the cowpea supply chain. Interestingly though, only the choice to sell to the Institutions node exhibited statistical significance and, as expected, a positive sign on the household's cropland holdings. A percent increase in cropland holdings increased the probability of selling to this node category 0.5%, significant at 5%.

Table 12: Logistic Regression Results for Cowpea Market Participants by Nodes

Variables	Consumers		Retailers		Traders		Institutions	
	Elasticity	z	Elasticity	z	Elasticity	z	Elasticity	z
Gender	-0.23**	-2.54	0.12**	1.98	-0.05	-0.77	0.02	0.14
Education	0.39	1.44	-0.53	-1.23	0.10	0.45	0.07	0.10
Southern	0.14*	1.75	-0.39***	-2.80			-0.10	-0.55
Northern	-0.54**	-2.05	-1.16**	-2.10	-1.77***	-4.52	-0.40	-0.93
Cropland	-0.24	-1.00	-0.57	-1.03	-0.20	-0.93	0.52**	2.23
Cowpea Share (%)	0.12	1.55	0.22**	2.08	0.13***	3.59	0.21*	1.93
F-value	4.87		5.96		13.07		4.62	
Prob > F	0.00		0		0		0.00	

* ≤ 0.10, ** ≤ 0.05 and *** ≤ 0.01 level of statistical significance respectively.

The foregoing results show the factors determining participation at the different not are not the same. For example, cropland exhibited a negative sign at lower levels of the supply and change to positive at higher levels for mixed beans, with the coefficient being negative and significant at the consumer level and positive but not significant at the Institutions node which was defined to encompass sales to government and institutions, cooperatives, trade associations, NGOs, etc. The coefficient for cropland in the case of cowpea exhibited the right sign for cropland except it was only significant at the highest level of the supply chain. The probability that females will sell cowpeas to consumers was 23% lower than the probability that males will sell cowpeas to consumers while the probability that they would sell cowpeas to retailers was 12% higher than that for males.

Objective 3

Smallholder producers' business objectives are multifaceted, encompassing family food security issues as well as cash needs to support products and services that are not produced by the household. This is in contrast to commercial producers' business objectives which can often be captured by a profit maximizing objective function. The inclusion of multiple variables in smallholder producers' decision framework suggests a more comprehensive approach to assessing the value emanating from their activities. Food security considerations suggest that most smallholder producers focus on ensuring their families have enough to eat from the production they undertake. This would support the subsistence characteristics of these producers and the fact that they only sell their surpluses after accounting for their family needs (Adi, 2007). Indeed, when asked the most important factor motivating mixed bean and cowpea production, food security ranked on top followed by the family tradition of producing the crop.

To completely appreciate the total value of any crop requires an immersion and understanding of the socio-economic activities of the producers. Without this appreciation, there is often the risk of underestimating the total value of production of any crop. Jackson and Cousins (1989) make this point when they note the indirect nature of the benefits of subsistence production and the severe methodological challenges it poses in measurement. The complexity of capturing non-market products and the intangibility of the benefits emanating from these products can lead to significant variability in the value of production agriculture for subsistence crops (Moll, Staal, & Ibrahim, 2007).

Within the context of these challenges, it is observed that beans and cowpeas are produced in Zambia for more than the dry grain that is often the focus of value measurement. For example, the bean young leaves, green pods, and fresh bean grains are used as vegetables. This contributes to alleviating food insecurity problems of the household, which are often acute in the period prior to harvest. Probably more importantly from a nutrition perspective, the bean leaves, green bean pods and fresh bean grains have been noted as good sources of iron and zinc micronutrients (Mamiro, Nyagaya, Mamiro, Jumbe, Ntwenya, & Bundara, 2012). The same is true of cowpeas, as noted by Saidi et al. (2010), who also note that there is little knowledge about the effect of leaf harvesting on grain yields, and hence, the profitability of cowpea (and similar) production systems. It is this potential interaction between the harvesting of other components of the crops that make evaluating the full value of the different harvested parts of the crop so crucial in assessing its value to the producer. Some households may harvest the stover for animal feed or for fuel while the pods may be used as animal feed, spread on land to increase organic matter content and/or burned as fuel. Estimating value of these crops solely on the dry grain may, thus, be underestimating their value to the household.

Generally, value of production is often limited to the traded quantity of dry grain. The foregoing discussion suggests that more components of the crop should be brought into the calculation of production value. Furthermore, limiting the calculation of production value to traded quantities alone often leads to gross underestimation of value because of the socio-economic structures in these communities. Total output for the purposes of valuation in these communities, therefore, may be conceived of as encompassing all components of the crop used for household consumption, gifts and in-kind payments for services, seed holdback, feed and other uses, and marketed surplus. This shows that focusing only on market surplus of dry grain leads to significant underestimation of value. This will explain why small producers are often shown as generating negative net incomes from production and still continuing to produce, leading to the erroneous conclusion that they are economically irrational.

The role and uses of the various components of beans and cowpeas in these production communities underscore the importance of estimating their value contribution to the benefits emanating from smallholders' production activities. The total value of production valuation model used in this research is defined as follows:

$$TV = NPV + PV \qquad (2)$$

where *TV* is total value associated with each crop and *NPV* is the non-pecuniary value while *PV* is the pecuniary value of each crop. Assuming each crop is harvested for leaves, fresh grain, green beans and dry beans, denoted by the subscript *i*, and that each of these products may be consumed (*c*), given away as gift (*g*) or stored for use as seed (*s*), denoted by subscript *j*, then if the imputed price for each of the products from the crop is defined as p_i, then the total non-pecuniary value from the crop may be defined as:

$$NPV = \sum_j \sum_i p_i r_{ji} q_{ji} \qquad (3)$$

where r_{ji} is the proportion of the quantity (*q*) of product *i* that is used for purpose *j*. The pecuniary value component is defined as the reported revenue received from the sale of the different products from each crop at different nodes of the supply chain. It is computed as follows:

$$PV = \sum_i R_i = \sum_i p_i Q_i \qquad (4)$$

where R_i is the reported revenue from the sale of product *i* and Q_i is the quantity of product *i* sold while p_i is as defined above.

Recall from the summary statistics that production of dry mixed bean grain averaged 257.2 kg while dry cowpea grain averaged 85.1 kg for the weighted sample. Their standard deviations were respectively 397.2 kg and 173.3 kg. Mixed bean output ranged from a low 2.3 kg to 3,240 kg while cowpea's ranged from 1.1 kg to 1,800 kg. Respondents were asked to estimate the quantity of dry grain that they did not sell and break down into the quantity consumed, kept for seed, given away as gift and lost due to pests, breakages or other. As observed from the previous section, gift was not a significant component of the distribution. However, quantity consumed and quantity kept for seed were. Therefore, they are used in the calculations of quantities of dry grain not sold by producers.

Table 13 shows the summary statistics of total dry grain not sold by households but used for consumption and/or seed. The table shows that the average for dry mixed bean grain was 75.2 kg but the average for males was 77.6 kg while that for females was 59.8 kg. A similar ranking are observed for dry cowpea grain, with the average of male-headed household being 51.5 kg and female-headed households being 26.4 kg. The results show that while female-headed households' average production of dry cowpea grain not sold was nearly 49% lower than that of male-headed households; that for dry mixed bean grain was only 23% lower.

Table 13: Summary Weighted Statistics for Dry Grain Not Sold

Variable	N	Weight	Mean	Std. Dev.	Min	Max
All Mixed Beans	558	45,738	75.2	90.7	2.3	1,080.0
Male Mixed Beans	487	39,790.3	77.6	91.1	2.3	1,080.0
Female Mixed Beans	70	5,886.2	59.8	87.0	2.3	432.0
All Cowpeas	432	27,960	47.8	69.7	1.0	900.0
Male Cowpeas	375	23,911.4	51.5	73.8	1.0	900.0
Female Cowpeas	56	3,987.6	26.4	29.1	2.8	180.0

The distributions of the proportion of total dry grain crop not sold by gender and province shows that while the average dry mixed bean grain not sold for males and females was about equal at 64.7% and 64.2% in Eastern Province, it was about 47% and 61.4% in Northern Province. The average dry mixed bean grain not sold was highest in Southern Province, where beans are not a major crop. On average, in this province, females did not sell any of their mixed dry beans while males did not sell almost 83% of their production. This implies that in Southern Province, mixed beans are produced essentially for household consumption while the commercial purpose of mixed been production in Northern Province is evident in the proportion of grain that is not sold.

Overall, it is observed that a larger proportion of dry cowpea grain is not sold – in excess of 68% in all provinces and by both genders. For example, although Eastern Province posted the lowest averages for dry cowpea grain not sold, the proportional average for males was 73.6% compared to 68.3% for females. This implies that females in Easter Province, on average, did not sell a lower proportion of their cowpea production compared to males. However, the average proportion of dry cowpea grain not sold was similar between the genders in Northern Province while nearly 100% of female production of cowpeas was not sold in Southern Province. This would lead to the conclusion that, in general, female-headed households in Southern Province producing cowpeas do not have commercial but food security orientation.

As indicated above, Zambian smallholder farm households harvest more than dry grain from their production activities. Tables 14 and 15 presented the weighted summary statistics of the revenues from the sale of these products for mixed beans and cowpeas. The average dry mixed bean revenue was about ZMK578,470 with a standard deviation of almost ZMK995,000. With 367 respondents providing information, dry bean sales revenue ranged from ZMK7,500 to ZMK8.9 million. Revenue from fresh grain was the second largest source of sales revenue, coming in at about ZMK36,000 and ranging from ZMK2,500 to ZMK800,000. With the lowest standard deviation per mean revenue, the coefficient of variation for dry leave revenues was the lowest of all revenues from mixed bean sales, coming in at about 87%.

As in the case of mixed beans, the largest single source of revenues for cowpea products was dry grain. Its weighted average revenue was approximately ZMK172,000 with a large standard deviation due to the significant variability in the sample and across provinces. The effect of this is a relatively large coefficient of variation – 172%. Leaves, both fresh and dried, provided more revenues for cowpea producers on average than did fresh grain. They averaged about ZMK35,000 and ZMK41,000 respectively. This may be explained by the fact that cowpea leaves are deemed to have more nutrition value, and is thus used more as a vegetable, than mixed bean leaves.

Table 14: Summary Weighted Statistics of Revenue (Pecuniary Value) from Sale of Mixed Bean Products (Zambian Kwacha (ZMK))

Variable	N	Weight	Mean	Std. Dev.	Min	Max
Dry Grain	367	32,370	578,470	994,693	7,500	8,900,000
Fresh Leaves	279	23,125	23,378	39,452	1,500	500,000
Dry Leaves	110	8,873	19,026	16,610	1,000	100,000
Fresh Grain	337	27,332	35,847	56,346	2,500	800,000

Table 15: Summary Weighted Statistics of Revenue (Pecuniary Value) from Sale of Cowpea Products (Zambian Kwacha (ZMK))

Crop Component	N	Weight	Mean	Std. Dev.	Min	Max
Dry Grain	157	10,474	171,998	312,200	5,000	2,400,000
Fresh leaves	233	15,085	34,688	204,307	1,000	4,050,000
Dry Leaves	188	12,304	40,858	224,383	2,000	4,050,000
Fresh Grain	205	14,001	22,246	16,920	1,000	200,000

The summary weighted statistics of the total pecuniary value for the two crops are presented in Table 16 by province and gender. On average females' pecuniary value from mixed beans was 46% lower than their male counterparts. For cowpeas, the female average was nearly ZMK117,000 with 45 participants and a standard deviation in excess of ZMK300,000. The male average for cowpeas was ZMK135,347 with 318 participants and a standard deviation of almost ZMK401,500. The female average pecuniary value from cowpea production was estimated to be only 14% lower than that for male in the sample. Given that the total weighted number of females in the sample was 124, the foregoing indicates that female market participation is just about 51% for mixed beans and 36.3% for cowpeas. On the other hand, male market participation for mixed beans and cowpeas was respectively 57.2% and 39.3%. The difference between the genders was statistically significant (|t| =3.03; P>|t| = 0.003) for mixed beans but not for cowpeas (|t| = 0.39; P>|t| = 0.69).

Table 16: Summary Weighted Statistics of Total Pecuniary Value by Gender and Province (Zambian Kwacha (ZMK))

Type	Variable	N	Weight	Mean	Std. Dev.	Min	Max
Overall	Mixed Beans	526	43,717	470,206	895,819	2,500	8,900,000
Overall	Cowpea	364	23,886	133,128	388,512	2,000	8,100,000
Total Female	Mixed Beans	63	5,284	266,991	458,513	10,000	2,700,000
Total Male	Mixed Beans	462	38,371	498,702	937,707	2,500	8,900,000
Total Female	Cowpea	45	3,222	116,949	300,060	2,000	1,803,000
Total Male	Cowpea	318	20,603	135,347	401,465	2,000	8,100,000
			Eastern				
Female	Mixed Beans	21	1,468	238,404	539,345	10,000	2,700,000
Male	Mixed Beans	165	10,842	234,835	402,177	5,000	3,540,000
Female	Cowpea	27	1,817	142,581	297,641	10,000	1,683,000
Male	Cowpea	177	11,663	140,139	469,431	5,000	8,100,000
			Northern				
Female	Mixed Beans	41	3,757	270,985	428,559	10,000	1,900,000

Type	Variable	N	Weight	Mean	Std. Dev.	Min	Max
Male	Mixed Beans	259	25,313	637,793	1,093,667	2,500	8,900,000
Female	Cowpea	5	420	215,702	584,605	8,000	1,803,000
Male	Cowpea	13	1,378	97,014	161,346	10,000	600,000
				Southern			
Female	Mixed Beans	1	59	720,000		720,000	720,000
Male	Mixed Beans	38	2,217	200,988	386,687	5,000	2,900,000
Female	Cowpea	13	985	27,579	28,003	2,000	110,000
Male	Cowpea	128	7,562	134,939	309,606	2,000	2,445,000

Table 17 shows the summary weighted statistics of the total non-pecuniary value from both crops by gender and region. The weighted average overall non-pecuniary value for mixed beans was ZMK331,181 and for cowpea ZMK224,840. Total non-pecuniary value for mixed beans ranged from about ZMK1,700 to ZMK3.9 million while that of cowpea ranged from just over ZMK3,000 to ZMK10.7 million. The average for females and males was respectively ZMK365,422 and ZMK326,214 for mixed beans and ZMK125,816 and ZMK242,345 for cowpeas. The difference between male and female weighted average total non-pecuniary value for cowpeas was significant ($|t| = 2.40$; $P>|t| = 0.02$) but that for mixed beans was not ($|t| = 0.60$; $P>|t| = 0.55$). The minimum of total female non-pecuniary value for mixed beans was about seven times that of males while minimum for cowpeas was the same for both. However, the maximum non-pecuniary value for cowpeas for males was a lot higher – about 20 times – than that of females. For both crops, the total non-pecuniary value for males was higher in Eastern Province and Southern Province. However, in the Northern Province, weighted average mixed beans' non-pecuniary value was higher for females by more than ZMK100,000.

Compared to the total average pecuniary value, the number of smallholder households reporting non-pecuniary values for both crops and both genders and in all regions was higher. For example, while only one female-headed household reported pecuniary value for mixed beans in Southern Province, nine reported non-pecuniary value for mixed beans in the same province. Additionally, while 13 male-headed households reported pecuniary value for cowpeas in Northern Province, the number was 56 for non-pecuniary value. These participation numbers confirm the importance of not ignoring non-pecuniary value in assessing value of production among smallholder producers.

Table 17: Summary Weighted Statistics of Total Non-Pecuniary Value by Gender and Province

Type	Variable	N	Weight	Mean	Std. Dev.	Min	Max
Overall	Mixed Beans	527	42,464	331,183	465,896	1,704	3,901,324
Overall	Cowpea	432	28,943	224,840	875,599	3,056	10,700,000
Total Female	Mixed Beans	67	5,382	365,422	500,558	12,500	2,800,000
Total Male	Mixed Beans	460	37,082	326,214	461,015	1,704	3,901,324
Total Female	Cowpea	59	4,226	125,816	126,923	3,056	518,875
Total Male	Cowpea	372	24,656	242,345	946,295	3,056	10,700,000
				Eastern			
Female	Mixed Beans	22	1,617	207,323	216,983	12,500	975,331
Male	Mixed Beans	141	9,275	241,394	372,399	7,000	2,203,526
Female	Cowpea	25	1,735	114,173	116,972	7,500	518,875
Male	Cowpea	129	8,623	366,451	1,409,006	7,500	10,700,000
				Northern			
Female	Mixed Beans	36	3,257	460,412	604,851	19,565	2,800,000
Male	Mixed Beans	240	23,477	358,338	473,191	1,704	3,237,500
Female	Cowpea	8	565	102,746	106,693	12,972	319,973
Male	Cowpea	56	5,253	160,906	881,586	4,500	10,700,000
				Southern			
Female	Mixed Beans	9	508	259,442	218,781	16,617	675,000
Male	Mixed Beans	79	4,331	333,725	543,068	15,000	3,901,324
Female	Cowpea	26	1,926	143,072	142,106	3,056	518,875
Male	Cowpea	187	10,781	182,759	276,201	3,056	2,594,376

Finally, the summary statistics of total value to smallholder households producing cowpeas in the three major beans and cowpea producing provinces in Zambia are presented in Table 18. Mixed beans is a far more valuable crop across the three provinces than cowpeas, posting a weighted average total value in excess of ZMK688,000 compared to cowpea's ZMK248,385. The number of participants in mixed beans was also higher. The difference between Northern and Eastern Provinces' average total value for mixed beans was significant ($|t| = 3.49$; $P>|t| = 0.00$) as was the difference between Northern and Southern Provinces' average total value for mixed beans ($|t| = 3.9$; $P>|t| = 0.00$). However, the difference between Eastern and Southern Provinces' average total value for mixed beans was not statistically significant. For cowpeas, only the difference between average total value in Eastern and Southern Provinces was significant ($|t| = 1.78$; $P>|t| = 0.07$).

Table 18: Summary Weighted Statistics of Total Value by Gender and Province

Type	Variable	N	Weight	Mean	Std. Dev.	Min	Max
Overall	Mixed Beans	570	46,146	688,143	1,058,325	8,128	9,650,000
Overall	Cowpea	470	31,799	248,385	886,887	3,056	10,700,000
Total Female	Mixed Beans	75	6,105	643,960	1,048,658	16,617	6,000,000
Total Male	Mixed Beans	495	40,041	694,879	1,060,687	8,128	9,650,000
Total Female	Cowpea	61	4,422	165,010	135,210	8,056	638,875
Total Male	Cowpea	408	27,315	262,239	954,817	3,056	10,700,000
				Eastern			
Female	Mixed Beans	24	1,734	380,179	323,284	59,449	1,535,000
Male	Mixed Beans	153	10,109	529,328	774,270	8,128	5,000,000
Female	Cowpea	152	10,490	377,805	1,377,440	6,000	10,700,000
Male	Cowpea	27	1,888	182,262	136,986	39,413	638,875
				Northern			
Female	Mixed Beans	41	3,803	788,538	1,279,234	18,000	6,000,000
Male	Mixed Beans	255	24,925	810,575	1,210,621	12,660	9,650,000
Female	Cowpea	9	668	113,638	108,006	21,620	369,973
Male	Cowpea	57	5,356	192,615	872,010	6,111	10,700,000
				Southern			
Female	Mixed Beans	10	567	480,806	563,903	16,617	1,875,000
Male	Mixed Beans	87	5,007	453,167	576,748	16,617	3,901,324
Female	Cowpea	25	1,866	165,961	142,055	8,056	548,875
Male	Cowpea	199	11,469	189,059	271,487	3,056	2,614,376

As expected, the average total value of producing these crops was higher for males, but the difference in average total value was not statistically different for mixed beans but statistically different for cowpeas ($|t| = 2.12$; $P>|t| = 0.035$). Females had higher average total value from cowpeas in Eastern Province and the difference was significant ($|t| = 1.74$; $P>|t| = 0.085$). The average total value of mixed beans in Southern Province was higher for females, but the difference was not statistically significant ($|t| = 0.55$; $P>|t| = 0.59$). The foregoing leads to the conclusion that males have higher average total value from the production of mixed beans and cowpeas in Zambia's three major pulses-producing provinces, and when females have higher average total value, the statistically significance of the differences is not strong. In short, males generally have equal to higher incomes than females for both crops in all regions.

On average, total non-pecuniary value accounted for about 58.3% and 75.7% of total value form mixed beans and cowpea production in the three Zambian provinces. It is, however, observed that non-pecuniary value accounted for 100% of total value in all situations considered – gender, crop and province but the range was as low as 0.4% for males growing mixed beans in Northern Province and 6.7% for males growing cowpeas in Eastern Province. As expected as a result of the foregoing discussion, the weighted average share of non-pecuniary value of cowpea production was above the overall average, coming in at 88.4% for males and 81.7% for females.

Table 19: Proportion of Total Value of Production Accounted for by Non-Pecuniary Value

Type	Variable	N	Weight	Mean	Std. Dev.	Min	Max
Overall	Mixed Beans	527	42,464	58.26%	28.93%	0.42%	100.00%
Overall	Cowpea	432	28,943	75.74%	26.19%	6.72%	100.00%
Total Female	Mixed Beans	67	5,382	61.62%	26.86%	3.80%	100.00%
Total Male	Mixed Beans	460	37,082	57.78%	29.22%	0.42%	100.00%
Total Female	Cowpea	59	4,226	71.36%	27.99%	10.07%	100.00%
Total Male	Cowpea	372	24,656	76.66%	25.65%	6.72%	100.00%
			Eastern				
Female	Mixed Beans	22	1,617	57.01%	31.44%	3.80%	100.00%
Male	Mixed Beans	141	9,275	55.84%	29.15%	1.91%	100.00%
Female	Cowpea	25	1,735	58.51%	27.81%	10.07%	100.00%
Male	Cowpea	129	8,623	64.58%	28.06%	6.72%	100.00%
			Northern				
Female	Mixed Beans	36	3,257	61.38%	24.04%	8.91%	100.00%
Male	Mixed Beans	240	23,477	56.08%	28.34%	0.42%	100.00%
Female	Cowpea	8	565	75.56%	28.43%	26.49%	100.00%
Male	Cowpea	56	5,253	72.35%	25.40%	10.53%	100.00%
			Southern				
Female	Mixed Beans	9	508	77.76%	25.93%	31.82%	100.00%
Male	Mixed Beans	79	4,331	71.13%	31.02%	3.45%	100.00%
Female	Cowpea	26	1,926	81.70%	23.98%	11.36%	100.00%
Male	Cowpea	187	10,781	88.42%	17.46%	10.55%	100.00%

There was no statistical difference between the genders within crops within provinces with the exception of cowpeas in Southern Province ($|t| = 1.89$; $P>|t| = 0.06$). This would suggest that, in general, the share of total value from these crops to smallholder households in the three Zambian provinces this study focused on did not differ between the genders within provinces.

The results indicate that the difference between the mean total value from mixed bean production in Northern and Southern Province was ZMK346,150, and this difference was statistically at the 1% level. Therefore, the hypothesis that mixed bean production is more valuable in Northern Province than in Southern Province cannot be rejected. The difference between Northern Province than in Eastern Province was estimated at ZMK507,494, also significant at the 1% level. Thus, as before, the hypothesis that mixed bean production is more valuable in Northern Province than in Eastern Province cannot be rejected. The mean total value of cowpea production for Southern Province was ZMK182,910 compared to ZMK346,296 and ZMK 183,852 for Eastern Province and Northern Province respectively. The difference between Southern and Eastern Province was negative ZMK163,386, which was found to be significant at the 10% level and the difference in mean total value from cowpea production between Southern and Northern Province was negative ZMK942, not statistically significant. Both hypotheses relating to cowpeas are rejected because: (1) In the case of the comparison with Eastern Province, Eastern Province's total value from cowpeas was higher, not lower; and (2) In the case of Northern Province, the difference is also negative but not significantly different.

Objective 4

Producers' perceptions about five policies were evaluated: Seed and fertilizer subsidies; Extension services; Special Training for Producers; Readily Available Markets as offered through the Food Reserve Agency's policies for maize; and Producer Price Controls, such as is seen for maize. Producers were asked to indicate the extent to which they believed government has used these policies to support or encourage bean and cowpea production. The results show that the proportion of producers who perceived the use of extension services to support and/or encourage mixed bean production was the highest at 11.4%, followed by the availability of special training for producers at 5.25%. Availability of input subsidies was seen by 5.0% of mixed bean producers as a tool that the government has used to help expand and/or support their efforts. Market availability and price controls received the lowest perceptions of about 2% each. For cowpea producers, the highest proportion of producers was 4.9%, found under the use of subsidies, followed by 4.8% for extension and the remaining policies received about 3% a piece.

The average proportion of producers indicating that the foregoing policies were employed to support mixed beans and cowpea production in the different provinces is presented below. The table shows that producer perceptions about government support policies were very low in Eastern Province. For example, while about 15% of producers saw extension services as supporting mixed bean production in Northern and Southern Provinces, no producer saw them applied in Eastern Province. Similarly, while about 6% and 13% saw producer training as supporting policies in Northern and Southern Provinces, less than 1% of producers perceived such in Eastern Province. A similar trend was observed in the case of cowpeas, except for markets and price support. Northern Province producers had the least proportion of producers perceiving these two policies as being in place in their industry.

Table 20: Proportion of Producers Indicating Existence of Policy Supporting Crop

Policy	Eastern	Northern	Southern
		Beans	
Subsidies	0.00%	3.04%	30.81%
Extension	1.85%	14.94%	15.24%
Training	0.92%	5.91%	13.10%
Markets	1.28%	0.80%	12.47%
Price Support	0.00%	0.97%	16.92%
		Cowpeas	
Subsidies	0.48%	2.40%	9.35%
Extension	1.94%	9.90%	6.36%
Training	0.48%	5.85%	4.92%
Markets	1.34%	0.00%	5.49%
Price Support	0.48%	0.00%	7.36%

There were no statistical differences between males and females in these perceptions for both crops. The extents to which these perceptions differ across provinces are presented below. They show that no statistical difference was detected between Eastern and Northern Province for all policies under cowpeas. Similarly, no differences were observed between these two provinces for markets and price support perceptions for mixed beans. Apart from these, the only other policies for which no differences were found were training and extension for bean production between

Northern and Southern provinces and training between Northern and Southern provinces for bean producers and markets for cowpea producers between Eastern and Southern provinces.

Table 21: Difference in Mean Proportion of Producers Perceiving Application of Each Policy by Province

	Eastern - Southern	Eastern - Northern	Northern - Southern
Beans			
Subsidies	-30.81%	-3.04%	-27.77%
Extension	-13.40%	-13.10%	-0.30%[@]
Training	-12.18%	-4.99%	-7.19%[@]
Markets	-11.20%	0.48%[@]	-11.67%
Price Support	-16.92%	-0.97%[@]	-15.95%
Cowpeas			
Subsidies	-8.88%	-1.92%[@]	-6.95%
Extension	-4.42%	-7.96%[@]	3.54%
Training	-4.45%	-5.37%[@]	0.92%[@]
Markets	-4.15%[@]	1.34%[@]	-5.49%
Price Support	-6.88%	0.48%[@]	-7.36%

[@] Mean of difference not significantly different at 5%.

Objective 5

The pilot governance initiative was conducted only at one stage in the supply chain: traders. The reason for this was driven both by time constraint and also the pragmatic conditions in the Zambian pulse market: the only principal processor we had anticipated using for this activity was undergoing significant financial challenges during the period of the study. Additionally, recruiting producers was difficult given that there was not time to provide the necessary education to enable product flow deals to be put in place.

Eleven traders were organized into a purchasing group that that focused on reducing transaction costs in the procurement process. The traders were trained in understanding the components of their procurement costs and organized into an informal buying "cooperative." The research group tracked their purchasing and sales information and the results show that their transactions cost did, indeed, decline in the short period after the project started. The most significant benefit emanating from the pilot initiative was non-monetary: it was time savings that the processes initiated afforded the participants. All but two of the traders involved in the pilot project were female.

Objective 6

The following policy recommendations are suggested for intervening in the bean and cowpea markets to help smallholder producers:

1. Provide education and training through the extension system and other programs to support the appreciation of potential food security value embedded in the production of these crops. The overemphasis on pecuniary value has led to a neglect of the non-pecuniary value emanating from the production of mixed beans and cowpeas. Indeed, this study shows that the non-pecuniary value of production accounted for about 58.3% and 75.7% of total value

from mixed beans and cowpea production. This should contribute to the food security objective of the Feed the Future initiative.

2. Females were under-endowed in the primary production resource – land. This affected their productivity and the production. Yet, females tend to have the primary responsibility for ensuring adequate nutrition for their families. Policies aimed at ameliorating these resource gaps among females will be very helpful in facilitating the achievement of the nutrition objective of the Feed the Future Initiative. For example, because land tenure systems tend to be communal and land transfer within families often goes to male heirs, community level education to help current parents understand the importance economic independence of their daughters may contribute to the amelioration of this problem. Another approach, which gets to the solution more permanently and enhances independence is to emphasize female education and make the necessary investments in the education of females. The results from the study indicate that while the overall education level of the population is at about the primary school level, females had had , on average, fewer number of formal schooling. Special incentives, such as scholarships and early childhood education that targets all children but provides special incentives to keep females in the program over the long term will contribute to alleviating the asset inequity over time.
3. The governance experiments with traders proved that providing business training can lead to significant improvement in well-being in very short periods. The interesting observation was that the participants in the program were eager to engage in these training programs. Therefore, developing education programs that targeted the provision of business skills' development to members of the supply chain at each node of operation will contribute significantly to enhancing total value from production.
4. Market expansion could contribute to production increases. One approach is to increase the demand for mixed beans and cowpeas produced by Zambia. This study did not assess the consumer demand for these products and it is recommended that an appreciation of this be undertaken to facilitate the development of tools and policies to expand demand. It is only when there is product pull in the market that the rewards from production are sustainably high.

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, Vincent Amanor-Boadu & Allen Featherstone
Elizabeth	Chishimba	Zambian	Female	B.Sc. Agric. Econ.	UNZA, Gelson Tembo & Mukwiti Mwiinga
Robert	Nhlane	Zambian	Male	B.Sc. Agric. Econ.	UNZA, Mukwiti Mwiinga & Gelson Tembo
Jairos	Sambo	Zambian	Male	B.Sc. Agric. Econ.	UNZA, Gelson Tembo & Mukwiti Mwiinga

Institutional Capacity Building: 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 occurred at Lusaka at the University of Zambia in spring 2012. Participants were students and faculty with invitations extended to the Central Statistics Office, Food Security Research Program and Ministry of Agriculture and Cooperatives.
- 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 held on October 11, 2011 in Lusaka. The training activity focused on bean and cowpea traders. Periodic engagements with the participants in the governance pilot program involved business management training.
- Workshop on value chains: This training session was to be a collaboration with Dr. Cynthia Donovan. Unfortunately, because of time constraint and changes in personnel in Mozambique, it was accomplished.

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. As project reports and papers begin to come out, more work will be disseminated through this website.

Explanation for Changes

No changes.

Networking and Linkages with Stakeholders

- Maintained operational communication with collaborating institutions – ZNFU, Central Farmers Association and Central Statistics Office
- Maintained briefing and exchange meetings with USAID Mission staff, particularly Mr. Ballard Zulu

- Worked with SABREN in collecting primary farm level data during survey instrument development as well as sampling process
- Worked with CIAT through SABREN to collect data on traders' activities.

Leveraged Funds
SABREN provided $6,000 and personnel support to help with the data collection as well as evaluation of survey instruments and testing of the instrument.

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, Dept. of Agric Economics, Univ. of Zambia, 2011.

Natasha Chilundika: Market Participation of Bean Smallholder Farmers in Zambia: A Gender-Based Approach, B.Sc. Thesis, Dept. of Agric Economics, Univ. of Zambia, 2011.

Chimuka Samboko: An Assessment of Factors Influencing the Profitability of Bean Production in Zambian, B.Sc. Thesis, Dept. of Agric Economics, Univ. 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 Agric Economics, University of Zambia, 2011.

These studies are available on the project website -- (http://valuechains.k-state.edu).

Cited Literature
See below.

Contribution of Project to Target USAID Performance Indicators
The number of individuals enrolled in degree programs was 14. Of these eight were females and six males. There were eight students in undergraduate programs and the remaining in post-graduate programs both at the University of Zambia and Kansas State University. Three of these graduate students are participating in the award-winning Master of Agribusiness program at Kansas State University.

We proposed to conduct one policy study and completed seven 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 Table below).

Contribution to Gender Equity Goal

Of the nine undergraduate students supported by the project, six were female and of the five graduate students, two are females. Thus, of the 14 students supported, eight were female.

Progress Report on Activities Funded Through Supplemental Funds

Not applicable.

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FY 2012 Performance Indicators for Pulse Value Chain Initiative - Zambia

Output Indicators	2012 Target	2012 Actual
Degree Training: Number of individuals enrolled in long-term degree training		
Number of women	1	2
Number of men	2	4
Short-term Training: Number of individuals who received short-term training		
Number of women	20	20
Number of men	31	30
Technologies and Policies		
Number of technologies and management practices under research	2	2
Number of technologies and management practices under field testing	2	2
Number of technologies and management practices made available for transfer	2	2
Number of policy studies undertaken	6	9
Beneficiaries		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	200	220
Number of rural households benefiting directly from CRSP interventions - Male Headed households	500	574
Number of agriculture-related firms benefitting from CRSP supported interventions	4	12
Number of producer organizations receiving technical assistance	2	2
Number of trade and business associations receiving technical assistance	4	2
Number of community-based organizations receiving technical assistance	3	0
Number of women organizations receiving CRSP technical assistance	1	1
Number of public-private partnerships formed as a result of CRSP assistance	2	3
Number of HC partner organizations/institutions benefiting	6	8
Developmental outcomes		
Number of additional hectares under improved technologies or management practices as a result of CRSP technical assistance	4186.75	Latest CSO data unavailable

Further Explanation to Sections of the FY12 Performance Indicators Chart

Degree Training

Some financial resources became available under the program due to HC partner changes. This provided money to support three more undergraduates than were projected under the proposal - one female and two males - in addition to the three MAB students currently completing their program of study.

Short-term Training

Participants in these management and strategy training programs included business and industry, trade association managers, university faculty, and students.

Technologies and Policies

The governance projects that were developed and initiated with the traders. These were researched, tested and implemented to help these traders improve their procurement decisions. We are continuing our work with them to facilitate direct connections with producers for formal contract and strategic alliance development.

Completed undergraduate and postgraduate students theses. We had the three MS students at UNZA complete their these, explaining the 50% higher output than anticipated.

Benficiaries

Number of rural households benefiting directly from CRSP interventions – Female and Male Headed households

The estimated sample size was 700 and focused entirely at the producer level. We included a survey of traders, an initiative executed in collaboration with SABREN and CIAT and MOA. This increased the respondents to 1600 for both levels. Upon cleaning and discriminating for only rural participants, we had approximately 1200 total and the distribution of those effectively benefitting is indicated here.

Number of agriculture-related firms benefitting from CRSP supported interventions

Freshpikt, Twa Pandula,Soweto Traders (8) participating in the governance project, BUK Ltd. In Kitwe, Palm Assoc.

Number of producer organizations receiving technical assistance

Central Growers Associaion & Zambia National Farmers Union

Number of trade and business associations receiving technical assistance

Grain Traders Assoc. & Central Growers Assoc.

Number of community-based organizations receiving technical assistance

Challenges on getting data collection completed and governance projects initiated did not allow us to engage any community-based organizaitons as we had projected.

Number of women organizations receiving CRSP technical assistance

The bean and cowpea traders participating in the governance projects were organized into a group to create critical mass to faciltiate their activities.

Number of public-private partnerships formed as a result of CRSP assistance
Freshpkt & UNZA; UNZA and SABREN; UNZA and CIAT. We had not anticipated the relationship that developed with CIAT and the extension of that into an agreement with UNZA to pursue research activities.

Number of HC partner organizations/institutions benefiting
MOA, UNZA, CSO, CGA, ZARI, CIAT, SABREN & ZNFU. We had not anticipated the relationship that developed with CIAT

<u>Developmental outcomes</u>
We have requested post-harvest survey data from CSO and MOA but have not received them yet.

Dry Grain Pulses CRSP
Research, Training and Outreach Workplans
(October 1, 2011 -- September 28, 2012)

FY 2011 SEMI-ANNUAL INDICATORS OF PROGRESS BY INSTITUTIONS AND TIME PERIOD

Project Title: *Pulse Value Chain Initiative - Zambia*

	Abbreviated name of institutions											
Identify Benchmark Indicators by Objectives	KSU		UNZA									
	4/1/12	**9/28/12**	**4/1/12**	**9/28/12**	**4/1/12**	**9/28/12**	**4/1/12**	**9/28/12**	**4/1/12**	**9/28/12**	**4/1/12**	**9/28/12**
Objective 1												
Complete producer survey instrument	**X**	**x**	X	x								
Complete downstream interview guide	X	x	X	x								
Complete producer survey and data entry			X	x								
Complete downstream interviews and data entry			X	x								
Identify and classify the different types of supply chains used in the industry	X	x	X	x								
Identify and describe characteristics of stakeholders and their choice of supply chains	X	x	X	x								
Objective 2												
Conduct an econometric analysis of how supply chain participation decisions are influenced by stakeholder characteristics	X	x	X	x								
Specifically analyze differences between male and female stakeholders' supply chain participation decisions and their characteristics	X	x	X	x								
Specifically determine any location and crop effects on supply chain participation decisions	X	x	X	x								
Objective 3												

Objective 3												
Describe the pecuniary value associated with beans and cowpeas at each stage in the different value chain		X		X								
Describe the non-pecuniary value associated with beans and cowpeas at each stage in the different value chains		X		X								
Estimate the total pecuniary and non-pecuniary value associated with beans and cowpeas at each stage in the different value chains and compare across value chains		X		X								
Analyze the relative value captured at the different stages across value chains		X		X								
Objective 4												
Complete interview guide for government officials		X		X								
Classify institutional and policy issues identified by industry stakeholders		X		X								
Analyze institutional and policy issues		X		X								
Conduct policy interviews with government officials using survey and interview results as inputs		x		X								
Develop report from interviews and analysis		x		X								
Name of the PI responsible reporting on benchmarks	Amanor-Boadu		Gelson Tembo									
Signature/Initials:	VAB		GT									
Date:	15-Sep-12											

Dry Grain Pulses CRSP		
Research, Training and Outreach Workplans		
(October 1, 2011 -- September 28, 2012)		
FY 2012 PERFORMANCE INDICATORS		
for Feed the Future		
Project Title: Pulse Value Chain Initiative - Zambia		
Lead U.S. PI and University: Vincent Amanor-Boadu, Kansas State University		
Host Country(s): Zambia		
	2012 Target	**2012 Actual**
Output Indicators	**(October 1, 2011-Sept 28, 2012)**	
Degree Training: Number of individuals enrolled in long-term degree training		
Number of women	1	2
Number of men	2	4
Short-term Training: Number of individuals who received short-term training		
Number of women	20	20
Number of men	31	30
Technologies and Policies		
Number of technologies and management practices under research	2	2
Number of technologies and management practices under field testing	2	2
Number of technologies and management practices made available for transfer	2	2
Number of policy studies undertaken	6	9

Beneficiaries:		
Number of rural households benefiting directly from CRSP interventions - Female Headed households	200	220
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Number of agriculture-related firms benefitting from CRSP supported interventions	4	12
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Number of trade and business associations receiving technical assistance	4	2
Number of community-based organizations receiving technical assistance	3	0
Number of women organizations receiving CRSP technical assistance	1	1
Number of public-private partnerships formed as a result of CRSP assistance	2	3
Number of HC partner organizations/institutions benefiting	6	8
Developmental outcomes:		
Number of additional hectares under improved technologies or management practices as a result of CRSP technical assistance	4186.75	?

Dry Grain Pulses CRSP

Institutional Capacity Building and Human Resource Development FY 2012 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 nondegree training and the purchase of equipment or other special funding 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 2012 activities for the entire Pulse CRSP program.

A. Degree Training

The Dry Grain Pulses CRSP is continuing to make human resource development and institutional capacity building a priority objective for all projects awarded. All Pulse CRSP projects include resources for institutional capacity building for our partner/host countries and each project supports a minimum of two to three degree candidates, and out Host Countries nationals focus on this as a key contribution to their research systems.

By design, Pulse CRSP degree training is closely linked to research activities and aligned with CRSP project research and outreach objectives. Researchers work to integrate graduate students into the research and outreach activities; dissertation research is focused on problems that are relevant to the Host Country context in addition to contributing 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 socioeconomic, 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 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.

Annex 1 provides data on all the degree trainees financially supported by the Dry Grain Pulses CRSP from October 1, 2007 through September 30, 2012. A total of 81 students were either fully or partially supported in graduate or undergraduate degree programs in FY 2012, with 45 currently active students. Table 1 provides the summary statistics on the formal degree training investments.

Table 22 Summary of Degree Training by the Dry Grain Pulses CRSP as of September 30, 2012

	No.of Trainees
Training Status	
▪ Active (during FY 12):	80
▪ New trainees	8
▪ Delayed/Pending	0
▪ Discontinued/cancelled:	1
▪ Training Completed:	34
Profile of "Active" trainees (45)	
Gender	
▪ Male	19
▪ Female	26
Region of Origin	
▪ East Africa	12
▪ Southern Africa	15
▪ West Africa	11
▪ 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

There are 9 graduate students at U.S. universities in 2012 that were "indirectly" or only partially supported by the Dry Grain Pulses CRSP. Leveraging resources enables us to ensure formal training for a larger number of young professionals. These are students with research assistantships or other stipends who are conducting their research in the host countries in collaboration with the HC PIs. CRSP funds 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. While these graduate level degree students are not "Participant Trainees", they are still included in the Pulse CRSP Trainee data base, given the support that they do have and the importance of their contributions (Annex 1). Under the Pulse CRSP, 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 also noteworthy that 29 of the total 45 degree students supported by the Pulse CRSP in FY 2012 were enrolled in universities either in Host Countries or in academically advanced institutions in other countries (e.g., South Africa) 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 lectures as well as serve on the guidance committees of graduate students. Finally, economies are achieved by supporting the training of USAID sponsored students at universities in countries in Africa and Latin America. The Pulse CRSP remains committed to finding opportunities in regional universities that provide the high quality training expected for CRSP research.

B. NonDegree and Short-term Training

Nondegree 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 nondegree training is integrated with research activities and is incorporated into the annual research work plans of each research project.

In FY 2012, an estimated 11,868 individuals benefitted from short term training subcontracted through Phase II and III projects in the Dry Grain Pulses CRSP. Beneficiaries included farmers, researchers, students, government analysts and others. Of these short term trainees, over 49% were female. Table 2 presents a listing of selected short-term training activities completed in FY 2012. Experience has shown that short term training is an effective strategy to build the capacity of technical staff at NARS and agricultural universities. Often, 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. Short term training also fits the needs of farmers and extension agents when specific technologies are available. The Pulse CRSP funding of short term training enables host institutions to work with CRSP PIs and colleagues to develop training materials that can be used repeatedly, with longer term gains and larger number of beneficiaries. Thus short term training is an attractive option for HC institutions.

Table 2: Examples of FY 2012 Short-term Training Activities Supported by the Pulse CRSP

Pulse CRSP Project: PII-MSU-3
Type of Training: Food safety — Hazard Analysis Critical Control Points
When did the Short Term Training Activity occur?: December 2011
Location of Short Term Training: Michigan State University
Who benefited from this Short Term Training Activity? Faculty of Sokoine University of Agriculture
Number of Beneficiaries by Gender: Male – 2; Female – 0; Total – 2

Pulse CRSP Project: PII-TAMU-1
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, discussions on way forward.
When did the Short Term Training Activity occur? June 1, 2012
Location of Short Term Training: Lusaka, Zambia
Who benefitted from this Short Term Training Activity? Government officials, NGO representatives, academic and extension staff of ZARI and UNZA
Number of Beneficiaries by Gender: Male – 10; FeMale – 11; Total – 21
Additional training provided to technicians at University of Zambia and local cowpea producers in Siavonga, Zambia: 1 female and 6 male

Pulse CRSP Project: PII-TAMU-1
Type of Training: Short term hands on laboratory training and discussions on research strategies
Description of Training Activity: Explaining preliminary findings and what they mean to cowpea promotion strategy, discussions on way forward.
When did the Short Term Training Activity occur? June 8-9, 2012
Location of Short Term Training: Nairobi & Katumani, Kenya
Who benefitted from this Short Term Training Activity? Academic and field staff of KARI-Katumani and Egerton University
Number of Beneficiaries by Gender: Male – 1; FeMale – 2; Total – 3

Pulse CRSP Project: PII-ISU-1
Type of Training: A series of short duration training sessions on production and post-harvest handling
Description of Training Activity: Training with farmers and extension agents included bean crop management practices and technologies, including varieties, post-harvest handling, and culinary aspects.
When did the Short Term Training Activity occur? March –September, 2012
Location of Short Term Training: Kamuli District, Uganda
Who benefitted from this Short Term Training Activity? Farmers in the Kamuli Region and extension agents with VEDCO
Number of Beneficiaries by Gender: Male – 9; FeMale – 58, Total – 67

Pulse CRSP Project: PII-MSU-2
Type of Training: Training on Collection and Analysis of Market Prices
Description of Training Activity: This training discussed the role of prices, price discovery and analytical challenges with prices as times series data, including a computer based session on price analysis. During the training, it was clear that analytical skills and computer skills were both lacking to be able to conduct thorough price analysis, but attendees were able to develop simple graphs and estimations of real prices as a result.
When did the Short Term Training Activity occur? Dec 12-13, 2011
Location of Short Term Training: Faculdade de Ciencias Agrarias, Chianga, Huambo, Angola
Who benefitted from this Short Term Training Activity? A combination of students of FCA, NGO staff members for World Vision, ADRA and others, staff members from the Ministry of Commerce, Agricultural Research Institute, and Agricultural Development Agency
Number of Beneficiaries by Gender: Male – 13; FeMale – 8; Total – 21

Pulse CRSP Project: PII-UIUC-1
Type of Training: internship
Description of Training Activity: biocontrol of cowpea pests, biopesticides
When did the Short Term Training Activity occur? Aug–Nov 2012 (ongoing)
Location of Short Term Training: IITA Benin
Who benefitted from this Short Term Training Activity? Technicians, students
Number of Beneficiaries by Gender: Male: 3; Female: 2; Total: 5

C. Equipment for Host Country Capacity Building

As has been done in the previous years, the Management Office of the Dry Grain Pulses CRSP budgets and competitively awards funds to Host Country institutions for capacity building. This funding assists National Agriculture Research Systems (NARS) and agriculture universities in acquiring and maintaining 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. These grants are designed to meet investment needs for human resource development, scientific equipment, laboratory and field facilities, computer technology, and infrastructure.

Host Country (HC) collaborators submit proposals to the MO for funding aspects which exceed the budgetary limits of the current projects, or respond to needs of agricultural research institutions in USAID priority countries which may be future collaborators.

In FY 2012, the Management Office (MO) in consultation with the Technical Management Advisory Committee (TMAC) approved the award of 5 supplemental activities totaling $113,911 that would enhance the capacity of host country institutions in strategic areas (e.g., development of seed production and storage capacity, training on MAS for breeding, 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).

Project	Last name	Given name	Country of citizenship	Gender	Training institute	Degree	Discipline	Training status as of Oct/12	Start month	Start year	Anticipated or realized completion month	Anticipated or realized completion year	Type of CRSP support
PI-CU-1	Chaves	Estevao	Angola	M	University Federal Vicosa, Brazil	M.S.	Agricultural Economics	Completed	4	2009	7	2011	Full
PI-CU-1	Diaz	Jorge	Peru	M	EAP-Zamorano	B.S.	Crop Science	Completed	1	2011	12	2011	Partial
PI-CU-1	Juma	Roselyne	Kenya	F	Moi University	M.S.	Plant Breeding/Evaluati on	Completed		2010	3	2011	Full
PI-CU-1	Marealle	Rosemary	Tanzania	M	Sokoine U. of Agriculture	M.S.	Nutrition	Completed	8	2009	11	2011	Full
PI-CU-1	Ngoma	Edna	Zambian	F	Univeristy of Zambia	B.S.	Agriculture Economics	Completed					Partial
PI-CU-1	Njeru	Crispus Mugambi	Kenya	M	Moi University	M.S.	Soil Science	Completed	2	2008	2	2010	Full
PI-CU-1	Odundo	Silvester	Kenya	M	Moi University	M.S.	Soil Science	Completed		2009	2	2011	Full
PI-CU-1	Onyango	Eunice	Kenya	F	Moi University	M.S.	Applied Environmental & Social Science	Completed		2009	9	2010	Full
PII-ISU-1	Abwate	Martha	Uganda	F	Makerere University	M.S.	Soil Science	Active	9	2010	8	2012	Full
PII-ISU-1	Adom	Medetissi	Togo	M	IITA Benin	B.S.	Entomology/Biolo gy	Active	5	2012	12	2012	Partial
PII-ISU-1	Dannon	Elie	Benin	M	IITA-Benin	Ph.D.	Entomology	Completed	9	2009	9	2011	Partial
PII-ISU-1	Jjagwe	George	Uganda	M	Makerere University	M.S.	Ag. Extension & Education	Active	8	2010	12	2012	Partial
PI1-ISU-1	Ndagire	Catherine	Uganda	F	Makerere University	M.S.	Food Science and Technolgy	Active	8	2009	12	2012	Partial
PII-ISU-1	Somakpon	Hermann	Benin	M	IITA-Benin	M.S.	Entomology	Completed	7	2009	7	2011	Partial
PII-ISU-1	Ssenyonga	Peter	Uganda	M	Makerere University	M.S.	Soil Microbiology	Active	9	2010	8	2012	Full
PI-MSU-1	Sanou	Apolline	Burkina Faso	F	University of Ouagadougou	Ph.D.	Entomology	Active		2011	7	2013	Partial
PI-MSU-1	Sarr	Mame Penda	Senegal	F	University of Dakar	Ph.D.	Plant Breeding/Patholog y	Active	10	2010	10	2013	Full
PII-MSU-2	Chimuka	Samboko	Zambian	M	University of Zambia	B.S.	Agriculture Economics	Completed					Partial
PII-MSU-2	Kayitesi	Eugenie	Rwandan	F	University of Pretoria	Pd.D.	Food Science	Active	1	2010	12	2012	Indirect
PII-MSU-2	Quinhentos	Maria da Luz	Mozambique	F	Michigan State University	M.S.	Agricultural Economics	Active	09	2011	06	2013	Partial
PII-PSU-1	Camilo	Samuel	Mozambique	M	Penn State	M.S.	Agronomy	Active	5	2011	12	2012	Full
PII-PSU-1	David	Antonio	Angola	M	University of Puerto Rico	M.S.	Plant Breeding	Completed	8	2009	8	2011	Full
PI-ISU-1	Nyakuni	Geoffrey Arijole	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Canceled					

Project	Last name	Given name	Country of citizenship	Gender	Training institute	Degree	Discipline	Training status as of Oct/12	Start month	Start year	Anticipated or realized completion month	Anticipated or realized completion year	Type of CRSP support
PI-ISU-1	Oloo	Caren	Kenya	F	University of Nairobi	M.S.	Plant Protection	Withdrew		2009			Full
PII-UPR-1	Chiona	Susan	Zambian	F	University of Zambia	M.S.	MS Food/Nutrition	Completed					Partial
PII-UPR-1	Komba	Charles	Tanzania	M	Sokoine U. of Agriculture	M.S.	Agronomy	Completed	9	2010	9	2012	Full
PII-UPR-1	Lege	Michael	USA	M	Washington State University	M.S.	Soil Microbiology/ Bioc hemistry	Completed	9	2010	8	2012	Full
PII-UPR-1	Moncañ o	Luis	Ecuador	M	EAP-Zamorano	B.S.	Crop Science	Completed	1	2011	12	2011	Partial
PII-UPR-1	Ndeve	Arsenio	Mozambique	M	University of California Riverside	Ph.D.	Plant breeding/Plant Pathology	Active	1	2012	10	2016	Partial
PII-UPR-1	Toffa	Joelle	Benin	F	IITA-Benin	Ph.D.	Entomology	Active	7	2010	7	2013	Partial
PII-UPR-1	Traore	Fousseni	Burkina Faso	M	University of Ouagadougou	Ph.D.	Entomology	Active		2009	3	2013	Partial
PI-UPR-1	Weya	Belinda Akinyi	Kenya	F	Egerton University	M.S.	Soil Science	Completed	8	2008	2	2011	Full
PII-UCR-1	Adebiyi	Kamarou	Benin	M	IITA Benin	M.S.	Entomology/Biolo gy	Active	7	2012	7	2013	Partial
PII-UCR-1	Cando	Marcelino	Ecuador	M	University of Puerto Rico	M.S.	Plant Breeding and Genetics	Active	1	2010	12	2012	Partial
PI-UCR-1	Costa	Manuel	Angola	M	University of Puerto Rico	M.S.	Plant Breeding/Patholog y	Canceled					
PII-UCR-1	Johnson	Sarah	Tanzania	M	Sokoine U. of Agriculture	M.S.	Food Science	Active	8	2009	11	2012	Full
PII-UCR-1	Khafa	Beata	Tanzania	F	Sokoine U. of Agriculture	M.S.	Plant Breeding	Completed	9	2010	9	2012	Full
PII-UCR-1	Nderitu	Alice	Kenya	F	University of Pretoria	Ph.D.	Food Science	Active	8	2010	6	2013	Full
PII-UIUC-1	Afatchao	Edinam	Togo	F	IITA Benin	B.S.	Entomology/Biolo gy	Active	5	2012	12	2012	Partial
PII-UIUC-1	Dorcinvil	Ronald	Haiti	M	University of Puerto Rico	M.S.	Soil Sciences	Completed	8	2006	5	2009	Partial
PII-UIUC-1	Gawde	Archana	India	F	Texas A&M University	Ph.D.	Molecular/Env. Plant Sci	Active	1	2009	12	2012	Partial
PII-UIUC-1	Gungulo	Ana Lidia	Mozambique	F	University of Pretoria, South Africa	M.S.	Agricultural Economics	Active	2	2009	12	2012	Full
PII-UIUC-1	Hachibamba	Twambo	Zambia	F	University of Pretoria	Ph.D.	Food Science	Active	8	2010	6	2013	Full
PII-UIUC-1	Hooper	Sharon	Jamaica	F	Michigan State University	Ph.D.	Food Science	Active	8	2009	5	2013	Partial
PII-UIUC-1	Lusweti	Jane Francisca	Kenya	F	University of Nairobi	M.S.	Plant Protection	Completed	10	2007	10	2009	Partial
PII-UIUC-1	Mukeshimana	Gerardine	Rwanda	F	Michigan State University	Ph.D.	Plant Breeding and Genetics	Active	8	2008	5	2013	Partial

Project	Last name	Given name	Country of citizenship	Gender	Training institute	Degree	Discipline	Training status as of Oct/12	Start month	Start year	Anticipated or realized completion month	Anticipated or realized completion year	Type of CRSP support
PII-UIUC-1	Ojwang	Leonard	Kenya	M	Texas A&M University	Ph.D.	Nutrition/Food Science	Completed	1	2010	12	2011	Partial
PII-UIUC-1	Pottorff	Marti	Philippines	F	U. California-Riverside	Ph.D.	Plant Breeding/Pathology	Active	10	2008	3	2012	Full
PII-UIUC-1	Sunga	Chalwe	Zambian	F	Univeristy of Zambia	B.S.	Agriculture Economics	Completed					Partial
PII-UIUC-1	Syanobe	Cyrille	Rwanda	M	Makerere University	M.S.	Food Science & Technology	Withdrew	8	2008			
PII-UIUC-1	Valentinetti	Sara	Italy	F	EAP-Zamorano	B.S.	Crop Science	Active	1	2012	12	2012	Partial
PII-UIUC-1	Zanana	Karimou	Benin	M	IITA Benin	MS	Entomology/Biology	Active	7	2012	7	2013	Partial
PIII-ISU-2	Diangar	Mouhamadou Moussa	Senegal	M	University of Quagadougou	M.S.	Plant Breeding/Genetics	Active	10	2010	2	2013	Indirect
PIII-ISU-2	Kabahuma	Mercy	Uganda	F	Iowa State University	M.S.	Crop Production/Physiology	Active	8	2010	5	2013	Full
PIII-ISU-2	Kamfwa	Kelvin	Rwanda	M	Michigan State University	M.S.	Plant breeding/genetics	Active	9	2010	8	2013	Full
PIII-ISU-2	Mbui Martins	Monica	Angola	F	University of Puerto Rico	M.S.	Plant breeding	Completed	8	2009	8	2011	Full
PIII-ISU-2	Musaazi	Aisha Nakitto	Uganda	F	Makerere University	M.S.	Food Science & Technology	Completed	8	2008	12	2011	Partial
PIII-ISU-2	Onyango	Stanley	Kenya	M	University of Nairobi	M.S.	Food Technology & Nutrition	Completed		2010	4	2011	Full
PIII-ISU-2	Sebuwufu	Gerald	Uganda	M	Iowa State University	Ph.D.	Agronomy	Active	8	2008	12	2012	Partial
PIII-ISU-2	Zulu	Esther	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed		2010	12	2011	Full
PIII-MSU-3	Amos	Nyangi	Tanzania	F	Sokoine U. of Agriculture	M.S.	Food Science	Active	9	2009	11	2012	Partial
PIII-MSU-3	Appoline	Sanou	Burkina Faso	F	University of Ouagadougou	Ph.D.	Entomology	Active		2010	7	2014	Partial
PIII-MSU-3	Jacob	Sacred	Tanzania	F	Sokoine University of Agriculture	M.S.	Nutrition	Active		2011	12	2012	Partial
PIII-MSU-3	Matambuka	Martin	Uganda	M	Iowa State University	Ph.D.	Food Science & Human Nutrition	Active	1	2009	12	2012	Partial
PIII-MSU-3	Myece	Agness	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed		2010		2011	Full
PIII-TAMU-1	Biaou	Jeanine	Beninese	F	IITA Benin	M.S.	Entomology	Active	9	2012	3	2013	Partial
PIII-TAMU-1	Gonzalez-Belez	Abiezer	United States	M	University of Puerto Rico	M.S.	Plant Breeding and Genetics	Completed	8	2010	5	2012	Full
PIII-TAMU-1	Iaacs	Krista	USA	F	Michigan State University	Ph.D.	Ecology and Nutrition	Active	8	2008		2013	Partial
PIII-TAMU-1	Kiprop	Billy	Kenya	M	Egerton University	M.S.	Biochemistry	Completed	1	2010	12	2011	Partial

Project	Last name	Given name	Country of citizenship	Gender	Training institute	Degree	Discipline	Training status as of Oct/12	Start month	Start year	Anticipated or realized completion month	Anticipated or realized completion year	Type of CRSP support
PIII-TAMU-1	Laraiaz	Laura	Guatemalan	F	EAP-Zamorano	M.S.	Crop Science	Active	1	2012	12	2012	Indirect
PIII-TAMU-1	Nkundabombi	Marie Grace	Rwanda	F	Makerere University	M.S.	Food Science & Nutrition	Active	8	2011	8	2013	Partial
PIII-KSU-1	Chesale	Virginia	Malawi	F	Penn State	M.S.	Plant Nutrition	Completed		2009		2012	Partial
PIII-KSU-1	Chilala	Cornard	Zambian	M	University of Zambia	M.S.	Economics	Active		2011	5	2013	Partial
PIII-KSU-1	Chilundika	Natasha	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Completed					Partial
PIII-KSU-1	Chishimba	Elizabeth	Zambian	F	University of Zambia	B.S.	Agriculture Economics	Active		2011	5	2013	Partial
PIII-KSU-1	Fousseni	Traore	Burkina Faso	M	University of Ouagadougou	M.S.	Entomology	Completed	9	2008	8	2012	Full
PIII-KSU-1	Karimou	Laouali	Niger	M	University of Niamey	M.S.	Entomology	Completed	9	2010	8	2012	Partial
PIII-KSU-1	Mtsocha	Lydia	Zambian	F	Kansas State University	MAB	Masters in Agribusiness	Active		2011	5	2013	Full
PIII-KSU-1	Mwansa	Martin	Zambian	M	Kansas State University	MAB	Masters in Agribusiness	Active		2011	5	2013	Full
PIII-KSU-1	Mwansa	Sosthenes	Zambian	M	Kansas State University	MAB	Masters in Agribusiness	Active		2011	5	2013	Full
PIII-KSU-1	Nhlane	Robert	Zambian	M	University of Zambia	B.S.	Agriculture Economics	Active		2011	5	2013	Partial
PIII-KSU-1	Okiror	Simon	Uganda	M	Makerere University	M.S.	Agricultural Economics/Agribu siness	Completed	8	2008	12	2010	Partial
PIII-KSU-1	Sambo	Jairos	Zambian	M	University of Zambia	B.S.	Agriculture Economics	Active		2011	5	2013	Partial
PIII-KSU-1	Sanouchi	Adere	Niger	M	University of Niamey	M.S.	Entomology/Biolo gy	Completed	9	2010	10	2012	Partial
PIII-KSU-1	Tuyiringire	Justin	Rwanda	M	Umutara Polytechnic University	BS	Agriculture	Completed			6	2012	Partial

Annex 2. Dry Grain Pulses CRSP FY 2012 Investments in Institutional Capacity Building

Total FY 2012 Investment by Dry Grain Pulses CRSP in Institutional Capacity Building--$113,911 across five projects

PII-UCR-1: Modern Cowpea Breeding to Overcome Critical Production Constraints in Africa and the U.S.

Award Amount: $10,000

CRSP cowpea breeders developed training for selected West African breeders and students in the development and application of DNA-based markers for Marker Assisted Selection (MAS) for use in their cowpea breeding programs. Two scientists were able to join other breeders for a training workshop at Riverside in FY2012. In conjunction with the Global Pulse Researchers meeting February 2012 in Kigali, Rwanda, CRSP researchers conducted a two-day training workshop through joint interpretation of data sets and progeny selections as a hands-on MAS and MARS experience. Pulse CRSP common bean breeders were also invited and trained at the Kigali workshop. Training was also conducted at meetings in Addis-Ababa, Ethiopia in May 2012, linked with CGIAR GCP-organized meetings.

PII-ISU-1: Enhancing Nutritional Value and Marketability of Beans through Research and Strengthening Key Value Chain Stakeholders in Uganda and Rwanda

Award Amount: $20,000

The objectives of this proposal were to: (1) develop training materials on improved bean management practices, (2) to evaluate training methods, and (3) to build capacity of VEDCO staff in Uganda. The project team developed new training materials and media (print, video) for improved management practices and technologies that was utilized in training more than 800 farmers in 60 demonstration sites. Topics covered by print and posters included germination testing; plant spacing; soil nutrient amendments (manure application); pest and disease management; harvesting, threshing, drying, and moisture testing; solarization and triple bagging; sorting and seed selection; and processing and preparation of food products from beans. Three different training methods/media, all followed by field demonstrations, were used in training on planting and triple bagging: (1) interactive training, (2) animated video, and (3) farmer acted video. The animated video on triple bagging was produced by Dr. Barry Pittendrigh and colleagues at the University of Illinois.

A small battery-powered projector (3M MPRO 150 Pocket Projector) with supplemental Speaker Case (Insignia) was used to present the video at farmers' training facilities. Trainers on foot or bicycle can easily carry these portable devices to places where farmers live and work. The visual and audio qualities were adequate, depending on the size of group. Groups with less than 10 participants exhibited a relatively low level of interaction and few group discussions among farmers during the training. However, when the size of the training group was more than 40, training became messy, and farmers sitting at the back had problem in hearing and watching the videos.

Research by an ISU-based graduate student in communication and sustainable agriculture (Ms. Tian Cai) explored the effectiveness of video to complement or replace existing lecture/demonstration training for small farmer groups in rural Uganda. Her master's thesis supervisor, Dr. Eric Abbott, is a development communications specialist. The study was conducted in four parishes in Butansi sub-county of Kamuli district during February-March, 2012. A total of 325 project farmers participated in the study in which quantitative and qualitative data were gathered through an experiment including a pre-test and a post-test with a control group design. Results showed that video could effectively complement or, in some circumstances, replace conventional lecture/demonstration training methods in knowledge improvement, attitude and intention to adopt improved management practices and technologies. Combining video, lecture and demonstration is especially effective for groups with little or no prior knowledge of a topic. Moreover, video alone or video plus lecture/demonstration can be as effective as conventional training in decreasing gaps in knowledge of training topic among subjects of both genders and varying education levels and scale of bean planting.

Consistent capacity building activities in Kamuli were guided by Dr. Haroon Sseguya, Makerere University faculty member from the Department of Agricultural Extension and Innovation. VEDCO's staff and Community Based Trainers (CBTs) learned advanced methods of farmer learning facilitation, and numerous farmers learned improved practices. The supplemental funding also strengthened collaboration among VEDCO, Makerere University and Iowa State University faculty and students. It helped scale up innovative management practices and technologies to wider populations in Uganda.

PII-UPR-1: Building Capacity for Enhancing Biological Nitrogen Fixation in Bean Production Systems in Central America, Haiti, Angola and Mozambique

Award Amount: $25,300

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 visited Angola in December 2011 and reviewed 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. Other IIA staff members currently receiving graduate training in plant pathology in Spain are expected to use the laboratory on completion of their degrees. Threshers were purchased by the bean research programs in Haiti and Angola. This equipment will permit the harvest of larger quantities of bean and cowpea seed on a timely basis. The purchase of a 4WD vehicle for the National Seed Service in Haiti was approved by the BTD project.

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: $40,000

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, specifically to develop a delivery system for endophytic strains of

Beauveria bassiana and *Metarhizium anisopliae* active against cowpea pod borer. The supplemental funds were also to develop sustainable virus production capacity at the farmer level in West Africa. Additional funds were included to collect and assess appropriate farm-level data to capture the effects of IPM extension messages and methods on changes in farmers knowledge, perceptions and behavior in Burkina Faso.

A technology 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. 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. An animated video on biocontrol for Maruca was created in collaboration with IITA and SAWBO (UIUC).

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, use of biocontrol agents to suppress pest populations, and proper preparation and use of Neem sprays. Three of these videos released in 2011 were translated in FY 2012 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 ten thousand downloads of these videos). The biocontrol video, developed with CRSP funds, has been completed and is soon to be released. 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. Over FY12 SAWBO has developed links with over 30 partner groups around the planet who are helping to create new videos, do voice overlays in local languages, and perform local deployment of these videos.

Between known field-deployment (where we have feedback from organizations), views & downloads from our online systems we estimate impact of well over 100,000 people. In FY12 we have performed studies to address the potential for spreading of these animations through cell phone networks in Burkina Faso and Niger. The results suggest that the videos do spread through Bluetooth® from cell phone to cell phone. This work continues to be developed in collaboration with the PIII-MSU-4 Impact Assessment project.

PII-PSU-1: Improving Bean Production in Drought-Prone, Low Fertility Soils of Africa and Latin America – An Integrated Approach

Award Amount: $18,611

The supplemental funding was used to acquire a irrigation pump for field research and refrigerator for bean seed storage, both at the Chokwe Research Cente of IIAM in Mozambique. The Chokwe motor pump was installed and is being used for direct irrigation to the experimental fields. A cold room facility was rehabilitated in Chokwe, to better preserve bean materials being evaluated and developed by the breeding component led by Celestina Jochua in Chokwe.

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