2006 Research and Training Highlights

The Bean/Cowpea
Collaborative Research Support Program

Regional Partnerships to Enhance Bean/Cowpea Consumption and Production in Africa and Latin America

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For Further Information, Contact:
Bean/Cowpea CRSP
321 Agriculture Hall
Michigan State University
East Lansing, MI 48824-1039, U.S.A.
Phone: (517) 355-4693
Fax: (517) 432-1073
Email: widders@msu.edu
www.isp.msu.edu/CRSP

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Regional Partnerships to Enhance Bean/Cowpea Consumption and Production in Africa and Latin America

...Applying Cutting-Edge Science
...Developing Value-Chains
...Building Human Resources

The *2006 Research and Training Highlights* Report presents noteworthy achievements by the Bean/Cowpea Collaborative Research Support Program (CRSP) during FY 2006, the fourth year of a grant funded by EGAT/USAID-Washington. The research and training achievements here-in resulted from collaborative activities between eleven U.S. universities and 25 partner Host Country National Agriculture Research Systems (NARS) and agricultural universities. This work was conducted as part of three integrated multi-disciplinary regional projects in developing countries of West Africa (WA), East and Southern Africa (ESA), and Latin America and the Caribbean Basin (LAC) to address priority constraints to bean and cowpea utilization and consumption.

The objective of this report is to "highlight" the technical progress made by each of the 19 different research teams. We hope that readers will be able to gain a macro-level overview of the broad scope of research and training activities supported through the Bean/Cowpea CRSP. Readers should be aware that the enclosed reports are only one-year snap shots of collaborative activities and as such report on technical progress and interim outputs during the past fiscal year (2006). The intended audiences for this report are collaborating organizations, donor entities, stakeholder groups and the international community of scientists working on beans and cowpeas.

The adopted slogan of the Bean/Cowpea CRSP, "*...Applying Cutting-edge Science, ...Developing Value-Chains, ...Building Human Resources*" represents the three pillar priorities which underpin all research and training activities and captures the essence of the Global Mission and Strategy of the program.

As is evidenced in this report, Bean/Cowpea CRSP scientists seek to make accessible, train in the use of, and ***apply cutting-edge science*** for the purpose of developing institutional capacity in developing countries through the collaborative research activities. Such cutting edge science includes methodologies and instrumentation utilized in modern molecular genetics to: develop gene maps, isolate, sequence and clone genes, introgress important resistance genes into beans and cowpeas, and identify molecular markers for genes of agronomic or nutritional importance. CRSP food scientists are utilizing new food processing technologies such as high temperature extrusion and micronization to reduce food preparation time and develop nutritious processed bean/cowpea-based food products sought by consumers. Socio- economists are utilizing Geographical Information Systems (GIS) and computer-based modeling to identify important agro-ecological zones for bean and cowpea production, to assess market opportunities and to describe regional trade patterns.

The Bean/Cowpea CRSP Regional Project Teams are committed to ***developing and strengthening bean and cowpea value-chains*** which extend from consumers to producers. As can be noted in the *Highlights* report, objectives of the research activities address all essential elements required to develop robust commodity value-chains, including the need to stimulate economic growth, increase utilization and consumption, enhance human nutrition and health, ensure access by women and minorities to technology and information, increase the sustainability of production systems, and enhance productivity and quality.

The third pillar priority of the Bean/Cowpea CRSP is to ***build human resources*** in developing countries. A sustained commitment to training is required to address the continuing shortages of scientists and professionals in agriculture and related fields in Africa and Latin America. A new generation of leaders is needed in such important fields as biotechnology, food industry development, marketing, nutrition and health, etc. Without investments in human resource and institutional capacity building, technological interventions resulting from research will not lead to sustainable development and improvements in the quality of life of individuals in developing countries.

The *2006 Research and Training Highlights* Report gives evidence of the dedication and commitment of Bean/Cowpea CRSP scientists to the objectives of this program. I wish to thank both the community of U.S. and Host Country scientists, their collaborators and all support staff for their efforts which have contributed to the productivity and success of the Bean/Cowpea CRSP.

Irv Widders, Director

Overview of The Bean/Cowpea Collaborative Research Support Program

Vision

The Bean/Cowpea Collaborative Research Support Program (CRSP) seeks to generate new knowledge and technological outputs through collaborative research and training with the ultimate goals of enhancing bean and cowpea consumption and utilization, and food security in Africa, Latin America and the U.S. These goals are achieved through improvement of the human and institutional capacity of agricultural universities and national agriculture research systems so that academic, research and outreach programs can be self-sustaining and contribute to continued long-term development of the bean and cowpea sectors in both the U.S. and partner host countries.

Strategy

In the new grant period (2002-2007) the Bean/Cowpea CRSP has adopted a Value-Chain strategy to guide the formulation and implementation of research and training activities to overcome regional-specific constraints associated with the bean and cowpea sectors. Value-chains recognize the importance of multiple independent, but interlinked, stakeholders/enterprises in commodity food chains which connect consumers to producers. The objective of a Value-Chain is to optimize the flow of product through the food chain by seeking to 'add value' to each component (subsector) of the network and to strengthen the linkages between the various components.

Organization

Regional Projects

The Bean/Cowpea CRSP seeks to achieve its vision through three Regional Projects in West Africa (WA), East and Southern Africa (ESA), and Latin America and the Caribbean Basin (LAC). A Regional Project organizational structure is considered vital to the implementation of a value-chain strategy in order to:

1. Coordinate integrated regional approaches that address constraints in each subsector of bean and cowpea value-chains in a multi-disciplinary manner, such that the interactions with, and issues important to, other subsectors are considered when planning and conducting research and training activities.
2. Promote greater mutual intellectual engagement by U.S.-HC Bean/Cowpea CRSP scientists, mutual ownership and collaboration in regional research and training activities, mutual participation in the evaluation of technical progress, and mutual benefits to both HCs and the U.S.
3. Promote a culture of greater interaction and partnership between national agricultural university and research system scientists with clientele/stakeholder groups (e.g., urban consumer focus groups, food industry advisory groups, micro-enterprise entrepreneurs, farmer associations, etc.), and governmental agencies in order to obtain guidance and feedback on research activities so as to maximize the development of appropriate technologies and shorten the time for their adoption.
4. Establish multi-lateral linkages with International Agriculture Research Centers (e.g., CIAT, IITA, ICRISAT), Non-Governmental Organizations/Private Voluntary organizations (NGOs/PVOs), private industry groups, and other CRSPs to:
   - Coordinate research/training activities at a regional level so as to ensure complementation and avoidance of duplication, as well as regional impact.
   - Share knowledge and provide access to research facilities/resources that may not be resident in particular HCs so as to accelerate progress in the development of technologies.
   - Enable joint solicitation and leveraging of research grant funds from international development foundations, governmental assistance programs, and NGOs.
   - Coordinate the dissemination of technologies at a regional level.

Research Components

The research and training activities of the Bean/Cowpea CRSP within a Regional Project are organized into components that fall under the following thematic areas:

1. Stimulate **economic growth** by developing new market opportunities for bean/cowpea grain and products.
2. Increase **utilization and consumption** by adding value to bean and cowpea grain and their by-products.
3. Enhance **human health and nutrition**, especially children, by increasing knowledge of nutritional constituents in beans/cowpeas and developing nutritious bean/cowpea-based food products.
4. Ensure maximum **access** by **women and minorities** to technology and information. Increase the **sustainability** of bean and cowpea production systems in divergent agro-ecological zones.
5. Enhance the **productivity and quality** of beans and cowpeas through genetic improvement, utilizing both tools of molecular biotechnology and traditional breeding.

6. Assess and **evaluate the impacts** of CRSP technologies.

The organization of this research highlights report follows the program organizational structure described here. Research activities within a regional project (WA, ESA and LAC) are organized by components (WA1, WA2..., ESA1, ESA2,..., LAC1, LAC2,... etc.) that generally follow the thematic areas listed above.

Strengths

The strengths of the Bean/Cowpea CRSP program are: 1) its distinguished internationally-recognized cadre of U.S. and HC scientists who serve as Principal Investigators and provide leadership for research and training; and 2) the long-term collaborative scientist-to-scientist and institutional relationships. The long-term collaborative relationships are necessary to overcome major constraints to agricultural food chains, and to build up human and technology-generating capacity in developing country institutions.

Because of the long-term multi-disciplinary features of the Bean/Cowpea CRSP, training is effectively linked to institutional capacity building, to problem-oriented research, to technology transfer, and ultimately to the impact of technologies. This is an important strength that distinguishes the Bean/Cowpea CRSP from short-term competitive grant programs. The Bean/Cowpea CRSP has a comparative advantage over the IARCs, private development foundations, and the NGO community in that it provides access for African and Latin American students to attend some of the most prestigious agricultural universities in the U.S. These students therefore have the unique opportunity to conduct research under the tutelage of the premier scientists in their respective fields.

Strengthening the Cowpea "Value-Chain" in West

The West Africa regional project of the Bean/Cowpea CRSP is comprised of several components involving four U.S. lead universities who are collaborating in research and training activities with national agricultural research programs and universities in Senegal, Ghana, Zimbabwe, Niger, Nigeria, Cameroon and Burkina Faso. The regional project provides research and training in all aspects of the cowpea food chain to promote enhanced cowpea utilization and consumption. Specifically, the areas covered range from genetic improvement (including biotechnology) research to develop improved varieties of cowpeas, increasing productivity of cropping systems, value addition through processing and the economics related to distribution and marketing of cowpeas and their products. In this Section, we highlight the progress of selected research activities conducted by the Bean/Cowpea CRSP West Africa Regional Project in FY 06.

U.S. AND HOST COUNTRY INSTITUTIONS PARTICIPATING IN THE WEST AFRICA REGIONAL PROJECT

Purdue University

Texas A & M University (TX A&M)

University of California-Riverside (UC-R)

University of Georgia (UGA)

Ahmadu Bello University (ABU), Nigeria

Abubakar Tafawa Balewa University (ATBU), Nigeria

Institut de l'Environment et de Researches Agricoles (INERA), Burkina Faso

Institut National de Recherches Agronomiques du Niger (INRAN), Niger

Institut de la Recherche Agronomique pour le Developpement (IRAD), Cameroon

Institut Senegalais Recherches Agricole (ISRA), Senegal

University of Ghana-Legon (UG-L), Ghana

University of Zimbabwe (UZ), Zimbabwe

WA1-A1

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Determination of the Demand and Market Opportunities for Cowpea Grain and Processed Products in West Africa

Principal Investigators and Institutions:
Jess Lowenberg-DeBoer and Joan Fulton, Purdue University, U.S.; Germain Ibro, INRAN, Niger; Mbene Faye, ISRA, Sénégal; Saket Kushwaha, Abubaker Tafawa Balewu University, Nigeria

Collaborators and Institutions:
Moussa Bokar, INRAN, Niger
Raymond Florax, Purdue University, U.S.

Justification and Objectives

This component of the Bean/Cowpea CRSP focuses on marketing and trade research with the aim of identifying new market opportunities for cowpea grain and processed products to stimulate economic growth. Preliminary diagnosis of cowpea marketing in West Africa has identified the following general picture. Characteristics of improved varieties of cowpeas are not necessarily those prized by consumers. There is poor flow of price and quality information between some countries. Transportation and transaction costs are high. Market power is exercised by some merchant communities. There is little value-added processing of cowpeas. Currently, price reporting systems are improving within countries. Research is needed to determine the extent to which price and quantity information improve the efficiency of markets and then to determine the best way to implement an improved market information system. Consumer demand analysis is needed for taste and other biochemical aspects of cowpeas including sucrose and protein content and cooking time.

Most cowpeas in West Africa are sold as grain and processed at home. The growing urban population and the increasing opportunity cost of women's time suggest that opportunities may exist for more value-added processing. Research is needed to determine the potential for value-added cowpea products that appeal to consumer preferences.

This report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Develop cowpea grain marketing opportunities by developing better estimates of the market value of cowpea cooking time and sugar content and determining the degree of marketing integration and market power in West African cowpea markets.
- Estimate potential demand for cowpea-based processed products in West Africa.

Research Approach, Results and Outputs

Market value of cowpeas: Market data on price and quality, including data on cooking time and sugar content in Senegal and on cooking time, protein level and sugar content were collected in Niger. The results of the research in Senegal have been published in the South African Journal of Economic and Management Sciences (Faye et. al., 2006). These results reveal that consumers are willing to pay a premium ranging from 13 FCFA to 59 FCFA per kg for cowpeas with a 1% higher sugar content. Regression co-efficients between cooking time and price are all negative, indicating that consumers are willing to pay more for a shorter cooking time. However, the cooking time relationship is only statistically significant in one market.

Table 1 reports the results from two markets in Niger, Petit Marche and Wadata. The regression co-efficients for cooking time are negative and for protein and sucrose content are positive, as expected. The co-efficients for protein and sucrose content are not statistically significant. The cooking time co-efficient is statistically significant for data collected at the Petit Marche suggesting that consumers are willing to pay more for cowpeas that cook in a shorter time.

Market Integration: Bokar Moussa completed his M.S. degree at Purdue University in the summer of 2006 and is now in a Ph.D. program. His research focus will be on market integration. For his M.S. thesis, Moussa analyzed the economic impact of cowpea storage technologies in West Africa. He has traveled to West Africa to collect market price data for the market integration research. Data were collected in Burkina Faso, Cameroon, Niger and Nigeria. In Burkina Faso, monthly data from 39 markets for the period 1998 through 2006 is available. In Cameroon, monthly data from seven markets for the period 1990B2005 were collected. In Niger, monthly data were obtained for 53 markets for the period 1990B2006. In Nigeria, monthly data from 53 markets for the period 1990B2005 were collected.

Assessment of potential demand for cowpea-based processed products: Consumers in three urban areas of Nigeria, Abuja, Kano and Bauchi, were surveyed to gain insight into factors considered when making purchase decisions concerning value-added cowpea products. A total of 150 consumers were surveyed during the summer of 2006. Over 85 percent of the consumers surveyed had purchased moin-moin, rice and cowpeas and cowpea pottage during the past week. These are all value-added products made from cowpeas that are produced and sold as street food. Over 70 percent of the respondents reported that they purchased these foods for good nutrition, to satisfy hunger, or to serve to their family. Consumers have strong loyalty to particular vendors for these value-added cowpea products. Seventy percent indicated that for four or more of their past ten purchases they used the same vendor. Taste, location, freshness, cleanliness and satisfaction were the reasons given for loyalty.

A total of 180 consumers were also interviewed about their purchases of akara/kosai, the deep fat fried fritter prepared from milled cowpeas. Over 77 percent of the respondents had purchased akara/kosai in the past week, with 45 percent having purchased akara/kosai four or more times in the past week. Consumers cited the same reasons for purchasing akara/kosai as noted above. In addition, 77 percent of the respondents indicated that they purchased akara/ kosai as alms for the hungry. Consumers reported an even higher degree of loyalty to the vendor for akara/kosai, with 75 percent having purchased from the same vendor four or more of the last ten purchases. Taste, location, freshness and cleanliness were again noted as the reasons for loyalty.

Hedonic price analysis for akara/kosai continued in FY 06. The results of analysis of cross section/time series data from Bauchi is consistent with the results reported for FY 05, which included cross section data from 13 states across Nigeria. The most notable result is that consumers pay a lower price per gram for small sized akara/kosai compared to when they purchase a large sized product.

Regression analysis was conducted to determine the factors that influence the level of profitability of the vendors who are purchasing cowpeas and producing value-added products for consumers to purchase as street food. For the vendors selling products such as moin-moin, rice and cowpeas and cowpea pottage, the length of time in business at a specfic location had a positive and statistically significant co-efficient. This is consistent with the results reported above, where it is noted that consumers have a high degree of loyalty to particular vendors. Regression results for the profitability of the akara/kosai vendors are reported in Table 2. The co-efficient for experience is positive and statistically significant, indicating that vendors with more experience are more profitable. In addition, the co-efficient for small size akara/kosai is negative and statistically significant, indicating that the vendors who sell the small size product are less profitable. Again, this is consistent with the results reported above, since if consumers are paying a lower price per gram of product, it follows that the vendors may earn smaller profits.

Literature Cited

Faye, M., A. Jooste, J. Lowenberg-DeBoer and J. Fulton. 2006. Impact of Sucrose Contents and Cooking Time on Cowpea Prices in Senegal. South African Journal of Economic and Management Sciences, Volume 9, No. 2, June, p. 207B212.

Tables/Graphs/Figures

Table 1. Hedonic Price Analysis for Cowpeas in Niger.

Variable	**Petit Marche**	**Wadata**
BowlWeight	-0.258 (-10.69)***	-0.190 (-6.933)***
Size	4.7465 (2.548)**	0.945 (0.807)
Holes	0.238 (0.577)	-0.071 (-0.179)
SkinColor	-19.199 (-2.342)**	-54.932 (-8.973)***
EyeColor	-12.444 (-1.455)	6.764 (1.070)
February	-11.663 (-0.928)	-1.362 (-0.153)
March	22.424 (0.793)	4.552 (0.238)
April	10.524 (0.644)	38.125 (3.626)***
May	28.704 (1.860)	41.004 (3.982) ***
June	46.446 (2.921)***	73.859 (6.864)***
July	71.896 (3.433)***	88.232 (6.604)***
August	78.195 (3.500)***	96.959 (6.732)***
September	16.260 (0.953)	15.070 (1.417)
October	-18.498 (-0.664)	-28.066 (-1.751)*
November	-31.563 (-1.100)	-18.649 (-1.149)
December	-1.678 (-0.062)	-18.250 (-1.372)
Year1	-65.929 (-5.946)***	-49.638 (-6.230)***
Year2	-64.617 (-4.076)***	-41.718 (-3.829)***
Year3	-62.146 (-2.602)**	-38.295 (-2.929)***
CookTime	-1.792 (-1.668)*	-0.997 (-1.147)
Protein	0.683 (0.417)	1.475 (1.465)
Sucrose	0.979 (0.500)	1.414 (0.656)
Contstant	625.96 (9.108)***	532.63 (11.12)***
System R^2	.9868	

Values in parenthesis are t-statistics. *** Statistically significant at 1% level, Statistically significant at 5% level, * Statistically significant at 10% level.

Table 2. Regression of Profitability of Akara/Kosai Vendors in Bauchi, Nigeria.

Variable	Coefficient	t-statistic
Moderately Clean	-1252.2	-1.501
Not Clean	-15770	-2.226**
Experience	348.33	1.840*
Duration	487.12.	1.334
Small Size Akara/Kosai	-5510	-2.025**
Constant	34199	8.141***
R^2	.1388	
Adjusted R^2	.1152	

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level.

WA2-A1

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Development of Cowpea-Based Value-Added Foods with High Nutritive Health Values Preferred by Consumers and Food Processors

Principal Investigators and Institutions:
R. Dixon Phillips, University of Georgia, U.S.; Esther Sakyi-Dawson, University of Ghana-Legon, Ghana

Collaborators and Institutions:
Sam Sefa-Dedeh, K. Tano-Debrah, E. O. Afoakwa, Agnes Budu, Sam Asuming-Brempong, F. K. Saalia and O. Sakyi-Dawson, University of Ghana-Legon, Ghana; Jess Lowenberg-DeBoer, Purdue University, U.S.;Manjeet S. Chinnan, Ronald r. Eitenmiller and Yen-Con Hung, University of Georgia, U.S.; and Paul Houssou, PTTAA-LTA, Benin

Justification and Objectives

The goal of this research component is to enhance the availability of nutritious/healthful, and affordable cowpea-based foods to consumers in both West Africa and the U.S., while developing prototype-products and processes that increase the income of small-scale food industry entrepreneurs. Research during the current phase of the CRSP has shown that interventions ranging from simply teaching people how to combine staples appropriately, to setting up small-scale manufacturing facilities can succeed in improving both nutrition and income among the rural and urban poor.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Extend existing knowledge and determine consumer preferences and market opportunities for value-added processed cowpea products.
- Develop processed foods with high nutritive and health values, including storable snack and fast foods.

Research Approach, Results and Outputs

Dissemination activities for value-added cowpea products in West Africa: A two-day training of trainers' workshop was organized for 20 agricultural extension officers and community health nurses from the Ministry of Health, in the Eastern region of Ghana. The format of the workshop was lecture/discussion and a practical hands-on demonstration of how to prepare the products. The following topics were included in the workshop:

- Nutritional value of cereals and legumes (cowpeas).
- Advantages of using cowpeas.
- The need for protein fortification of cereals and how protein deficiencies in the cereals can be addressed.
- Processing of cowpea-fortified traditional foods.
- Introduction to the Theory of Reasoned Action Methodology and how it is used. This was to enable the participants to understand how information on the "drivers" for adoption and "barriers" to the adoption of the products were obtained.
- The process of developing communication strategies. A lecture on using the findings from the adoption study to develop communication activities - identifying messages, channel and media were given.

The development of effective communication strategies was stressed as being important for influencing the community positively and getting them to accept the fortified products. Participants were taken through the steps involved in the preparation of cowpea-fortified maize dough and gari followed by a hands-on preparation of cowpea-fortified maize dough. On the second day, participants were grouped and asked to develop communication activities for the cowpea-fortified maize dough.

Messages developed by the participants to aid and promote the cowpea-fortified maize dough included: Cowpeas are highly nutritious, affordable and available compared to animal proteins, and help in preventing nutritional deficiencies (e.g., Kwashiorkor); cowpea-fortified maize dough is good for nursing mothers and children being weaned; and eating cowpea-fortified maize dough will result in less hospital bills. Some of the channels identified by the participants to help disseminate the messages included community health workers, agricultural extension officers, opinion leaders within the communities such as religious leaders, educators and traditional leaders; other channels are women's groups, traditional birth attendants, school health officers, health workers and volunteers and development-oriented non-governmental organizations. Some mechanisms or media identified for communicating nutritional messages related to food products included posters and handouts, role play dramatization, health durbars, child welfare clinics, community or group meetings, farmers' meetings, and home visits. Specific processes should be chosen to suit specific environments or communities.

Cowpea-peanut milk: An experiment was conducted to determine the effect of adding malt enzyme to extracted cowpea-peanut milk (original method) or to blended slurry of cowpea-peanut before extraction of the milk. The diastatic power of the malt extract enzymes were also determined. Quality characteristics of the cowpea-peanut milk assayed included protein content, fat, titratable acidity, viscosity, and total solids. Sensory quality characteristics of the different milks were also rated as well as their acceptability. Results of this experiment indicate that at three days of germination, the rice malt had the highest diastatic activity followed by sorghum and then maize. The viscosity of the milk hydrolysed with the maize had the highest viscosities (39.3-42.2cP) while those hydrolysed with rice malt were less viscous (21-23cP). These viscosity readings correlated with the total solids content, with products hydrolyzed with rice malt having the lowest total solids of approximately 9% compared to approximately 11% for the maize malt products. There was no significant difference between the titratable acidity of the samples though generally the rice malt samples had the lowest free fatty acid contents (0.62-0.79%). Fat content ranged from 4.36-4.74%. Protein content of the samples were similar ranging from 5.5-5.8%.

The color of the samples was significantly affected by the type of malt extract used and there were clear sensory differences. The rice malt samples had less of a beany and nutty flavor compared to the others. On an overall liking scale, the samples were ranked in the following order CPMR1>CPMR2 =CPMS2=CPMS1 >CPMM2 >CPMM1 (See Table 1 for sample codes). The malt enzyme source had a more significant impact on the products than the point in the process at which the hydrolyzation was done. Based on the results, the use of rice or sorghum malts are recommended for the processing of cowpea-peanut milk.

Process optimization and product characterization of cowpea-based tempeh: Tempeh is a traditional Indonesian fermented food (cooked, dehulled legumes usually soybeans, or other materials, bound into a solid cake by the growth of a mold, most commonly *Rhizopus oligosporus*). A Central Composite Rotatable Design with K=3 (boiling time of 5-30 minutes, incubation temperature of-25-50˚C, and incubation time of 12-48 hours) was used to investigate the preparation of tempeh from cowpeas. Nigeria and Togo cowpea varieties were used for the study. *Rhizopus oligosporus* obtained from germ cultures (U.S.), was used for the fermentation. The cowpea tempeh was prepared as shown in Figure 1. The optimized cowpea tempeh was analyzed for its chemical and physical characteristics. Sensory difference and acceptability tests were conducted to compare the cowpea tempeh to soybean tempeh.

Results indicate that boiling time of the cowpea cotyledons, incubation time and incubation temperature all significantly influenced most of the chemical and physical indices studied. The optimum processing conditions required to achieve the optimum quality of tempeh were a boiling time of 20-30 minutes (depending on the hardness of the cowpeas), incubation time of 28 hours and incubation temperature of 37˚C. With the exception of the ash and carbohydrate content, there was an increase in the proximate composition after fermentation. There was a significant reduction in the ash content of the cowpeas when fermented into tempeh. The protein content of the tempeh samples was higher than the unfermented cowpeas. A sensory difference test indicated that the tempeh from the soybean and cowpea tempeh differed significantly. Even though both the soybean and cowpea tempeh were acceptable or liked, the soybean tempeh was rated higher than the cowpea tempeh. The flavor of the tempeh from the soybean was the most preferred, followed by that of the Nigeria cowpea and then the Togo cowpea.

Cowpea flour production and use in Benin: A survey was conducted in Benin and Togo to understand the processing and consumption of a traditional griddle cooked (TG) legume food (kpedjigaou). The raw material for this product is cowpea flour. It is a low fat, fast cooking food which is consumed mainly in Togo and Benin. It has a potential for wider use if the process is modified to improve its sensory characteristics such as texture and taste. A semi-structured questionnaire was developed to collect information on processing, packaging and consumption of the product so as to design a study on optimizing the processing and product characteristics. The results of the survey indicate that only women were involved in processing and commercialization of TG legume foods and most of them lack basic education. The TG legume foods are circular in shape with uniform thickness and have a porous structure around the surface. They are brownish in color and sometimes covered with black spots. They are similar to the English crumpets or Scottish pancakes in appearance. Cowpeas and Bambara groundnuts were the two major raw materials used for processing. Other minor ingredients added to the paste prior to griddling were water, potassium and sodium salts and sometimes cassava flour to increase the viscosity of the paste, especially when using Bambara nuts as a raw material. The cowpea seeds are milled after sorting and cleaning, The equipment/utensils for cooking/griddling are flat stones (63.33%) and aluminum plates (36.67%). Griddling time was approximately five minutes.

Constraints that have direct influence on product quality and acceptability were difficulties in paste formation and regulation of heat when cooking. For example when heating was excessive and the paste too thick, the products tend to be undercooked within but would have burnt on the surface making the product unacceptable to consumers. A process optimization study which is a follow up from the survey has been designed to address some of these constraints.

Milling of cowpea flour using a cyclone assisted milling: A modified Super Wing Mill DM-200 was used to generate flours from 180g samples of cowpea seeds. Particle size analysis was conducted using a Malvern Mastersizer S laser diffraction system and geometric mean diameter (dgw) and geometric standard deviation of particle diameter by mass (sgw) calculated. Mill design, turbine speed, and airflow restriction all had a significant effect on the dgw of cowpea flour; all three parameters and milling time had a significant effect on yield. The modified wing mill configuration produced cowpea flour with a larger dgw and yield (17.13 μm, 69.05%) than the original wing mill configuration (16.84 μm, 59.88%). Turbine speed at 7200 rpm produced cowpea flour with a smaller dgw and greater yield (16.80 μm, 74.45%) than a speed of 5400 rpm (17.18 μm, 54.44%). Restriction of the airflow to 15^o produced cowpea flour with a smaller dgw and yield (16.67 μm, 49.98%) whereas the 90^o restriction produced cowpea flour with a larger dgw and greater yield (17.30 μm, 78.95%). The only significant difference (a=0.05) in feed method and milling time was that yield was higher at five minutes (69.55%) than for one minute (59.38%). Overall, the dgw for cowpea flour produced in this portion of the experiment was less than 18 μm for the various treatment regimens with the exception of a modified configuration operating at 5400 rpm using a 90^o restriction for five minutes of milling producing the largest dgw of 17.92 μm.

Quality and consumer acceptance of akara processed from wet and dry milled cowpeas: Previous research identified critical factors important for the processing of cowpea meal with desired functional properties for making akara. A study was conducted in FY 06 to examine the particle size distribution of two cowpea meals–hammer milled (HM) and freeze-dried (FD)–during the akara making process, and the physical structure and consumer acceptance of akara made from the meals. The objective was to determine if acceptable akara could be produced using dry cowpea meal as a starting material. Akara produced from both the meals was found acceptable by sensory panelists with no significant difference for any of the attributes or overall liking between the two samples. This data showed that the readily hydratable meal can be used to make acceptable akara. Of the two meals examined, the hammer milled meal was relatively easy to process, and akara made from the meal required less time and labor than akara made from the whole peas. The freeze-drying process required significantly more resources (i.e., time and energy) than the hammer milling process. It is evident that the benefits of freeze-drying a cowpea meal do not outweigh the costs, and an acceptable meal can be produced using the less expensive hammer milling process.

Nutritious convenience/snack foods: While nutrient composition data from governmental and international sources is based on averages and often on few observations, it is commonly used to project nutrient delivery via diets. In this project, we used a combination of data from the U.S. and FAO/WHO sources because only ingredients commonly found in West Africa are being considered (no wheat or soy, even though imported and available). The greatest challenge was acquisition of meaningful price data for the commodities of interest. Consistent price data from Francophone countries was available for a 2-5 year period from a website (http://www.resimao.org/html/en/(country name)/home). After considerable effort, an extensive database of commodity prices in Ghana (Ghana National Average Wholesale Price Database) over a 30 year period was located. Guidance on the proper way to utilize these data was sought from agricultural economists. The following steps taken: 1) Consider prices for the last five years; 2) Use the Consumer Price Index from each country and each year and adjust prices to a 2005 price basis; 3) Use appropriate conversion rates and convert prices to U.S. dollars; and 4) Use the lowest and highest prices for the period as a starting point and derive the least cost formulations for each time period. These should illustrate possible cost fluctuations within a five-year period.

Using this approach, multiple formulations have been generated that meet the nutritional target using commonly consumed West African commodities. Based on these, processing formulations with limited fat content were calculated such that when additional fat was added the remaining nutrients would meet the target. A significant portion of the protein in these formulations is contributed by cowpeas and/or peanuts. Peanuts are the logical source of fat in the region, although isolated fats were also included in the ingredient list. Past experience suggests that mixtures with 15% or more moisture and 5-7.5% fat may be extruded into acceptable products. Extrusion experiments are pending.

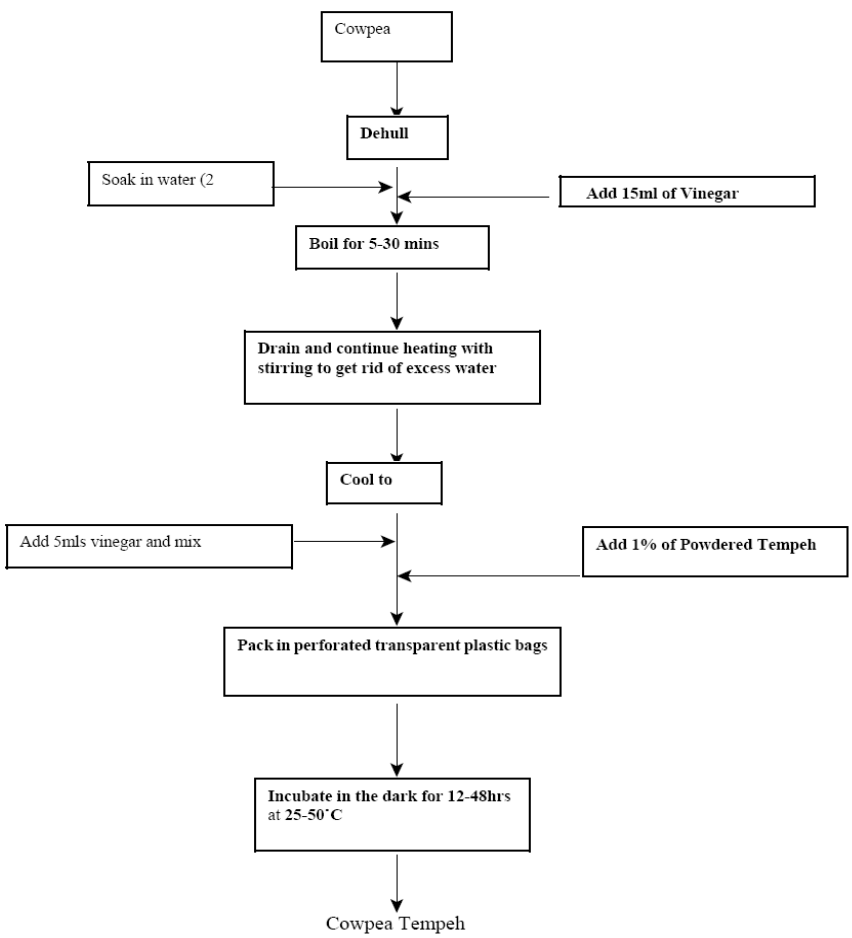
Tables/Graphs/Figures

Table 1. Key to sample codes.

PROCESS	***Sample code**
Addition of malt to slurry before pasteurizing and homogenizing.	$CPM_{M1;}$ $CPM_{R1;}$ CPM_{S1}
Cowpea-peanut milk hydrolyzed with maize malt enzyme extract after homogenizing and pasteurizing.	$CPM_{M2;}$ $CPM_{R2;}$ CPM_{S2}

- M:- maize malt; R:- rice malt ; S :- sorghum malt

Figure 1: Flow diagram for the processing of cowpea Tempeh.



WA3-A1

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Enhancing the Sustainability of and Intensifying Cowpea-Based Cropping Systems in Sudano-Sahelian Zones of West Africa and in the U.S.

Principal Investigators and Institutions:
William Payne, Texas A&M University, U.S.; Mohamadou Gandah, INRAN, Niger

Collaborators and Institutions:
Germaine Ibro, Seyni Sirifi, Hamidou Zeinabou, Dahiratou Marafa and Zaberiou Tahirou, INRAN, Niger

Justification and Objectives

Because current cowpea cropping systems in West Africa are not keeping pace with food demand, are causing soil degradation, and are becoming less productive, they are clearly not sustainable. Cropping systems must therefore be intensified in manners that meet local food demands, protect or improve the soil resource-base, and generate income. Technologies to accomplish these goals certainly exist, but require capital and labor, which are often in short supply

Cowpeas can play a key role in intensifying cropping systems and income generation in West Africa because of its multiple uses in human and animal diets (Rachie, 1985). In Niger, Ghana and other West African countries, cowpea grain and fodder are widely traded commodities. Other benefits of increased cowpea production include improved human and animal nutrition, improved soil properties to facilitate sustainability, more efficient water use, and substantial opportunities for income generation among women, e.g., through marketing of raw or processed cowpea goods or small-scale livestock operations.

The Panhandle region of Texas is also faced with increasingly unsustainable cropping systems in terms of economics, soil degradation, and especially water supply. Drought, low commodity prices, falling water tables, and rising energy and fertilizer costs have in recent years forced many farmers to focus mostly on economic survival. The predominant wheat/sorghum/fallow dryland rotation is viewed as inefficient in terms of production and water use because of the fallow component. Because cowpea is a legume that is adapted to dryland conditions and its fodder may have value in local markets for cattle feed, it has potential to improve the sustainability of cropping systems in the Texas Panhandle.

The report highlights progress made in research activities in FY 06 to achieve the following objective:

- Development and implementation of sustainable, intensified cowpea-based cropping systems for semi-arid West Africa and Texas. Emphasis will be on optimum agronomic practices for production, sustainable management of soil and water resources, pest management, and income generation.

Research Approach, Results and Outputs

In Niger: Long-term cropping system experiments were installed in May 2005 at INRAN stations near Kollo and Tara. The new experimental sites were located far enough from frequently used fields to avoid high or heterogeneous levels of residual P from past station experiments. Cowpeas were grown with pearl millet in Kollo, which is located in a medium (400-500 mm/year) rainfall zone, and with sorghum in Tara, which is in a high (>700 mm/year) rainfall zone. Fences were built around experimental plots to protect them from uncontrolled livestock. A Latin square design was adopted that simplified management and statistical analyses..

Treatments included cropping system, management intensity and cowpea cultivar. The four cropping systems includes: 1) Rotation, 2) Intercrop 3) Strip crop; and 4) Monocrop. The four technology levels were: 1) Low, in which neither fertilizer nor pesticide are used and hill spacing is 1x1 m for both crops; 2) Medium 1, which includes Tahoua rock phosphate at a rate of 30 kg/ha P_2O_5 and 30 kg N/ha, a readily available insecticide recommended by IITA, and a planting density of 17000 hills/ha; 3) Medium 2, which includes a “micro dose” of NPK (15-15-15) at 6 g per hill (102 kg/ha) and 30 kg N/ha, the same IITA-recommended insecticide, and a planting density of 17000 hills/ha.; and 4) High, which includes super triple phosphate at a rate of 30 kg/ha P_2O_5, 50 kg/ha N as urea, the insecticide Karaté applied at 2.5 l/ha, and a planting density of 20000 hills/ha. The four cowpea cultivars were 1) ITK 90, an early, erect genotype for grain production; 2) TN 28 87, a dual purpose cultivar of medium duration; 3) the local landrace, a fodder cultivar of late duration, and 4) IT99K-213-11-1, a cultivar tested for efficient P uptake.

A "satellite" study was also conducted in 2005 and 2006 at Kollo in which P uptake efficiency from Tahoua rock phosphate was evaluated among cowpea varieties selected by B. B. Singh of IITA for P efficiency using single super phosphate. A Latin rectangle design was used for the satellite study, with cowpea varieties making up the rows and Tahoua rock phosphate rate making up the columns.

The 2006 season was characterized by an erratic start and occasional floods later in the season. However, total rainfall amounts were generally near the norm. Yield results for the 2006 season are summarized in Tables 1 and 2. In the northern site, cowpeas and pearl millet yield responded to the cropping system, but only pearl millet responded to technology level. The highest grain, hay and stover yields were obtained in the rotation cropping system, followed by mono-cropped systems. The highest yielding technology for pearl millet was the "Medium 2" treatment that included the "micro-dose" fertilizer application, which would normally not have out-yielded the "High" technology treatment. Cowpea grain and hay yields were very low at this site and unaffected by cultivar, possibly due to micronutrient deficiency, as evidenced by yellowing leaves, and high plot-to-plot variability. In the southern site, both sorghum and cowpeas responded to the cropping system. Cowpea grain and hay yields were greatest in the rotation and monocrop systems, but pearl millet grain and stover yield were greatest in the rotation system, followed by the monocrop system. Neither crop responded significantly to technology level, suggesting that P levels may not have been extremely low in the zero input treatment. Plot variability was also high at this site, especially for sorghum. However, there were large differences among cowpea cultivars for grain and hay yield. The highest grain yield was for the "dual-purpose" cultivar TN 28 87, followed by the early cultivar ITK 90. However, the landrace, which had zero grain yield, had by far the greatest hay yield.

Chemical analyses of soil samples taken after harvest in 2005 provide an early indicator of the response of two key soil fertility parameters, plant P availability and pH, to agronomic treatments (Fig. 1). Compared to the lowest level of technology (T1), P increased, especially in plots with rock phosphate (T2) and triple super phosphate (T4) application. However, there had yet to be a response in soil pH even with application of rock phosphate, which includes Ca.

In Texas: Yield data for the last three years at Bushland, Texas are summarized in Table 3.. Cowpea grain was nil in 2004 because of late planting (due to lack of moisture) and frost kill. The earliest variety had the highest grain yield in 2005 and 2006, but yield was very low in 2006 because of frost kill before podfill. Cowpea hay yield was greatest for the late variety in 2004 and the intermediate variety in 2005, possibly due to slower growth of the late variety. The late variety tended to have the greatest hay yield in 2006 but this was not significant due to high plot variability.

Wheat crop was lost to hail in late spring of 2004 and to early spring drought in 2006. In 2005, there was no significant rotation effect on wheat grain. Sorghum did not respond to treatment effect in any year, including in 2006 when it was planted into failed wheat. Results therefore do not suggest any negative rotation effect on subsequent cereal crops when replacing summer fallow with even the latest cowpea variety. On the other hand, no significant positive yield effect has been observed on subsequent cereal yield.

Soil water storage data for sorghum, and sorghum after failed wheat, reveal that there was a tendency for plots following fallow and/or early cowpeas to have slightly more soil-stored water than those following late cowpeas, but the differences were seldom significant. Similarly, there was a tendency for plots with the early cowpea cultivar to have slightly more soil-stored water than those with late cowpeas, but again, the difference was usually small and never significant. A block effect on soil-stored water that was significant only in fallow plots without crops was associated with depth to caliche. Overall, the soil water data support the hypothesis that low storage efficiency of fallowing wastes water that could better be used growing an economical crop. Even though we thus far have no evidence that rotation with cowpeas increases cereal yield, lab results on submitted soil samples may yet show that soil organic carbon, a key indicator of sustainability, is beginning to respond to cowpeas.

Data from the preliminary, non-replicated heifer grazing study indicate increased daily weight gain from strips of cowpeas with sorghum sudan grass. The overall objective this year was simply for the farm crew to gain practical experience with this new system. Next year more pasture will be available for replicated trials.

Additionally, a Ph.D. study has been undertaken to determine genetic variability for P uptake efficiency among a core collection of ~700 cowpea accessions using Tahoua rock phosphate as the phosphate source, and to assess key physiological mechanisms of P uptake in cultivars with contrasting P uptake efficiencies. Results suggest a high degree of variability in cowpeas for adaptation to low P conditions and for the ability to use Ca-bound P in ground rock phosphate. Density distributions were in each case normal but tended to be more skewed and have higher kurtosis under No P conditions. The manner in which plants responded to low P conditions and TRP addition also varied greatly in terms of biomass, biomass partitioning, and height. This high degree of variability suggests a need for further studies to determine physiological mechanisms of adaptation, as well as heritability of traits that confer adaptation. The wide variability observed in this study suggests that breeding for improved cowpea adaptation to low P availability, and in particular to P utilization from rock phosphate, is a feasible goal that may contribute substantially to intensification of cropping systems in Sub-Saharan Africa.

The cowpea research program is generating interest. Producers are inquiring about the incorporation of cowpeas into cropping systems as a grain, fodder, or green manure crop. The motivation appears to be due to the dramatic rise in N fertilizer cost, which has stimulated interest in N fixation via green manuring, and the continued dramatic influx of dairy operations into the Texas southern and High Plains region.

Tables/Figures

Table 1. Yield (kg/ha) results for cropping systems experiment near Kollo, Niger, 2006.

	Cowpea Grain	Cowpea Hay (kg/ha)	Pearl Millet Grain	Pearl Millet Stalks
Cropping System				
Rotation	189	502	1579	1375
Intercrop	14	24	454	419
Strip Crop	22	49	281	330
Monocrop	58	216	530	621
SE	41*	102*	63***	78***
Technology				
Low	47	165	448	511
Medium 1	59	272	525	516
Medium 2	129	206	1109	973
High	48	143	761	745
SE	41ns	101ns	63**	78**
Cowpea Variety				
ITK 90	38	18	643	725
TN 28 87	146	161	812	796
Local landrace	68	427	603	533
IT99K-213-11-1	30	184	785	691
SE	41ns	102ns	63ns	78ns

*,**,*** Significant at 0.10, 0.05, and 0.01 probability levels. Ans@=non-significant.

Table 2. Yield (kg/ha) results for cropping systems experiment near Tara, Niger, 2006.

	Cowpea Grain (kg/ha)	Cowpea Hay (kg/ha)	Sorgham Grain (kg/ha)	Sorghum Stalks (kg/ha)
Cropping System				
Rotation	521	3535	1045	9150
Intercrop	241	2334	239	1563
Strip Crop	135	2424	263	1963
Monocrop	681	3652	609	4175
SE	107	335*	149**	1083**
Technology				
Low	203	2844	497	2912
Medium 1	347	3652	558	4038
Medium 2	512	2696	526	4788
High	520	2654	576	4113
SE	107ns	335ns	149ns	1083ns
Cowpea Variety				
ITK 90	518	1357	520	3688
TN 28 87	722	2323	591	4675
Local landrace	0	4861	465	2838
IT99K-213-11-1	341	3305	580	4650
SE	107**	335*	149ns	1083ns

*,**,*** Significant at 0.10, 0.05, and 0.01 probability levels. "ns"=non-significant.

Table 3. Texas yield summary (kg/ha).

	2004				2005				2006			
1 Rotation	Cowpea Grain	Cowpea Hay	Wheat Grain	Sorghum	Cowpea Grain	Cowpea Hay	Wheat Grain	Sorghum	Cowpea Grain	Cowpea Hay	Sorghum‡	Sorghum
Fallow	†	†	‡	1583	†	†	1061	4545	†	†	653	1945
Early	0	2418	‡	1643	2168	4001	982	3902	316	328	868	2115
Medium	0	2992	‡	2466	925	5969	1118	4852	51	678	1002	1359
Late	0	6825	‡	2282	599	3243	854	4333	83	1298	738	1932
SE	ns	687*	‡	502^{ns}	168**	342**	223^{ns}	589^{ns}	85^{ns}	356^{ns}	158^{ns}	370^{ns}

† No cowpea grown
‡Wheat crop lost to hail (2004) or drought (2006). In 2006, sorghum was planted in the failed wheat plots.
*P<0.01 and **P<<0.005

WA4-A1

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Development of Improved Cowpea Cultivars with Increased Yield Potential, Tolerance to Biotic and Abiotic Stresses, and Having Grain Quality Traits Preferred by Farmers and Consumers for Three Target Agro-Ecological Zones, the Sahel and the Sudan/Guinea Savanna Regions in West Africa and the U.S. Southwest

Principal Investigators and Institutions:
Phillip Roberts, University of California-Riverside, U.S.; Ousmane Boukar, IRAD, Cameroon; Ndiaga Cissé, ISRA, Sénégal; Issa Drabo, INERA, Burkina Faso

Collaborators and Institutions:
Jeff D. Ehlers, University of California-Riverside, U.S.; Mohammed Ishiyaku, Institute for Agricultural Research, Zaria, Nigeria; Larry Murdock, Purdue University, U.S.; Francis Padi, SARI, Tamale, Ghana; Jeremy Ouedraogo, INERA, Burkina Faso; Mike Timko, University of Virginia, U.S.

Justification and Objectives

On-farm cowpea yields in West Africa average 240 kg/ha even though potential yields in the region, as demonstrated in on-station and on-farm trials, are often five to ten times greater. Most of the loss in yield potential is due to pests, but drought and poor soil fertility are also important constraints. The goal of this research component is to develop improved cowpea cultivars that resist or tolerate these biotic and abiotic stresses for three target agro-ecological zones, the Sahel and the Sudan/Guinea Savanna regions in West Africa and the U.S. Southwest.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Identify and characterize cowpea germplasm for resistance to insect pests, diseases and drought.
- Develop high yielding, pest resistant cowpea varieties with improved grain quality adapted to the Sahelian and Savanna zones of West Africa and to the U.S.
- Develop and characterize genetic populations and molecular tools necessary for implementation of marker-assisted selection (MAS).

Research Approach, Results and Outputs

CRSP Cowpea Core Database development: The CRSP Core Collection was evaluated in 2006 for the following characteristics: days to maturity in California (under both long and short day conditions), Cameroon and Burkina Faso, drought tolerance in California (in both greenhouse and three field trials), resistance to flower thrips in Senegal, resistance to pod bugs, bacterial blight and viruses in Cameroon and Burkina Faso, resistance to brown blotch in Burkina Faso, and resistance to *Striga* in Cameroon. From the data summarized thus far, it is clear that biotype differences for bacterial blight exist between Cameroon and Burkina Faso, and that the virus complex is different in these two countries. This emphasizes the need for conducting selection in the actual target environment. These data also allow identification of lines with broadly effective resistance to pests and pathogens, such as breeding line IT98K-498-1, which has shown resistance to cowpea aphid, pod sucking bugs, bacterial blight and viruses in Cameroon and also resistance to bacterial blight, viruses and brown blotch in Burkina Faso. This line, however, is susceptible to drought, Fusarium wilt, and races of Striga present in Cameroon.

Identification of sources of Aphid Resistance: An off-season screenhouse evaluation of 16 advanced cowpea lines was conducted in Burkina Faso in 2006. Seedlings were grown in pots and artificially infested with aphids. Four lines, UCR5038, UCR1340, KVx 741-14-2 and KVx 709-13-5, were judged to have strong resistance to the Burkina Faso cowpea aphid.

In the aphid resistance field trial conducted in Burkina Faso in 2005, KVx165-14-1, KVx146 and KVx295-2-124 exhibited strong resistance to aphids. They have been used as donor parents for crosses with elite cultivars KVx 396-4-5-2D and KVx414-22-2.

Identification of breeding lines with resistance to Pod Sucking Bugs: In 2005, two sets of resistant lines were tested for resistance to pod sucking bugs at two Burkina Faso locations, Donsin in the central region and Tenkodogo in the eastern region. At Donsin, damage caused by pod sucking bugs to lines KVx 908-1, KVx 910-2, and KVx 910-40 was similar to the resistant check variety and lower than on the susceptible check variety sprayed with conventional insecticide. Three of the resistant lines, KVx908-1, KVx908-32, and KVx907-34 had a grain yield similar to the check variety sprayed with conventional insecticide. Three other lines (KVx 907-40, KVx 910-2 and KVx 900-38) performed better than the resistant check variety IT86D-716, with grain yields of about 1000 kg/ha under no-spray conditions.

At Tenkodogo, the yields of the lines were lower than those recorded at Donsin due to high pressure of Striga. All the lines performed better than the resistant check variety IT86D-716. The best varieties were KVx 906-9, KVx 908-1, and KVx 908-44, with grain yields ranging between 429 and 532 kg/ha.

In 2006, 13 varieties were evaluated for resistance to the pod sucking bugs at Kamboinsé in central Burkina Faso. Less than 1% damaged pods were recorded on lines KVx 907-1P2, KVx 907-2P2, KVx 908-3P2, KVx 909-2P2, KVx 910-2P2, and KVx 909-1P2. These varieties were less attacked than the check variety KVx 61-1. Among these, two varieties, KVx 907-1P2 and KVx 908-3P2, had significantly higher yields than the check variety.

Identification of sources of resistance to Striga: In field trials in Cameroon, lines with grain yield higher than 1000 kg/ha that did not show *Striga* infestation included IT97K-499-35, IT99K-573-1-1, IT98K-692, and IT97K-1497-2. The second trial was comprised of 20 promising lines selected from previous years' CITs and replicated four times. Lines showing resistance based on no emerged *Striga* were IT96D-757 and IT98K-317-12.

In Senegal, results were consistent across trials and years (2005-2006) and indicate that only IT90K-59 is immune to Striga. CB27, IT82E-18, UCR 779, ISRA 819, and Mouride had few emerged Striga plants (0.25-1 plant/m2) indicating moderate resistance. Very susceptible entries included IT90K-76, Bambey 21, and Mougne.

Development of Potential New Varieties: Substantial progress was made in FY 05-06 by all the breeding programs. Advanced lines developed over years of selection and testing are nearing release in Senegal, Burkina Faso and California. Identification of promising advanced lines as parental lines for future crosses and as potential varieties occurred in all the breeding programs and new populations and early generation breeding lines were generated.

ISRA 2065 is a promising new cowpea variety for Senegal with very strong resistance to flower thrips, cowpea aphid, cowpea aphid-borne mosaic virus and bacterial blight. This variety is very early to mature and has similar plant type and seed characteristics (large white grain) as Melakh, but with slightly higher yield potential. ISRA 2065 was evaluated in 'on-farm' trials in the southeastern regions of Tambacounda and Kolda during the 2005 growing season, where flower thrips are prevalent and devastating.. ISRA 2065 has been evaluated in several on-farm trials in 2005 and 2006with support from the Sahel Institute to farmer organizations. The substantially stronger resistance to thrips in ISRA 2065 compared to Melakh was evident in these on-farm trials. Early production of pods during the 'hungry period' (August-September) was appreciated by farmers.

03Sh-49 and 03Sh-50 are potential new blackeye-type cowpea varieties developed at UC-Riverside for growers in the southwestern U.S. These lines have superior grain quality and pest resistance than the current standard blackeye cultivars. In 2006, 03Sh-49 and 03Sh-50 were evaluated for the third year in replicated trials with check entries CB46 and CB27 at the Kearney and Shafter Research and Extension Centers in the San Joaquin Valley under long and short season production systems and at UC-Davis Experimental Farm under short season conditions. 03Sh-49 and 03Sh-50 were also grown in large-scale replicated strip trials at two experiment station locations (UC Shafter and Westside Research and Extension Centers) and in three on-farm strip trials in Tulare, Madera and Colusa counties. Two of the on-farm trials consisted of plots about 10 ha in size and were harvested and cleaned by commercial entities, which allowed 'real world' assessments of overall production and cleaning 'performance.' Canning tests conducted by Suzanne Nielsen and Steve Smith at Purdue University showed that these selections have excellent canning quality. Formal release of one or both lines is projected for 2007. At the specific request of the Blackeye Council of the California Dry Bean Advisory Board, a program was begun to rapidly multiply pure seed of these lines. On August 23, 2006, 0.4 ha of a purified subline of each selection was planted at the UC-Riverside Coachella Valley Agricultural Research Station under drip irrigation, producing about 600 kg of each selection.

Six backcross/selection cycles were completed in order to develop a version of the standard blackeye cowpea variety CB46 with improved resistance to root-knot nematodes. This potential variety is referred to as

CB46-INR (for Improved Nematode Resistance). In November 2005, nine sublines from CB46-INR BC6F3 families were selected from a nematode resistance screening nursery at South Coast Field Station. Sublines of these selections were generated in the greenhouse during the spring of 2006. These sublines were screened for resistance to *M. javanica* root-knot nematode at Kearney and for agronomic and grain quality characteristics at the UC Kearney and Shafter Research and Extension Centers and at the UC-Riverside farm. Laboratory 'pouch-tests' were conducted in the fall 2006 that confirmed the field resistance evaluations. All of the lines appeared to be essentially identical to the recurrent backcross parent CB46. The improved version of CB46 could be released in 2008. The first large-scale on-farm trials with a new persistent-green variety, UC-R G-741, were conducted on 18 ha in two farmers' fields in California. Four commercial entities have expressed strong interest in buying the 30,000 kg of grain that were produced from these strip trials. An improved version of the standard blackeye cultivar CB46 was developed with enhanced resistance to root-knot nematodes using a backcross breeding approach. During 2005-2006, the sixth backcross/selection cycle was completed, resistant families selected. Sublines of these selected families are being selected and the seed increased for final evaluations that are a necessary part of the release process.

Identification of promising lines for use as parents or varieties: Other high yielding lines with resistance to aphids and thrips were identified from trials conducted in 2005 and 2006 in Senegal, including ISRA 3050 and ISRA 3052, both from the cross of Mame Penda x Yacine. At Bambey, the line ISRA-3006 with speckled seeds favored by some consumers in Senegal has shown high yield potential in three successive years of testing. It has been obtained from a cross between the local variety Baye Ngarne and ISRA-514, a breeding line with the same speckled grain type but has resistance to aphids. ISRA-3006 has also large grain size (22g/100) seeds.

In Burkina Faso, an elite group of 18 selections were evaluated in multi-location trials to identify the best five lines for on-farm tests in 2007. The selection criteria used include earliness, resistance to diseases and insects and *Striga* resistance. Farmers input will be used to choose which of the five will be released.

In Cameroon and Burkina Faso, several IITA Cowpea International Trials (CITs) were conducted in FY 05-06, including Early Maturity CIT, Medium Maturity CIT, *Striga* Resistance CIT, No-Spray CIT and Dual Purpose CIT. Advanced trials comprised of lines from earlier CITs were also conducted in FY 06. In Cameroon, lines IT96D-610, IT97K-568-18, IT98K-1111-1, IT98K-491-4, IT99K-494-6, IT93K-452-1, and IT98K-131-2 showed high yields in a 'no-spray' trial conducted at Guiring, This trial was repeated in 2006. Lines IT98K-128-4, IT00K-901-5, IT00K-1150, IT99K-429-2, IT00K-1263, IT00K-898-5 and IT99K-529-1 were among the best early maturing lines while IT98K-131-2, IT98D-1399, IT99K-718-6, IT00K-1263, and IT93K-625 were the best medium maturing lines.

In California, 22 new breeding lines were selected for inclusion into Preliminary Yield Tests conducted at two locations in 2006. The 22 lines were also evaluated for resistance to root-knot nematodes at the Kearney *M. javanica* nematode screening field site. The goal is to select 10 elite breeding lines for more detailed grain yield trials.

Development of new populations and early generation breeding lines: In Burkina Faso in 2005, selection of more than 400 single plants (F_5 to F_8) was made from populations initially developed at UC-Riverside. These were planted in 2006 and subjected to further selection. A number of promising lines were identified. Lines BC3-1-2 and IT97K-819-118 were promising as dual purpose (grain and hay) cultivars, while IT99K-1060, IT98K-205-8, IT98K-506-1 and IT98K-111-1 produced 500 kg/ha or more without insecticide application and were judged to be promising under 'no-spray' cultivation. Lines IT98K-205-8, IT99K-491-7, and IT98K-628 were identified as promising *Striga* resistant lines. Other lines exhibiting high yield potential included IT98K-128-3, IT98K-111-1, IT93K-625, IT98K-205-8, IT99K-316-2, and IT99K-491-7.

Two preliminary yield trials were conducted at Pobé in 2005 using lines with high levels of antibioses (high level of larval mortality). A total of 31 lines having grain yields higher than 1500 kg/ha were selected.

In 2005, two sets of resistant lines were tested at two Burkina Faso locations, Donsin in the central region and Tenkodogo in the eastern region. At Donsin, damage by pod sucking bugs on three resistant lines KVx 908-1, KVx 910-2 and KVx 910-40 was similar to the resistant check variety and less than on the susceptible check variety sprayed with conventional insecticide. Three of the resistant lines, KVx908-1, KVx908-32, and KVx907-34, had grain yields of about 1,500 kg/ha, which was similar to the check variety sprayed with insecticide. Three other lines (KVx 907-40, KVx 910-2, and KVx 900-38) performed better than the resistant check variety IT 86D 716 with a grain yield reaching 1000 kg/ha. At Tenkodogo, the yields of the lines were lower than those recorded at Donsin due to Striga. All the lines performed better than the resistant check variety IT

86D-716. The best varieties were KVx 906-9, KVx 908-1 and KVx 908-44 with grain yields ranging between 429 and 532 kg/ha. In 2006, 13 varieties were evaluated for resistance to the pod sucking bugs at Kamboinsé in central Burkina Faso. Less than 1% of damaged pods were recorded on the following varieties: KVx 907-1P2, KVx 907-2P2, KVx 908-3P2, KVx 909-2P2, KVx 910-2P2 and KVx 909-1P2. These varieties were attacked less than the susceptible check variety KVx 61-1. Among these, two varieties, KVx 907-1P2 and KVx 908-3P2, had better yields without any spray (526 kg/ha and 304 kg/ha, respectively).

In Cameroon during the 2006 cropping season, advanced lines (F_6, F_7 and F_8) were identified for several crosses made to improve seed size. Preliminary yield trials will be conducted next year for these lines.

A backcross program to incorporate the persistent green trait into germplasm adapted to the southwestern U.S. was continued and fourth generation backcross derived lines were evaluated as potential varieties at two locations in California. In 2005, four lines, 04-11-655, 04-11-741, 04-11-747, and 04-11-749 were judged to be suitable for large, on-farm trials that were planted in 2006. These lines were planted on a total of 16 ha on two farmers' fields and produced about 32,000 kg of grain. Harvested grain will be sent to a food processor for evaluation of product suitability in fresh-rehydrated and frozen products. An additional cycle of backcrossing and selection was made with other 'green' breeding populations in FY 05-06 to create high yielding dry-green cowpea varieties.

A backcross program to introgress late flowering genes to develop later maturing versions of California cultivars CB46 and CB27 was continued. Lateness due either to photoperiod genes (genes that delay flowering under long days), or genes that delay the onset of reproductive development regardless of photoperiod are being introgressed from late African cowpea lines IT93K-503-1 and 24-125B, to develop later maturing blackeyes. The BC_2F_2 generation of these materials was grown out at UC-Riverside in 2004, advanced in the greenhouse and 268 sublines at the BC_2F_4 generation planted and evaluated during the 2005 growing season. Selections with the appropriate maturity were planted in 2006 for further selection.

A large number of other breeding lines were developed and evaluated, including lines developed from crosses of elite blackeyes, and lines being developed with especially large and attractive grain. Large-seeded cowpea varieties are valued and bring a premium price in West African markets. F_3 bulks of breeding populations (including many new crosses with 03Sh-49 and 03Sh-50 as parents) were made at Shafter and planted at the UCR Coachella Valley Ag. Research Station on Aug. 23, 2006. Single plant selections from these were harvested in late November to establish a new set of F_4 breeding lines.

Amplified Fragment Length Polymorphism (AFLP) studies were conducted on the CRSP Core Set at UC-Riverside to determine primers that yield polymorphisms and to estimate the degree of relatedness among varieties within and among U.S. and West African cowpea breeding programs, including IITA. Using six near infrared fluorescence labeled primer sets, a total of 486 polymorphic bands were present out the 752 bands that were scored among the accessions. A Principle Components Analysis of the data from this study showed that cultivars within breeding programs were much more likely to have AFLP markers in common compared to breeding lines from other programs. This work was published in "Genetic Resources and Crop Evolution" (available online now, anticipated date of publication in journal, Dec. 2006).

During 2002-06 six sets of Recombinant Inbred Lines (RILs) were developed, along with development of four sets of Near-Isogenic Lines (NILs) of cultivar CB46 differing in either root-knot nematode resistance, delayed flowering, anthocyanin pigment production, or in the chlorophyll expression pathway that results in the persistent green phenotype. The new RIL sets will allow us to map important agronomic and resistance traits that could not be mapped with other available RIL populations, including resistance to bacterial blight, cowpea aphid, Cowpea Aphid-borne Mosaic Virus (CAbMV), cowpea weevil, photoperiod sensitivity, flowering time, seed size, high sucrose and drought. The NIL sets will allow us to measure the impact of individual traits/genes (i.e., nematode resistance, lateness, anthocyanin and chlorophyll degradation) in a common genetic background under field conditions as well as to characterize genetic mechanisms of each trait. The practical outcome of the development of these NIL sets is the development of a high yielding commercial cultivar with either improved nematode resistance, all-white or persistent-green grain, or late maturity/higher yield potential.

In Senegal in 2005, 102 F_8 lines of the Mouride x Bambey 21 recombinant inbred lines (RIL) set were tested for *Striga* resistance under field and screenhouse conditions in order to map and develop markers for this trait. In 2006, this set of RILs from the cross of Bambey 21 (drought susceptible) and Mouride (drought tolerant) was carefully phenotyped for drought tolerance in order to associate molecular markers with drought tolerance genes or quantitative trait loci (QTLs). A second RIL population of 150 lines developed from the cross of ISRA-819 and 58-77 was inbred to the F_8 generation in 2006. This population is being developed to map genes or QTLs for flower thrips resistance present in 58-77. A RIL population obtained from the cross between Mame Penda and Yacine was inbred to the F_7 generation. This population should allow mapping of resistance to aphids.

Two RIL populations were under development in Burkina Faso during 2005-06 from crosses between *Striga* resistant and susceptible parents for identification of DNA markers linked to resistance to different races of this pest. For *Striga* race 1 resistance, a population has been developed from a cross of B301 (resistant) x KVx404-8-1 (susceptible). For *Striga* race 3 and race 4 resistances, B301 (susceptible to race 4 and resistant to race 3) was crossed to IT81D-994 (Susceptible to race 3 and resistant to race 4). These lines have been advanced to the F_3 generation.

A series of cDNA preparations was made for providing a SNP marker platform using genotypes from the CRSP Core Collection. For cDNA library construction, most of the RNA has been prepared from five genotypes. Preliminary microarray analyses of RNA from cowpea genotypes water-stressed and non-stressed were performed by challenging the soybean Affymetrix genechip (The GeneChip Soybean Genome Array). The data were used to identify several single feature polymorphisms (SFPs) as a tool in marker development. These results indicate the potential utility of the soybean genechip for analysis of cowpea expression patterns and marker generation. In a second analysis, RNAs from young radicals of root-knot nematode resistant and susceptible near-isogenic lines were screened on the soybean array. Results again showed the potential for this approach, with several thousand transcripts hybridized following gene filtering, and of those, a subset of highly up-regulated transcripts in the resistant geneotype were identified.

WA4-A2

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Assessment of the Nematode Incidence and Speciation in West African Soils, Identification of Genetic Resistance to Nematodes in Cowpeas and the Development of Strategies to Control Nematodes in Cowpea-Based Cropping Systems

Principal Investigators and Institutions:
Phillip Roberts, University of California, U.S.; Ousmane Boukar, IRAD, Cameroon; Ndiaga Cissé, ISRA, Sénégal; Issa Drabo, INERA, Burkina Faso

Collaborators and Institutions:
Mame Birame, CLN, Dakar, Senegal; A. S. Sawadogo, INERA, Burkina Faso

Justification and Objectives

A determination of the incidence and species present of root-knot *(Meloidogyne spp*.) and other nematodes including *Scutellonema cavenessi* on cowpeas and in cowpea-based production systems is needed in West Africa. While the presence of some important nematode species has been documented and their suppression of yield potential inferred from field observations, the significance of their impact to cowpea productivity in these countries has not been determined. There is a strong likelihood that nematodes contribute to the low fertility soil regimes in which cowpea productivity is low. Nematode infection reduces the function of root systems to take up water and mineral nutrients. The specific types of nematodes and their prioritized ranking for importance to cowpea productivity must be determined, in order to target genetic improvement in cowpeas based on incorporating resistance to the most damaging nematode parasites. In California, determination of the prevalence and crop loss impact of two *Meloidogyne* species in cowpea production has led the way to development of resistant cultivars from the breeding programs, and their subsequent implementation into nematode management schemes in commercial cowpea production.

Research is needed to determine the extent to which plant parasitic nematodes are reducing cowpea production in West Africa, and the extent to which this problem can be solved by breeding nematode-resistant cowpea cultivars. This information will be critical in guiding cowpea breeding for nematode resistance in different agro-ecological zones. In this project, the focus is on Sénégal and Burkina Faso. Development of cultivars with nematode resistance is expected to contribute to increases and improved stability in cowpea yield.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Determine species composition and incidence of nematode parasites through standard survey procedures within each Host Country cowpea-growing region.
- Determine the susceptibility or resistance of common Host Country cowpea genotypes and UC-R's advanced breeding lines to the most important nematode species on cowpeas.

Research Approach, Results and Outputs

Species composition and incidence of nematode parasites: Within-season surveys of fields planted with cowpeas are being used to assess the presence, distribution and incidence of plant parasitic nematodes that are associated with root-parasitism of cowpeas. In 2006, analyses of nematode samples extracted from the soil and root samples collected during the field surveys in Burkina Faso and Senegal have continued. The genus and species identity of the extracted nematodes is being made using a combination of morphological characters visualized by light and scanning electron microscopy. Confirmation is being made to the genus and in some cases species levels based on molecular sequence analysis of rRNA D2/D3 expansion regions of the nematode genome. At the genus level, there is confirmation of presence in the primary northern production region (the peanut basin) of Senegal of six genera of nematodes with potential for damage to cowpeas (*Meloidogyne*, *Pratylenchus*, *Helicotylenchus*, *Scutellonema*, *Tylenchorhynchus*, and *Hoplolaimus*). The *Scutellonema* species in Senegal consistently is *S. cavenessi*, and it was found in 100 percent of the sites in the field survey and also at the field experiment sites being used under Objective 2. In the last three cowpea growing seasons, samples have been collected of roots and soil in *S. cavenessi* infested field locations and specimens sent under permit to UC-Riverside to establish live cultures for use in cowpea germplasm screening. One of the 2004 cultures has started to reproduce under greenhouse conditions and additional cultures from 2005 have started to grow. These will be used for cowpea germplasm screening.

In the Burkina Faso nematode surveys, previous studies reported common nematode genera found in the three cowpea production zones: the Sahelian zone (rainfall <600mm/year), the North-Central Sudan Savannah zone (rainfall of about 800mm/year), and the meridional Sudan Savannah zone (rainfall between 900mm and 1200mm/year). Based on samples of soil and cowpea roots from 75 fields in these cowpea production zones, 12 nematode genera were identified (*Meloidogyne*, *Pratylenchus*, *Helicotylenchus*, *Scutellonema*, *Tylenchorhynchus*, *Telotylenchus*, *Hoplolaimus*, *Rotylenchulus reniformis*, *Paratylenchus*, *Criconemella*, *Xiphinema* and *Paratrichodorus*) using microscopy of morphological characters. As with the Senegal samples,genus and some species confirmations were made based on molecular sequence analysis of rRNA D2/D3 expansion regions, including six genera (*Helicotylenchus*, *Scutellonema*, *Tylenchorhynchus*, *Telotylenchus*, *Pratylenchus*, and *Meloidogyne*) that were the most prevalent depending on the growing region. The *Scutellonema* samples were found consistently to contain the species *S. clathricaudatum*, which had been reported previously in Burkina Faso and some other neighboring countries. *S. cavenessi* was not found in the samples. These results further confirm our initial report that *Scutellonema* is present in both Senegal and Burkina Faso cowpea fields, but that the genus is represented by different species in the two countries. The field experiments (Objective 2) being used to determine cowpea susceptibility and nematode damage potential on cowpeas revealed that local cowpea varieties in both countries are highly susceptible to these *Scutellonema* species. For example, in Senegal final population densities of *S. cavenessi* in untreated soil at cowpea maturity averaged 382 per liter of soil in 2005. Similar levels of *S. clathricaudatum* were found in untreated cowpea plots in Burkina Faso. Molecular sequence profiles confirm that the *Helicotylenchus* species in Burkina Faso samples from cowpea fields is *H. dihystera*, the same as in Senegal. The *Meloidogyne* species found in samples from cowpea fields in the Bobo-Dioulasso region (meridional Sudan Savannah zone) were compared to standard cultures of common *Meloidogyne* species that were sent under permit to Burkina Faso after typing at UC-Riverside. The prevalence of the *Meloidogyne* species in the Burkina Faso cowpea samples was determined to be 63% for *M. incognita* and 23% for *M. javanica*. These *Meloidogyne* isolates from Burkina Faso fields are being used to screen for nematode resistance in cowpea genotypes using controlled growth-pouch tests.

Cowpea genotype susceptability to nematode species: At the ISRA field station in Thilmakha, Senegal, a fourth year of field experimentation is being conducted on a site with high infestation of *Scutellomena cavenessi* and a history of poor cowpea growth. The experiments were designed to determine the impact of the nematode on cowpea growth and yield and the extent of root infection and nematode population multiplication during the cowpea season. In each of the last four seasons, cowpea lines were grown on nematicide-treated (with Mocap) and untreated plots in a split-plot arrangement. Soil samples were taken before treatment and planting and then during the season and at harvest. Previous reports on the 2003 and 2004 experiments, in which the Mocap treatment had a significant effect in reducing the nematode populations in the early season, and the numbers developing per cowpea line differed, indicate that there may be genotype differences for hosting ability. However, the effects on cowpea yield between treated and non-treated plots were not significant, and numbers of *S. cavenessi* were high in all plots at harvest time. The Mocap treatment was efficient in reducing the nematode population only during the first 30 days of growth, and no difference in grain yield was recorded for any of the seven genotypes. In 2005 and 2006, we repeated the experiment, but substituted the Mocap treatment with the soil fumigant nematicide 1,3-Dichloropropene (Telone II). The fumigation treatment is nematode specific, but much stronger in its control effect than Mocap. The fumigant treatment reduced the nematode populations, as expected. The effects of nematicide treatment on cowpea variety yields could not be assessed due to mid- to late-season drought in 2005. The nematicide treatments reduced *Scutellonema* by 90% and *Meloidogyne* by 95% at cowpea maturity, based on soil population densities in treated and nontreated plots. In 2005, the varieties of cowpeas were all highly susceptible to *S. cavenessi* and the *Meloidogyne* species was present at the field experiment site.

In Burkina Faso, field experiments were conducted each year from 2003-06 on two cowpea field sites near Bobo-Dioulasso, in the southwestern Sudan Savannah zone. These sites contain the common community of phytoparasitic nematode genera that were identified during the countrywide cowpea field surveys. At Léguéma, a vegetable growing area, field experiments revealed significant population levels of *Meloidogyne*, *Helicotylenchus*, *Scutellonema*, *Tylenchorhynchus*, and *Pratylenchus*. *Pratylenchus* and *Helicotylenchus* predominated in the samples and their populations increased on cowpeas. Most nematode populations reproduced under different cowpea genotypes, except *Tylenchorhynchus* which decreased under cowpeas. Comparison of nematode reproduction by cowpea genotype revealed differences in nematode susceptibility at Léguéma. Previously,variations were found in cowpea lines for host response to *Pratylenchus*. In 2005, several lines (CB27, N'Diambour, 24-125B-1, Goram Local, and IT86D-716) appeared less susceptible than others to *Meloidogyne* at this site.

At the second site, an INERA field station at Farako-Bâ, near Bobo-Dioulasso, *Meloidogyne* and *Scutellonema* were the main nematodes on cowpeas with high population levels produced on cowpea lines. Using the local *Meloidogyne* isolates, controlled laboratory screenings of cowpea lines in seedling growth pouches were used extensively in both 2005 and 2006. Preliminary screening results from the first lab screens indicated that several lines (KN-1, N'Diambour, Mougne, 24-125B-1, KVx396-4-5-2D, CB27, IT89KD-288, Moussa Local, IT86D-716, UCR779, and KVx61-1) were less susceptible to the local root-knot nematode population than some other lines, such as Goram Local and CB46. The re-screenings in 2006 are being used to verify these genotype susceptibility differences, since there are inconsistencies on some cowpea lines between susceptibility or resistance indicated by field versus laboratory screenings. The use of standard species isolates will be helpful in determining the local variation among nematode isolates from different field sites. The cowpea lines and varieties that show consistent nematode resistance will be included in a pre-release field trial in the south and southwest regions of Burkina Faso in 2007.

At Riverside, California, additional local African cowpea lines and varieties were screened in 2004-2006 for resistance to common root-knot nematode *M. javanica*, and confirmed that most are susceptible to this nematode. We have developed four near-isogenic cowpea lines (NIL) differing in the presence of three root-knot nematode resistance genes currently available, plus the susceptible null line. These were made in a common CB46 background. The NIL set was evaluated in 2005 in field plots in southern California, in three adjacent sites infested with virulent *M. incognita*, avirulent *M. incognita*, and *M. javanica*. The 120 plots per nematode type were created with different initial nematode population densities. The plots were hand-harvested in early November to obtain grain yield, and root systems and soil samples assayed for nematode infection and final population densities, respectively. The data provided quantitative descriptions of the protective value to cowpea yield of the resistance genes against different levels of nematode infestation under field conditions. The ranking of genes in order of most to least protective of cowpea growth and yield were gene Rk2, gene Rk, and gene Rkg. These results provide direction for the nematode resistance breeding efforts for both California and West Africa. Studies of these same lines in constant temperature regimes using plants grown in pots in water baths determined that genes Rk and Rk2 are effective at rhizospheric soil temperatures as high as 35 C, and can be considered as heat stable R genes, unlike many common root-knot resistance genes.

WA4-A3

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Improved Methods for Rapid Sucrose Analysis of Cowpea Grain and Assessment of Genetic Environmental Influences on "Sweetness"

Principal Investigators and Institutions:
Phillip Roberts, University of California, U.S.; Ousmane Boukar, IRAD, Cameroon; Ndiaga Cissé, ISRA, Sénégal; Issa Drabo, INERA, Burkina Faso

Collaborators and Institutions:
Esther Sayki-Dawson, University of Ghana-Legon, Ghana; Kaka Saley, INRAN, Niamey, Niger; Mbene Faye. ISRA, Senegal; Jeff Ehlers, University of California-Riverside, U.S.; Mohammed Ishiyaku, Ahmadu Bello University, Samru-Zaria, Nigeria; Joan Fulton, Purdue University, U.S.; Germaine Ibro, INRAN, Niger; Musa Shehu, University of Kano, Nigeria; Anna Temu, SUA, Tanzania

Justification and Objectives

Cowpea grain with a sweet taste is rare, but seems to be preferred by many consumers in West Africa. Price and quality studies in Senegalese markets indicate that for a 1% increase in sucrose content consumers are willing to pay 13 to 59 FCFA/kg more. In Niger, preliminary price and quality data indicate that consumers pay a premium for sweeter grain. Formal blind taste tests conducted at Purdue University showed that the Cameroon sweet line was preferred to its non-sweet 'sister' (closely- related) line. Informal taste tests in California also indicated that the flavor of the Cameroon sweet cowpea was preferred to California blackeyes by most tasters. Thus, there is a tremendous opportunity to enhance cowpea consumption in both Africa and the U.S. by developing better tasting cowpea varieties.

Traditional procedures used to measure sucrose content are expensive, require specialized equipment and training and have slow throughput. These constraints severely limit the number of samples that can be evaluated and the progress by breeders and geneticists to breed sweet cowpeas and to understand the genetic basis of the trait and for socio-economists to collect meaningful data to efficiently evaluate the economic value and consumer preference for sweetness. The development and dissemination of a simple and efficient sucrose content assay methodology would allow a comprehensive survey of existing germplasm resources to identify the best possible parents for use in breeding. Such a methodology would greatly facilitate genetic studies of the sweet trait, including investigations of the possibilities of combining genes to obtain even higher levels of sucrose as well as studies to assess the impact of the growing environment on grain sucrose content. Economists would use the sucrose analyses as a tool to further characterize the link between sucrose content of cowpea grain and market value of the cowpeas. This project provides resources for interaction between economists and cowpea breeders. Dissemination of the improved technique through a formal training effort will help ensure progress in breeding sweet cowpeas and in socioeconomic surveys.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Develop an improved methodology for measurement of sucrose content of cowpea grain.
- Determine the environmental and genetic variability of cowpea grain sucrose content and assess a range of cowpea germplasm for sucrose content.
- Improve measures of sucrose market price premiums for cowpeas and common beans.

Research Approach, Results and Outputs

Methodology for measuring sucrose content of cowpea grain: The methodology selected for the measurement of cowpea grain sucrose content in this study incorporates newer technologies now available in Blood Glucose Monitoring Kits commonly available in drugstores. A workshop was held to teach the methodology and Blood Glucose Kits at the CRSP All-Researchers Meeting in September 2005 in Dakar, Senegal.

Activities at Purdue University involved: a) improving the seed extraction procedure; b) simplifying the overall protocol by reducing the number of steps; c) re-verifying the reliability of the assay compared to standard food science methods for sucrose analysis; d) attempting to lower the blanks; e) adapting the methodology to the new monitors now available, which are equipped with multiple-sample cartridges, store up to 1000 data points, and provide for data transfer to a computer as well as routine calibration; and f) assembling 10 sucrose assay kits for distribution and use by African colleagues at Dakar for use by the UC-R cowpea breeding team. HC Collaborators compared the accuracy and efficiency of the new protocols with the existing standard methods for sucrose analysis.

The assay technique utilizes an improved method of preparing the flour, taking advantage of a low-cost widely available coffee grinder. Many combinations of flour fineness (particle size) were tested together with various periods of extraction with buffer to optimize sucrose extraction. Similarly, many combinations of incubation times with different amounts of invertase enzyme were evaluated. The result of this study is an optimized protocol (described in the Technical Report).

The following individuals received training and/or kits: Mbene Faye, Ousmane Ndoye (ISRA) Joan Fulton, Germaine Ibro, Saket Kushwaha, Anna Temu, Amadou Fall (ISRA), Issa Drabo, Mohammad Ishiyaku, Ndiaga Cisse, Ousmane Boukar and Jeff Ehlers. Assay kits in most cases consisted of: Coffee grinder, Pipette tips (500 or more), 1ml, 200 microliter, 10 microliter micro-pippette tips, 1 1000 ul and 1 10 ul pipetter, Weighing papers, Accu-Check Active Monitor, Eppendorf tubes (500 or more), Metal heating block, and Plastic zip-lock sample bags.

A systematic study was also carried out to determine if any naturally-occurring mono-, di-, or oligosaccharides are present in cowpeas which might interfere with the glucose-monitor-based sucrose assay. It was found that certain common saccharides influence the reading obtained through the assay procedure. These include galactose, maltose and stachyose, the last of which gave a response of 20-50 percent that of sucrose, whereas melezitose and raffinose were not detected by the glucose monitor. Users of this technique should be cautious and remember that other naturally-occurring saccharides have the potential to contribute to the sucrose estimate. Even so, based on use of the technique for thousands of samples and comparisons of the results with the more rigorous HPLC technology, the researchers believe that the potential for interfering factors is minor. Consequently, it is recommended that more rigorous assays for sugar content and "sweetness" be conducted when critical decisions are to be made in breeding programs.

Assessment of environmental and genetic variability of cowpea grain sucrose content: Grain samples from diverse growing environments were grown to obtain samples with a potential range of sucrose contents a shown in Table 1. Growing environments included greenhouse and field sites, including field sites at moderate (UC-Riverside) and high temperature (Coachella) locations. Grain samples were also grown in the field at Bambey, Senegal and at Saria and Pobe, Burkina Faso. Measures were taken to prevent flower thrip and pod bug infestation in these experiments since pod set and 'load' on plants can affect grain quality and sucrose content. The grain samples produced in Africa were also exposed to potential drought conditions, depending on seasonal rainfall conditions. This was considered during interpretation of the results. Researchers are also assaying the percentage of sucrose in the grain of the CRSP Core Cowpea Collection of 60 genotypes using the new technique, utilizing grain samples grown in two common environments (Coachella CA, and Pobe and Saria, Burkina Faso) to determine the range of sweetness existing in the collection.

Samples of 60 CRSP Cowpea Core Collections grown and assembled for sucrose determination:

2005	Pobe, Burkina Faso - Rainfed - Main season dry
2005	Saria, Burkina Faso- Rainfed - Main season normal
2005	Coachella, CA- Irrigated, Fall season

Canned samples from three genotypes grown at two environments were compared for sucrose content. The growing environments affected sucrose content of the cooked peas and broth, but the rank order of genotypic sucrose content did not change. In an assessment of sucrose content of seven genotypes of canned cowpeas, the expected order of genotypic ranking was observed, with 'sweet' genotypes (KVx61-1 and 24-125B) having about double the cooked pea and broth sucrose concentrations as non-sweet genotypes. Sucrose analysis is in progress on these samples utilizing the improved Rapid Sucrose Analysis protocol.

Measures of sucrose market price premiums for cowpeas and common beans: Building on the work by Faye and colleagues in Senegal (Faye, 2005), the project is using the new Rapid Sucrose Analysis method to: 1) Continue sucrose testing of cowpeas in Senegal to build a longer data series on price and quality in six markets; 2) Improve the consistency of cowpea sucrose testing in the on-going cowpea price and quality study in two markets in Niger; 3) Test sucrose levels in a newly launched cowpea price and quality study in Kano, and 4) Determine sucrose levels in the Tanzania price and quality study.

The updated Rapid Sucrose Analysis method was introduced to the economics group at the Africa Bean/Cowpea Economics Group meeting in Bambey, Senegal, Sept. 17-19, 2005. Rapid Sucrose Analysis kits were provided to representatives for the four countries participating in the data collection. In all four countries, the data collection followed the method summarized by Langyintuo et al. (2004) with adaptation to local market conditions and the hedonic analysis following the method outlined by Faye (2005). Sucrose is entered as a variable in the hedonic pricing model. Because sucrose seems to be affected by growing conditions as much as by genetics, the longer data series in Senegal will help capture more of the year to year variation. Niger and Nigeria represent the cowpea heartland. It is important to understand the role of sucrose in consumer preferences there. The Kano study is being implemented using the standard protocol developed for the price and quality studies in West Africa. In theory, sucrose levels could affect consumer bean preferences and market prices in the same way that they seem to affect those of cowpeas. Adding sucrose to the Tanzania bean price and quality study is providing some initial data to test that hypothesis.

Data collection is in progress. The data collected in Senegal and Niger will be added to the data on sucrose content already collected as part of WA1 to form a longer time series. Data collection only began in 2006 in Nigeria. Analysis of the data collected to date in Senegal and Niger reveals that consumers are willing to pay a price premium for cowpeas with higher sucrose content (assumed to be sweeter cowpeas). This premium is as high as 59 FCFA (US$0.12) per kg for a 1% increase in sugar content.

Tables/Graphs/Figures

Table 1. Cowpea genotypes, grain sucrose contents, growing locations, and environmental conditions used to determine environmental influence (genotype x environment interaction) on grain sucrose content.

Genotype	Origin	Sucrose Content
24-125B-1	Cameroon	High (typically 6-7%)
KVx61-1	Burkina Faso	High (typically 6-7%)
CB46	California	Low (typically 2-3%)
Melakh	Senegal	Very Low (typically 1-2%)

Year	Location	Growing Environment
2005	Bambey, Senegal	Rainfed-Main season normal
2005	Pobe, Burkina Faso	Rainfed-Main season, drought
2005	Saria, Burkina Faso	Rainfed-Main season normal
2005	UC-Riverside	Irrigrated-Main season
2005	UC-Riverside	Greenhouse-Fall
2006	UC-Riverside	Greenhouse-Spring
2006	UC-Riverside	Greenhouse-Fall
2006	UC-Riverside	Irrigrated-Main season
2005	Coachella, CA	Droughted-Fall season
2005	Coachella, CA	Irrigated-Fall season
2006	Coachella, CA	Irrigated-Fall season

WA5-A1

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Molecular Genetic Improvement of Cowpeas for Growers and Consumers

Principal Investigators and Institutions:
Barry Pittendrigh, Purdue University, U.S.; Idah Sithole-Niang, University of Zimbabwe, Zimbabwe

Collaborators and Institutions:
Larry Murdock and Matt Jenks, Purdue University, U.S.; T. J. Higgins, CSIRO, Australia

Justification and Objectives

In sub-Saharan Africa, cowpeas suffer heavily from insect damage both in the field as well as when the grain is stored after harvest. Traditional host plant resistance--the breeding and deployment of cultivars carrying genes that condition resistance to the insect pests--has proven to be of limited value. This is because the genome of cowpeas may be devoid of major resistance genes to many insect pests that attack cowpeas. IITA, among other organizations, has carried out extensive screening of cowpea germplasm for resistance to thrips, pod-sucking bugs, pod borer (*Maruca vitrata*), and cowpea weevil. At best, weak sources of resistance were found. Lacking strong insect resistance genes, the breeder's task of introducing insect resistance into the crop is difficult, or even impossible. Attempts to bring insect resistance into cowpeas from another source, wild *Vigna* species, have failed because there are high genetic barriers between these species and cowpeas, *V. unguiculata*.

In recent years, advances in molecular and cellular biology have made it possible to move genes from one species into another species. The transferred gene can impart a needed trait in the recipient plant, and thereby enhance its vigor, health, resistance to biotic or abiotic stresses, productivity, or nutritional value to humans or livestock. Insect resistance genes currently in hand, in particular those encoding *Bt* crystal toxins, alpha-amylase inhibitors and cysteine proteinase inhibitors, can undoubtedly be used to increase cowpea production and storability via genetically-engineering them into the crop. Currently, however, the use of this technology for cowpeas is stymied by the lack of an efficient method for the genetic transformation of cowpeas.

A limitation to the utilization of cowpeas by consumers is the presence of flatulence-causing oligosaccharides, particularly raffinose and stachyose. Frequently, African mothers avoid using cowpeas in weaning foods because of the flatulence and discomfort experienced by their children upon consuming products containing these oligosaccharides (A.C. Uwaegbute, e.a., 2000, Food Chem. 68, 141-146). While there are processing technologies that reduce the levels of oligosaccharides, they add cost to the food product. Advances in molecular biology have now made it possible, in principle, to block the synthetic pathway leading to the formation of oligosaccharides in cowpeas. By utilizing techniques of modern molecular genetics, one can envision the engineering of new cowpea genotypes that have very low levels of flatulence causing factors.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Verify an existing genetic transformation system for cowpeas.
- Lay the basis for introducing a consumer-friendly trait into cowpeas through genetic engineering by reducing flatulence causing oligosaccharides.

Research Approach, Results and Outputs

Development of an Efficient Genetic Transformation System: Bean/Cowpea CRSP collaborator Dr. T. J. Higgins of CSIRO, Canberra, Australia has reported success in transforming cowpeas that now express the *Bacillus thuringiensis* (*Bt*) Cry1Ab toxin (see past CRSP Highlights). In FY 06, Mr. Eugene Parsons, a Zimbabwean graduate student supported by the CRSP and working at Purdue under the direction of Dr. Matt Jenks, has been transforming cowpeas with the sunflower seed albumin to improve the protein content and quality in cowpeas. The putatively transformed lines currently are being grown and will soon be tested to determine if they have been stably transformed. Thus, this component team will soon have two traits available for cowpeas that have been created using the transformation technology.

Reducing flatulence causing oligosaccharides: Work towards this objective continued in Dr. Idah Sithole-Niang's laboratory in Harare where researchers isolated a 450 bp fragment galactinol synthase (golS) cDNA which was cloned into the pGEM-T Easy vector and sequenced. A BLAST-search revealed high nucleotide sequence homology to pea and Arabidopsis golS. Arabidopsis has seven homologues of golS. In Arabidopsis, these genes encode three different groups of stress-related proteins that have been implicated in cold, salt and water stresses. In an attempt to establish the presence and identity of these seven homologues in cowpeas, this research team has initiated a study using the reverse transcription-polymerase chain reaction (RT-PCR) on total RNA isolated from different plants. Total RNA was isolated from a) germinating cowpea seeds, b) plants subjected to cold, c) salinity, d) water stress, and e) control plants. RT-PCR has been performed on all five groups of samples to quantify the degree of expression of golS. Results from these ongoing experiments will serve two purposes. They will identify: 1) which abiotic stress or developmental stage to use when isolating mRNA to construct a cDNA library, and 2) which homologue needs silencing by RNAi. While RNAi is being used here to down-regulate golS, developing the RNAi tool for cowpeas will create a versatile new tool for biotechnology for the cowpea community that will have many applications beyond the current objective of reducing oligosaccharides.

Dr. Idah Sithole-Niang will visit Purdue in June 2007 to complete the RNAi experiments. It is envisaged that enough experiments could be conducted in order to realize a publication out of this work. It is expected that the ongoing research will result in two achievements: (1) the creation of a methodology for using RNAi in cowpeas – a first. This methodology can then be used for other purposes as well; and (2) Lay a foundation for the development of new cowpea genotypes that express lower levels of oligosaccharides in the seed.

WA5-A2

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Toward a Comprehensive Resistance Management Plan for Bt Transformed Cowpeas to Control Maruca vitrata in West Africa

Principal Investigators and Institutions:
Larry Murdock, Purdue University, U.S.; and Mohammad Ishiyaku, Ahmadu Bello University, Nigeria

Collaborators and Institutions:
Barry R. Pittendrigh, Purdue University, U.S.; Ibrahim Baoua, INRAN, Niger; Jean-Baptiste Tignegre and Madame Debire, INERA, Burkina Faso; Manu Tamo, IITA, Benin; Bill Moar, Auburn University, U.S.

Justification and Objectives

The development of a resistance management plan is essential prior to the dissemination of Bt-cowpeas in West Africa. Such a plan would ensure that the Bt-technology introduced into cowpeas is sustainable. To develop a viable insect resistance management plan (IRM) for Bt cowpeas, the scientific community must have a deeper understanding of the distribution, abundance and migration of *Maruca vitrata* populations in the Nigerian grain-shed, the region where Bt cowpeas is most likely to be introduced.

An additional and critical component of this research involves characterizing the sensitivity of *Maruca* populations to Bt across the Nigerian grain-shed. Continual monitoring of Bt-sensitivity in *Maruca* sub-populations across the region will be an integral part of assessing the effectiveness of the IRM plan, plus detecting any Bt resistance developing in *Maruca* populations and discovering supplemental Bt genes. Supplemental genes would be needed to pyramid a second Bt gene into cowpeas to assure durability of the technology.

A potential problem facing Bt cowpeas is that cowpeas evolved and were domesticated as a crop in central Africa. Wild relatives of cultivated cowpeas persist in some areas adjacent to cowpea fields. Thus, research is needed to better understand and prevent pollen (and gene) flow from cultivated to wild plants. Two potential ways to do this involve (a) developing an obligate cleistogamous cowpea and (b) developing cowpea lines that are asynchronous in flower opening with wild cowpeas. Other mechanisms that reduce the incidence of outcrossing that might be useful in the prevention of gene flow include the manipulation of the duration and timing of anthesis in such a way as to ensure inter-varietal isolation. Research work undertaken by this component is intended to lead to the eventual production of - or recognition of existing -obligate cowpea lines with the possible addition of a late and short flower-opening traits. This trait could be introgressed into Bt cowpea lines in the future as a mechanism to limit gene flow from cultivated to wild cowpeas.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Determine distribution, abundance and migrations of *Maruca vitrata* adults.
- Characterize *Maruca* populations with regards to susceptibility to specific Bt proteins (cry1Ab, cry2Ab and cry2Aa). Samples from the same populations tested will be subjected to micro-satellite analysis.
- Define micro-satellite markers for *Maruca* and use these markers to characterize *Maruca* populations over a two-year period over multiple collection sites located in the Nigerian grain-shed.
- Develop obligate cleistogamous cowpea genotypes.

Research Approach, Results and Outputs

Determine distribution, abundance and migrations of *M. Vitrata* adults: *Burkina Faso* – In FY 06, a total of four light traps to monitor *Maruca* adult numbers were operated throughout Burkina Faso, including locations at (1) Kamboinsé, (2) Fada, (3) of Farako-Ba, and (4) Pobé. As expected (in keeping with last years results) the light trap located at Pobé, which was the most northerly light trap, only showed sporadic catches of *Maruca* adults. A greater number of *Maruca* adults was observed in the light trap of Farako-Ba in the southwestern part of the country, followed by Fada and Kamboinsé. This year, the first generation of *Maruca* adults infesting cultivated cowpeas at the beginning of the cropping season (July to September) was lower than in the previous year. This was most likely due to the fact that the rainy season was late in 2006. However, there was a significant increase in the number of adults caught in October, with a peak of 80 adults captured on October 12, 2006 at Farako-Ba. Greater levels of damaged pods were observed at Kamboinsé as compared to Farakoba. *Maruca* adults were observed in the light traps between June and November, 2006, at Farako-Ba.

A wild perennial plant was observed hosting *Macura* larvae before and after its occurrence on cultivated cowpeas. This later finding suggests that natural refugia exists, at least in some parts of Burkina Faso, for *Maruca*.

Adults and larvae of *Maruca* have been collected from cultivated cowpeas and the wild host and have been sent to Purdue University for molecular characterization.

Nigeria – A single light trap was established in Zaria. *Maruca* adults started appearing in the light trap on September 12, 2006 and to date only 88 adults have been caught in the trap. Fewer than nine adults were caught before the end of September. Weekly catches rose to over 10 adults in the beginning of October reaching its peak in the last week of that month, with 21 adults. The frequency of catches again fell to less than eight per week in November, with no adult *Maruca* being caught after the second week of November. Although the trap is still being monitored, no *Maruca were* caught after November 17, 2006. One explanation for the low levels of *Maruca* catches in this area, as compared to our other trapping sites, is likely due to the high pesticide usage in the Zaria area, including on cowpea cropping systems. As far as the wild hosts are concerned, *Maruca* larvae were observed only on a weed species, *Seisbania*. Other known hosts of the insect were either not available to the insect pests at the time the cowpeas were flowering.

About 40 vials each containing *Maruca* larvae have been collected so far, beginning September 25, 2006. These collections were made from both scouting from around the light trap as well as around Kaduna and Kano. The adult and larval *Maruca* have been shipped to Purdue University for molecular analysis.

Niger – *Maruca* adults were caught in the light traps at Maridi between the end of August (2006) and the end of October (2006). The adult *Maruca* population occurred later in the year and in lower numbers as compared to 2005's light trap catches. This delay and drop in numbers is most likely due to delays in the rainy season that occurred in 2006. Larval sampling and scouting revealed the timing and host plants that *Maruca* larvae were developing on. Larval samples were also collected at the Niamey location, but due to low population levels, no adults were observed in the light traps. Adult and larval samples have been shipped to Purdue University for molecular analysis.

Standard feeding bioassays for Maruca and routine toxicological assay: Laboratory *Maruca* populations are in the process of being established in Burkina Faso and Niger respectively by Drs. Dabire and Baoua during 2006. In the early part of 2007, Dr. Bill Moar will travel to Burkina Faso to train both scientists in Bt bioassays with these insects. Participating scientists will carry out standard toxicological assays on *Maruca* larvae in their own laboratories in Kamboinse, Burkina Faso, and Tarna Station, Maradi, Niger.

Define micro-satellite markers for Maruca: Micro-satellite-enriched libraries have been created for *Maruca* and have been screened using potential primers (not labeled with dye) for putative micro-satellites. Seven promising candidates have been selected for further analysis. Currently, the team has seven sets of primers now labeled with IR dye, which will be used to look for their polymorphic value in *Maruca* populations. Analysis of the FY 05 and FY 06 samples will be completed in the spring of FY 07. The team has also established a methodology to make mitotic chromosomal spreads from the ovaries of adult moths for further studies with micro-satellites. *In situ* hybridization of micro-satellites to these chromosomes will help establish whether microsatellite are associated with independent chromosomes and therefore determine if each of these micro-satellites will be (or potentially may not be) unlinked.

Develop obligate cleistogamous cowpeas: In FY 06 the putative cleistogamous cowpea lines were carried forward into the next generation. Four varieties were evaluated for the second time in pots for number of unopened flowers (cleistogamy). These varieties have been previously evaluated in the field. Flower buds due to open in 24 hour time were tagged. The tagged flowers were then monitored over a 72 hour period to determine time from flower opening/corolla visible until the young pod started developing.

Of the four varieties evaluated, IT90K-284-2 showed the highest frequency of unopened flowers. Progeny testing of the putative cleistogams showed that the majority of plants produce a mixture of both cleistogamous and non cleistogamous flowers. However, such plants produce more cleistogamous flowers. Three plants breeding true for cleistogamy are being tested at the F_2 generation. Seeds from these plants will be multiplied for further testing under different moisture, humidity and temperature regimes.

Generating New Knowledge and Technologies in East and Southern Africa

The East and Southern Africa regional project of the Bean/Cowpea CRSP is comprised of several components involving six U.S. lead universities who are collaborating in research and training activities with national agricultural research programs and universities in Malawi, Tanzania, Mozambique and South Africa. The regional project focuses on research and training to promote enhanced consumption, utilization and production of both beans and cowpeas. Specifically, the areas covered range from genetic improvement research to develop improved varieties of beans resistant to biotic and abiotic stresses, increasing seed system efficiency, value addition through processing, promoting health and nutrition of vulnerable populations and the economics related to distribution and marketing of beans/cowpeas and their products. In this Section, we highlight the progress made on some of the research activities conducted by the Bean/Cowpea CRSP East and Southern Africa regional project in FY 06.

U.S. AND HC INSTITUTIONS PARTICIPATING IN THE EAST/SOUTHERN AFRICA REGIONAL PROJECT

Michigan State University (MSU)

Oregon State University (OSU)

Purdue University

Texas A & M University (TX A&M)

Washington State University (WSU)

University of Minnesota (UMN)

USDA-ARS/Prosser

Bunda College of Agriculture, Malawi

University of Eduardo Mondlane (UEM), Mozambique

Instituto de Investigacao Agraria de Mozambique (IIAM), Mozambique

Sokoine University of Agriculture (SUA), Tanzania

University of Free State (UFS), South Africa

University of Pretoria (UP), South Africa

ESA1-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Market Assessment of Bean and Cowpea Grain and Processed Value-Added Products, and Determination of Both Constraints to and Potential for Growth of Markets in the ESA Region

Principal Investigators and Institutions:
Jess Lowenberg-DeBoer and Joan Fulton, Purdue University, U.S.; Patrick Kambewa, Bunda, Malawi, Anna Temu, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions:
Manuel Duarte-Filipe, INIA, Mozambique; André Jooste, University of the Free State, South Africa

Justification and Objectives

Most of the bean and cowpea research by the Bean/Cowpea Collaborative Research Support Program (CRSP), National Agricultural Research Systems (NARS), and the International Agricultural Research Centers (IARCs) in Eastern and Southern Africa has focused on production issues. Few studies have focused on bean and cowpea marketing in the region. A greater understanding of bean and cowpea markets is a prerequisite for CRSP impact in the region. Consumer preference and market information could help target CRSP research to traits and practices that lead to bean and cowpea products having characteristics that facilitate marketing. The benefit of the new bean and cowpea products should be felt directly by producers as they should be able to sell more of their product at a higher price.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Provide an initial description of the market structure for beans and cowpea grain and processed products in Malawi, Mozambique and Tanzania.
- Improve understanding of consumer bean and cowpea preferences in Eastern and Southern Africa.

Research Approach, Results and Output

Description of market structure for beans and cowpea grain and processed products: In FY 06, Manuel Filipe began data collection for his dissertation research. The objective of his dissertation research is to estimate the potential supply of beans for both the Mozambican domestic market and export markets in South Africa and Malawi under various technology scenarios. He is collecting farm level data in Niassa, Tete, Zambezia, Manica and Gaza provinces, and doing key informant interviews with merchants, truckers, regulatory agency staff and others involved in the bean trade in those same locations. The data will be used to develop representative farm mathematical programming models for the main farm types. Farm level results will be aggregated to estimate the Mozambican national supply of beans given transport and handling costs. Validation data will be drawn from information being collected by Filipe for the Purdue-International Center for Maize and Wheat Research (CIMMYT) smallholder price risk management project funded with a USAID Linkage Grant.

Fulgence Mishili also started work on his dissertation proposal. The general objective will be to determine how dry grain legume trade in Eastern and Southern Africa is affected by infrastructure (e.g., roads, bridges), policy and taxation. Because dry grain legumes are substitutes in consumption and several pulses are produced in the region, pigeon pea, chickpea, soybean, cowpea and common bean will be included. Key informant interviews are planned in Tanzania, Kenya, Uganda, Zambia, Namibia and Botswana. The primary data will be complemented by secondary data from South Africa, Democratic Republic of Congo, Rwanda and Burundi. A region trade model for beans similar to Augustine Langyintuo's model of cowpea trade in West Africa will be developed.

Understanding consumer preferences: In FY 06, bean price and quality data collection continued in Tanzania, Malawi and Mozambique. In Tanzania, bean samples were purchased monthly in two markets in the Morogoro region, Sabasaba and Central markets. Two markets in the Dar Es Salaam region were added to the study. Dar Es Salaam is on the coast, has a major port and is the economic capital of Tanzania. Morogoro is a smaller city situated approximately 193 kilometers inland west of Dar Es Salaam close to a major bean production area.

The descriptive statistics reported in Table 1 covers the period between March and July 2006. During this period, the average prices of beans in Morogoro and Dar Es Salaam markets were 710 and 525 Tanzania shillings, respectively. This is typical as bean prices are generally lower in Dar Es Salaam markets as compared to Morogoro markets. These results are counter intuitive because prices of agricultural commodities are often lower near production areas. Dar Es Salaam prices are probably lower since this market is supplied by production areas in all parts of the country, even imports. In contrast, the Morogoro market is more isolated. The average bean damage per 100 bean seeds is 1 and 0 holes per 100 bean seeds in Morogoro and Dar Es Salaam markets respectively (Table 1). The bean damage levels in Dar Es Salaam marketsare lower than in the Morogoro market, probably because of sorting in Dar Es Salaam due to stiff competition. The average weight of 100 bean seeds in Morogoro was 38.84 grams per 100 grains as compared to 37.55 grams per 100 grains in Dar Es Salaam (Table1). Bean size is slightly larger in Morogoro markets. This could partly explain why prices of beans are higher in Morogoro than in Dar Es Salaam. Preliminary analysis in Tanzania, Malawi and Mozambique indicates that consumers generally will pay higher prices for larger sized bean grain.

Descriptive statistics for the bean price and quality study in Mozambique are reported in Table 2. The average price of beans for the three markets of Fajardo, Central dé Lichinga and Belenenses was 30476, 12022 and 16987 Mozambique Meticals per kilogram respectively. The key reason for the higher price in the Maputo market of Fajardo is location. Maputo is the political and economic capital of Mozambique with substantial population and purchasing power, but it is located far from major bean production areas.

The relative higher prices of beans in Fajardo markets can partly be explained by the bean size in this market compared to the other two markets of Central dé Lichinga and Belenenses. The weight of 100 seeds was 43.49, 40.87 and 37.23 grams per 100 bean seeds in the markets of Fajardo, Central dé Lichinga and Belenenses, respectively (Table 2). The damage levels where relatively high in the Belenenses market in Nampula in northern Mozambique. The average number of bruchid holes per 100 bean seeds is 1 hole per 100 seeds in Fajardo and Central dé Lichinga markets and 4 holes per 100 seeds in the Belenenses market. The lower damage level observed in the Fajardo market is associated with sorting and grading of beans done by traders.

A preliminary least squares regression analysis was done for the three markets of Farardo, Central dé Lichinga and Belenenses in Mozambique (Table 3). The main value of a preliminary OLS analysis is to show that the data are complete enough for statistical analysis and show plausible patterns. The R2 indicates that explanatory power of the model is adequate in all three markets, though much lower in Beleneses, than the other two markets. The results suggest that bean consumers in all three markets value larger bean grain size. The variable for grain size is positive in all three markets as expected and statistically significant in the Fajardo market. The variable for bean grain damage is estimated by the number of bruchid holes in 100 bean grains. The results for the Fajardo and Belenenses markets for the number of holes variable are negative as expected, but not statistically significant. The result for the Central dé Lichinga market for the number of holes is positive and statistically significant. This unusual result may be related to the use of OLS and violation of OLS statistical assumptions. Most previous cowpea and bean hedonic pricing analysis in Africa has used seemingly unrelated least squares (SUR) to correct for heteroskedasticty linked to differences between markets. In depth analysis planned for 2007 will use SUR.

Tables/Figures

Table 1: Production and Sales of Cowpeas and Beans in Zambia, 2004/2005 (mt).

Region/Data	Market	Prices (TShskg-1)	Holes/100 grains	100 grain Weight (g)
Morogoro	Central	727 (350, 1200)	1(0,8)	38.12(21.14, 53.84)
	Sabasaba	693(350, 1000)	1(0,15)	39.55(23.12, 52.33)
	All Markets	710(350, 1100)	1(0,12)	38.84(22.13, 53.09)
Dar Es Salaam	DSM1	546(200, 1000)	0(0,3)	37.90(21.51, 49.56)
	DSM2	504(140,920)	0(0,3)	37.19(27.73, 47.70)
	All Markets	525(170,960)	0(0,3)	37.55(24.62, 48.63)

1. Source: Tanzania data collection for the period between March and July 2006.
2. Tshs = Tanzania Shillings ($ US 1 = Tshs. 1331 - November 16, 2006).
3. Sample size (n): Central = 33, Sabasaba = 34, DSM1 = 30, DSM2 = 32.

Table 2: Average Bean Seed Characteristics (min., max. value in parentheses) in Mozambique Markets.

Region/Data	Market	Prices (MZMkg-1)	Holes/100 grains	100 grain Weight (g)
Maputo	Fajardo	30476 (20000, 45000)	1 (0, 29)	43.49 (30.00, 60.00)
Lichinga	Central de Lichinga	12022 (3333, 28000)	1 (0, 7)	40.87 (33.00, 48.00)
Nampula	Belenenses	16987 (4706, 41176)	4 (0, 19)	37.23 (20.00, 53.20)

1. Source: Mozambique data collection for the period between May 2005 and May 2006 except for Lichinga which is May 2005 to April 2006.
2. MZM = Mozambique Metical ($ US 1 = 25,200.0 MZM - 11/17/2006).
3. Sample size (n): Fajardo = 52, Central de Lichinga = 52, Belenenses = 105.

ESA2-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Value-Added, Processing and Qualities of Cowpea- and Bean-Based Foods

Principal Investigators and Institutions:
Ralph Waniska, Texas A&M University, U.S.; Louis Pelembe, Eduardo Mondlane University, Mozambique; Amanda Minnaar, University of Pretoria, South Africa

Collaborators and Institutions:
Leda Hugo and Ana Edwards, Eduardo Mondlane University, Mozambique; Ricardo Macia, Brasilino das Vitrolas Salvador, Alice V. Mkanda, University of Pretoria, South Africa; Agnes Mwangwela, Bunda College, Malawi; Manuel Amane, IIAM, Mozambique; Creighton J. C. Miller, Texas A&M University, U.S.; Jeff Ehlers, University California-Riverside, U.S

Justification and Objectives

The preferences and desires of consumers for bean or cowpea products should be considered in the development of improved germplasm. Information required includes food quality attributes preferred by consumers as well as simple methods to rapidly determine these attributes. Optimized technologies for uncooked cowpea flour, the low-temperature processing and high-temperature processing of some legumes have been investigated. For example, micronization, an infra-red, high-temperature, semi-moist processing method, reduces the cooking time of some legumes (i.e., lentils and pinto beans) while maintaining their protein digestibility and nutritional quality. Selected technologies will be adapted and/or modified for regional preferences and optimized to yield functional ingredients and foods.

Aspects of raw bean grain that need to be better understood for improving quality include genetic differences, environmental effects (location, cultural management, etc.) and effects of grain storage (hard-to-cook problem). Processing issues that need to be considered include cost-effectiveness, pre-process conditions (e.g., soaking), treatment conditions (thermal, grinding, decortication, etc.), post-process conditions (holding hot, drying (if necessary), and packaging for a range of whole and milled products. Consumer issues requiring investigation include demand for milled and pre-processed food products, sensory acceptability of such products (appearance, odor, texture, taste), nutritional properties, and value of products versus price (cost of manufacturing, packaging, distribution, marketing, etc.).

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- To utilize consumer preferences for cowpeas- and bean-based foods to develop rapid, food quality, and screening methods for crop improvement.
- To develop and utilize low-cost value processing technologies in foods containing cowpeas or beans.

Research Approach, Results and Outputs

Development of rapid, food-quality, and screening methods for crop improvement: Physico-chemical, descriptive sensory properties and consumer acceptability of six different varieties of dry common beans grown in two locations in South Africa were investigated. Six dry bean varieties (Jenny, Kranskop, PAN 148, AC Calmont, PAN 150 and Mkuzi) grown in two locations (Mpumalanga and Orange Free State) were measured for seed size, hydration capacity, swelling capacity and cooking time. A Descriptive Sensory Evaluation was also done to identify attributes that were liked or disliked by consumers. There was significant ($p<0.05$) location x variety interaction effects for both physicochemical and sensory attributes. Of the six bean varieties, Jenny OFS, Mkuzi MP and PAN 148 MP, had long cooking times (>60 min).

A Descriptive Sensory evaluation showed that PAN 150 (both locations) had many split beans, thick broths as well as bitter, soapy and metallic sensations in the mouth whereas Mkuzi (MP) was characterized as having a hard texture, thin broths and raw bean flavors. The latter may be responsible for the low consumer acceptability. The most acceptable varieties during a consumer sensory evaluation (i.e., Jenny MP Kranskop MP + OFS and PAN 148-MP) were characterized with sweet, cooked bean flavors, soft and mushy textures probably due to good hydration capacities that facilitated softening during cooking.

Effect of hard-to-cook phenomenon on cooking and physicochemical characteristics of cowpeas: The effect of storing cowpeas (Mogwe-o-Kgotsheng from Botswana) at 42ºC and 67% RH for 21 days on cooking and physicochemical characteristics was evaluated. Storage of cowpeas under these conditions resulted in hard-to-cook (HTC) seeds with the cooking time increasing from 89 to more than 270 minutes. HTC cowpeas had decreased pH, pectin solubility and phytic acid content and had increased phytase activity, moisture content and a harder cooked texture (Table 1). Due to the reduced pectin solubility, HTC cowpeas had a harder texture, decreased degree of splitting and consequently, reduced water absorbed during cooking as compared with fresh cowpeas. The decrease in pectin solubility in HTC cowpeas, which coincided with decreased phytic acid content and increased phytase activity, was significantly correlated with the reduced water absorption during three hours of cooking and six hours of soaking. The amount of water absorbed by HTC cowpeas after 18 hours of soaking was significantly (P=0.05) higher than that absorbed by control cowpeas. These results can be taken as supporting evidence for the most widely accepted theory to explain HTC defect in legume seeds. The theory consists of pectin insolubilization via the binding to divalent cations (i.e., Ca2+ and Mg2+) resulting from phytate hydrolysis by phytase at relatively high temperatures and relative humidities.

Effect of tempering/pre-conditioning in a solution of monovalent cations and micronization on cooking characteristics of hard-to-cook cowpeas: The effects of tempering cowpeas (to 41% moisture) in solutions with and without monovalent (Na+) cations followed by micronization (to final surface temperature of 153ºC) on physicochemical characteristics of normal (fresh) and hard-to-cook (HTC) cowpeas (Mogwe-o-Kgotsheng) were investigated. For the fresh cowpeas, tempering cowpeas regardless of the type of solution used decreased the cooking time significantly (by 50%) (Table 1). Furthermore, micronization after tempering in either water or monovalent (Na+) cations decreased the cooking time significantly by 58% and 66%, respectively. For HTC cowpeas, tempering the cowpeas in water had no significant effect on the cooking time, whereas tempering the cowpeas in a solution containing monovalent (Na+) cations significantly reduced the cooking time by about 44%. Micronization after tempering in water had a similar effect. However, tempering cowpeas in a solution containing monovalent (Na+) cations followed by micronization reduced the cooking time of HTC cowpeas by at least 78%.

Tempering of cowpeas in a solution containing monovalent (Na+) cations improved pectin solubilization for both normal (fresh) and HTC cowpeas significantly (Table 2). The solubilization of pectins as induced by tempering cowpeas in a solution containing monovalent cations (Na+), not only depends on the solubilization effect of water used during the tempering process (Clemente et al., 1998), but also on a conversion of insoluble pectinates to soluble pectins in the middle lamella (Vidal-Valverde et al., 1992) due to exchange of pectin divalent cations (i.e. Ca2+ and Mg2+) by monovalent cations (i.e., Na+) present in the tempering solution (Valle et al., 1992; Léon et al., 1992).

The process of micronization also improves the pectin solubility for both normal (fresh) and HTC cowpeas significantly. Micronization could have induced breakage of pectin molecules into lower and more soluble molecular fractions in the middle lamella, via ß-elimination reaction (Liu, Phillips & McWatters, 1993). These findings are supported by the significant (P=0.05) negative correlation between the cooking time and pectin solubility (r= -0.91) in both normal (fresh) and HTC cowpeas. Micronization was also found to reduce the cooking time of cowpeas (Mwangwela et al., 2006; Phadi, 2005) and lentils (Scanlon et al., 1998; Arntfield et al., 1997). Pectin is extremely sensitive to elevated temperatures in a near-neutral solution (Liu et al., 1993; Sajjaanantakul, Buren & Downing, 2003). At these conditions, there is breakage of glycosidic links between methylated galacturonate residues by an unusual ß-elimination reaction where a trans double bond is inserted between C-4 and C-5 rather than the usual hydrolysis to form lower molecular weight fractions (Liu et al., 1993). It is therefore possible that the reduction in the cooking time of tempered and micronized fresh and HTC cowpeas is in part due to improved pectin solubilization via its breakage into lower and more soluble molecular fractions (Liu et al., 1993) as well as the exchange of divalent (Ca2+, Mg2+) by monovalent (Na+) cations thereby increasing pectin solubility (Valle et al., 1992; Léon et al., 1992).

There was a significant (P=0.05) positive correlation between the cooking time and the texture of cooked cowpeas (r= +0.88). The reduction in the hardness of cooked cowpeas tempered in water and micronized could be associated to the greater increase in pectin solubility when cowpeas were tempered in a solution with monovalent (Na+) cations, which was enhanced by micronization (Table 3). Significant negative correlation was found between pectin solubility and cooked texture of both fresh and HTC cowpeas (r= -0.97). In this study, both cooked texture and cooking time are associated with pectin solubility of cowpeas.

The variables, state of cowpeas (fresh or HTC) and micronization, showed significant interaction in terms of the degree of splitting of cowpeas. Tempering cowpeas in either water or in a solution containing monovalent (Na+) cations in combination with micronization increased the degree of splitting of fresh and HTC cowpeas when compared with control samples (Table 3).

The development of cracks in the testa and cotyledon of cowpeas during micronization (Mwangwela et al., 2006) probably increased the degree of splitting of both fresh and HTC cowpeas. The rapid temperature increase probably causes liquid water to turn into steam (gas). If the seed is able to hold the expanding gas, then pressure builds up and the cotyledon collapses under the pressure or explodes to release the pressure, resulting in modified cotyledon cells (Mwangwela et al., 2006). A significant positive correlation (r= +0.88) was found between the degree of splitting and pectin solubility in both fresh and HTC cowpeas. As pectins are known to contribute to the maintenance of structural integrity of the cell wall (Uzogara et al., 1990), it is possible that the higher degree of pectin solubility as influenced by micronization could have contributed to the higher degree of splitting of cowpeas during cooking.

The hydrothermal treatment of cowpeas, using the popcorn popper was conducted by Luisa Nyambir, Ms. Adélia Chiziane and Ms. Amélia Furvela at the Food Technology & Biotechnology Section of the Department of Chemical Engineering, Eduardo Mondlane University (UEM). This is a continuation of the previous year's research. Next year 2006-2007, when funds are made available to repair the gas microniser built in Texas, we will concentrate on the effects of hydrothermal treatment on physico-chemical, nutritional and functional properties of cowpeas as well as on sensory studies of the resulting food products made by cowpeas treated on the gas micronizer.

Cowpeas of INIA-36, CP-2 and IT-16 were supplied by IIAM (Instituto de Investigaçao Agraria de Mozambique) and represent the most common varieties in Mozambique. Soaking time and heating time in the popcorn popper were varied to attain minimum treatment times that decreased cooking times of thermally processed cowpeas. The chemical and physio-chemical properties of the processed cowpeas were recorded. Both soaking time and heating time significantly affected most parameters; however, the variety of cowpeas had little impact (not significant) on the measured parameters. Increased thermal treatment caused decreased nitrogen solubility and water solubility index and increased starch digestibility. With hydrothermal treatment cowpea starch gelatinizes and proteins denature.

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Tables/Figures

Table 1. Effect of tempering alone and in combination with micronization on the cooking time of Normal (fresh) and HTC cowpeas. [Note: Means followed by the same letter are not significantly different at level *P>0.05*].

Treatments	Cooking time (min)	
	Normal (Fresh)	**Hard-To-Cook**
Control	89 ± 3.2 e	270* g
Tempered in H_2O alone	44 ± 4.8 c	270* g
Tempered in monovalent (Na^+) cations alone	43 ± 5.3 bc	150 ± 9.6 f
Micronized after tempering in H_2O	37 ± 3.4 ab	148 ± 9.2f
Micronized after tempering in monovalent (Na^+) cations	30 ± 5.1 a	59 ± 4.0 d

Table 2. Effect of tempering alone and in combination with micronization on the pectin solubility of Normal (fresh) and HTC cowpeas. [Note: Means followed by the same letter are not significantly different at level *P>0.05*].

Treatments	Pectin solubility ($mg.g^{-1}$)	
	Normal (Fresh)	**Hard-To-Cook**
Control	4.9 ± 0.36 b	3.2 ± 0.50 a
Tempered in H_2O alone	7.4 ± 0.50 c	5.3 ± 0.43 b
Tempered in monovalent (Na^+) cations	8.1 ± 0.71 d	6.9 ± 0.50 c
Micronized after tempering in H_2O	10.8 ± 0.50 f	9.9 ± 0.50 e
Micronized after tempering in monovalent (Na^+) cations	14.2 ± 0.89 h	11.8 ± 0.90 g

Table 3. The effect of micronization after tempering cowpeas in solutions containing either water or monovalent (Na+) cations on the degree of splitting of normal (fresh) and HTC cowpeas. [Note: Means followed by the same letter are not significantly different at level *P>0.05*].

Treatments	Degree of splitting (%)	
	Normal (Fresh)	**HTC**
Control	41.9 ± 2.8 b	5.5 ± 2.7 a
Micronized after tempering in H_2O	71.2 ± 2.6 e	56.1 ± 1.3 c
Micronized after tempering in monovalent (Na^+) cations	73.3 ± 2.8 e	61.4 ± 3.4 d

ESA2-A2

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Analysis of Cooking and Consumer Preference Traits to Achieve Wider Impact from Bean/Cowpea CRSP Developed Bean Cultivars

Principal Investigators and Institutions:
Ralph Waniska, Texas A&M University; and James R. Myers, Oregon State University, U.S.

Collaborators and Institutions:
Amanda Minnaar, University of Pretoria, South Africa; Agnes Mwangwela, James Bokosi and Yamikani Chewere, Bunda College, Malawi; Jeff Ehlers, University of California-Riverside, U.S.; Phil Miklas, ARS Prosser, Washington, U.S.; J. Creighton Miller, Texas A&M University, U.S.; Susan Nchimbi-Msolla and Theobald Mosha, Sokoine University, Tanzania; Louis Pelembe, Eduardo Mondland University, Mozambique; Catherine Madata, Tari, Uyole, Tanzania; Carol Miles, Washington State University, U.S.; Roland Chirwa, CIAT Chitedze, Malawi; Sossi Kweka, Selian Research Center, Tanzania

Justification and Objectives

Plant breeders have traditionally focused on enhancing productivity and pest resistance in varieties. Although this was the initial approach with the Bean/Cowpea CRSP in ESA, it was soon recognized that improved varieties must have appropriate cooking and palatability traits, and must be acceptable in the marketplace. However, it has been difficult to define specific cooking traits. Food scientists can help breeders develop rapid and efficient procedures for evaluating varieties, and achieving greater impact when a variety is released.

Characteristics that are usually considered as important in determining consumer acceptance include digestibility, cooking time, color, flavor and aroma, integrity of the product, and broth characteristics. Cooking time has traditionally been determined with a Mattson cooker, a process that without automation is very time consuming. For other characteristics, there have been no standard methods developed. Consumer preferences may be regionally or locally determined, but there are certain varieties that are popular across cultures. It is possible that certain aspects of consumer preference can be quantified and developed into a means of objectively evaluating bean varieties.

In Eastern and Southern Africa (ESA), limited consumer preference studies have been conducted at various times in specific regions. In most of these, the focus has been on dry seed characteristics with less attention paid to cooking time and palatability traits. Earlier studies were performed in Malawi by Ferguson and Kambewa; more recent studies have been conducted by Temu, Lowenberg-DeBoer, Fulton, Kambewa, Duarte-Filipe, and Joost, in Tanzania, Malawi, South Africa and Mozambique (FY 04 ESA Progress Report). The emphasis of these studies was on smallholder farmers and their preferences, both for food security and for beans as a cash crop. More recent studies have focused mainly on markets with the emphasis on urban consumers. These studies have contributed to improved understanding in general terms of consumers' preference traits in the beans that they eat. Quality traits that drive consumer demand however, are not well understood. In addition, consumer preferences may vary; local/regional preferences may not be the same as for export markets.

In this study, the research team seeks to integrate teh food utilization and plant breeding components of ESA to: a) understand and quantify consumer preferences, and b) improve the efficiency of the breeding program to release bean varieties that will be successful in the marketplace. Steps are also taken to integrate cowpea research in ESA with that of beans. The concepts and technologies developed in this research can be adapted to cowpeas, as well as transferred to other regions.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Determine cooking quality attributes of traditional and improved varieties of beans and cowpeas using a rapid screening method.

Abstracted from FY 06 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Research Approach, Results and Output

A workshop was held in Maputo in March 2006 that brought together important participants who will be responsible for conducting the rapid cooking assay in several country programs in ESA. The program included many underlying principles of the several cooking attributes that are measured or rated and practical training in how to accomplish each step of the procedure. An inter-laboratory trial was started where each participating laboratory was provided with 51 bean samples (17 lines from Bunda, 17 lines from CIAT and 17 lines from the DPO, South Africa) and 18 cowpea samples (12 lines from Bunda, 2 varieties from Agricol, SA and 4 lines from IIAM). Data from these evaluations have not been received to date.

Two sets of cowpea samples were provided to TAMU for cooking quality evaluations in 2005 and 2006. The evaluations were conducted by Hway Seen Yeung. The first set of cooking evaluations was included in a poster that was presented at the Cooperative Program for Central American Crops and Animals (PCCMCA) in Nicaragua in April. The cooking quality of the second set of cowpea samples is included in this report (Table 1). By replicating the rapid cooking evaluation method four times the team was able to estimate variability of each cooking parameter and potential problems.

Cowpeas were soaked in distilled water for 16 hours to determine the weight gain during soaking. Higher soak absorption relates directly to shorter cooking time in many beans. This was not observed in either set of cowpeas because the cowpeas were cooked for the same time (27 minutes). Cooked doneness and tactile texture were positively correlated with cook absorption but negatively correlated with soak absorption and Brix. Aroma of cooked peas or broth was also not significantly correlated to cooked doneness or tactile texture. Splitting of testa and cotyledons during cooking was significantly correlated to higher cooked doneness and tactile texture. Higher soak absorption was related to higher Brix values.

Ten of the cowpea lines were grown in the same two locations. Some attributes of cooked cowpeas were affected by the growing location. Aroma of cooked peas and broth and broth opacity were mostly not impacted by growing location. A higher Brix was observed at UC-Riverside, while soak absorption was higher at Fall Coachella Valley. Seed properties did not affect cooked cowpea attributes except for longer seeds had more splitting of the cotyledon.

Cooking attributes of cowpeas that were undercooked (doneness = 1) and overcooked (doneness = 5) were compared to those with an additional five minutes cooking time for undercooked and with five minutes less cooking time for overcooked cowpeas (Table 2). Cooked doneness and tactile texture generally moved to values between 2 to 4 after manipulating cooking time, as expected. Cooking overcooked cowpeas five minutes less did not have much impact on cooking attributes except for increased broth aroma. Cooking undercooked cowpeas five minutes more increased splitting of testa and cotyledons and in some varieties increased broth opacity, Brix and aroma of cooked cowpeas. Thus, undercooked cowpeas should be cooked longer to better determine their cooking attributes; however, five minutes shorter cooking of overcooked cowpeas did not change cooking attributes very much. Hence, determination of the cooking time for the set of samples is very important and should be biased towards the overcooked side [and not undercooked].

Tables/Figures

Table 1. Effect of variety on cooking attributes of cowpeas. [Note: italic bold values are in the lowest LSD range and normal bold values are in the highest LSD range of the attribute; sorted in decreasing Cook Doneness order.]

Variety	Cook Done	Tactile Text.	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Pea Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Brix
IT84S2246	**5**	**5.0**	134	**227**	***1.8***	1.8	**98**	**98**	***1.7***	**1.1**
IT98K-128-2	**4.5**	**4.5**	126	202	3	2.7	82	82	***1.7***	0.87
IT85F-3139	4.1	4.0	133	190	2.8	1.8	**99**	**97**	***1.2***	0.97
Mouride	3.8	4.0	135	175	***1.6***	1.8	**90**	**90**	3	0.8
IT97K-569-9	3.7	3.8	126	**219**	2.3	2.3	84	**84**	2.3	0.9
IT98K-498-1	3.6	3.2	157	201	2.6	**1.6**	**97**	**95**	2	1.07
IT93K-693-2	3.3	3.3	132	183	***2***	1.8	80	75	***1.5***	0.83
CB27	3.2	3.2	133	181	3.0	2.2	55	52	3.3	0.93
IT86F-2014-1	3	3.3	158	**215**	3	**1.7**	**89**	**84**	**4.3**	0.9
IT98K-428-4	3	3.0	140	169	2.2	1.8	20	19	2.5	0.8
1393-1-2-2 (+)	3	3	141	171	***2***	1.8	29	28	3.5	0.8
1393-2-3 (-)	3	3.0	138	183	***1.5***	1.8	31	31	3.0	0.83
IT97K-499-39	3	3.0	132	***161***	2.4	2.2	30	27	2.2	0.86
Prima	3	3.0	152	179	2.8	**3.2**	29	27	4.0	0.88
IT98K-205-8	3	2.8	***117***	***156***	2.8	2.6	42	42	2	***0.66***
IT95K-207-21	3	2.8	128	181	3.2	2.8	**99**	**87**	***1.8***	0.98
IT93K-2046	3	2.7	143	173	2.3	**3.3**	42	33	2.3	0.85
CB46	2.8	3.2	129	186	**3.3**	2.7	75	76	2.5	0.88
IT89KD-288	2.8	2.7	132	***161***	***1.6***	2.1	32	23	3.0	0.83
KVx-61-1-1	2.8	3	132	166	3.0	2.2	**89**	77	***1.5***	0.83
Early Scarlet	2.8	2.8	155	177	**3.3**	2.8	***15***	**6**	4	0.9
CRSP NIEBE	2.8	2.3	147	165	2.3	**3**	***13***	**12**	2	0.87
IT98K-317-12	2.7	3.0	129	179	2.5	1.8	50	48	2.3	0.85
Vya	2.7	3.0	136	***163***	***1.5***	2.3	25	25	3.0	0.9
IT82E-18	2.7	2.7	***121***	***162***	**3.3**	2	73	50	**4.3**	1.05
Cameroon 7-29	2.7	2.5	132	***161***	***1.8***	2.3	23	**18**	2.3	0.85
58-53	2.6	2.5	144	165	2.6	2.3	***7***	**6**	***1.7***	0.84
58-57	2.6	2.8	134	***154***	2.6	2.6	30	22	2.3	***0.73***
IT95K-181-9	2.5	2.7	144	186	2.9	2.5	**89**	76	***1.4***	0.89
Cam12-58	2.5	2.8	163	190	2.5	**1.5**	37	40	2.7	0.97
Melakh	2.5	2.5	136	***156***	2.3	2.0	18	**17**	2.3	0.93
Iron Clay 101	2.5	2.3	131	***153***	***1.9***	**1.4**	21	21	**4.7**	0.84
IT93K-93-10	2.4	2.5	135	***163***	2.4	2.2	42	39	**4.7**	1.03
UCR-830	2.3	2.3	149	***164***	2.3	**1.5**	***9***	**6**	**4.7**	1
IT95M-190	2.3	2.3	139	168	**3.8**	**3.0**	20	**15**	***1.5***	0.8
Apagbaala	2.3	2.0	129	169	3.0	**3**	81	75	2.7	0.85
CC-85-2	2.3	2.3	149	173	2.3	2.0	***3***	**3**	2.3	0.83
IAR7/8-5-4-1	2.3	2.2	140	***153***	2.6	2.8	***5***	**5**	3.2	0.83
IT83D-442	2.2	2.8	140	165	**3.6**	2.4	77	75	**4.5**	0.9
24/25B-9	2.2	2	**173**	187	**3.3**	**3.5**	78	45	***1.8***	**1.1**
IT95K-1479	2.1	2.1	139	***158***	***2.0***	1.8	25	28	2.5	0.93
24-125B-1	2	2.2	155	175	3.1	**3.2**	65	44	***1.7***	**1.18**
IT97K-819-132	2	2.8	146	167	2.4	2.2	20	**18**	**4.8**	1.03

Variety	Cook Done	Tactile Text.	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Pea Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Brix
Mounge	2	2.5	156	172	***1.8***	**1.5**	***6***	**6**	4	0.97
IT90K-284-2	2	2.4	152	174	2.4	**1.2**	40	34	**4.4**	1.07
IT95K-1105-5	2	2.3	164	188	**3.3**	1.8	67	56	**5**	**1.13**
IT93K-503-1	2	2.0	128	168	2.6	2.1	66	61	3.0	1
01CC-110-1	2	1.8	141	***157***	2.3	2.5	38	28	2.3	0.95
01CC-85	2	1.8	148	170	***1.8***	2.5	***8***	**6**	2	0.98
Suvita 2	2	1.8	136	***152***	2.8	2.8	73	30	***1.7***	**1.1**
IT98K-558-1	2	***1.5***	141	179	**4.3**	2.5	73	68	2.3	**1.1**
IT97K-556-6	***1.7***	2.3	141	173	2.7	**1.7**	43	29	**4.7**	**1.1**
UCR 779	***1.7***	1.8	146	***160***	***1.9***	1.9	***10***	**3**	**4.5**	**1.09**
IT95K-1093-5	***1.7***	***1.3***	158	187	2.7	2.0	72	43	2.0	1
IT95K-1491	***1.3***	***1.5***	137	***158***	**3.3**	**3.0**	***14***	**15**	2	1.03
Bambey 21	***1.3***	***1.0***	139	***158***	3	1.8	72	49	***1.3***	1.03
LSD	**0.7**	**0.7**	**5**	**12**	**1.2**	**0.9**	**13**	**15**	**0.7**	**0.1**

Table 2. Effect of shorter or longer cooking time properties attributes of cowpeas. [Note: bold values are the significantly higher vlaue for that attribute of the variety.]

Variety	Cook Time	Cook Done	Tactile Txture	Soak Abs (%)	Cook Abs (%)	Cook Broth Aroma	Cook Pea Aroma	Splt Testa (%)	Splt Cotyl (%)	Broth Opacity	Brix
Undercooked Cowpeas Cooked an Additional 5 Minutes											
Bambey 21	32	**2**	**2.0**	138	**172**	2.7	**2.7**	**86**	61	**2.3**	1.03
Bambey 21	27	1.3	1.0	139	158	3	1.8	72	49	1.3	1.03
IT95K-1479	32	1.7	**2.3**	136	165	**3.7**	**2.7**	**36**	**39**	2	1
IT95K-1479	27	1.8	1.5	139	156	1.7	2	11	16	2.5	1
IT95K-1491	32	**2**	2	135	163	4.0	3.0	**34**	**73**	**3.5**	**1.15**
IT95K-1491	27	1.3	1.5	137	158	3.3	3	14	15	2.0	1.03
UCR 779	32	1	1.5	136	150	3.0	2.5	17	2	5.0	**1.2**
UCR 779	27	1	1.2	135	151	2.5	2.5	8	0	4.4	1.08
Overcooked Cowpeas Cooked 5 Minutes Less											
IT84S2246	27	**5**	**5.0**	134	**227**	1.8	1.8	98	98	1.7	**1.1**
IT84S2246	22	3	3.5	138	201	2.0	2.0	98	88	2.0	1
IT98K-128-2	27	**4.5**	**4.5**	126	202	1.5	1.8	82	82	1.7	0.87
IT98K-128-2	22	3.3	3.7	125	207	**3.3**	**2.7**	85	85	2.3	0.95
IT85F-3139	27	**4.3**	3.8	127	186	1.8	2.3	102	98	1.0	0.83
IT85F-3139	22	3	3.5	123	178	**3**	2.5	100	90	1.5	0.85

ESA3-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Enhancement of Child Survival and Rehabilitation of Malnourished Children Through the Development of Inexpensive Bean/Sorghum/Maize Foods

Principal Investigators and Institutions:
Maurice Bennink, Michigan State University, U.S.; Henry Laswai, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions:
Theobald Mosha, Sokione University of Agriculture, Tanzania

Justification and Objectives

Malnutrition is very common in Tanzania. Various forms of nutrient deficiencies, especially protein and micronutrients, are widespread among infants and young children. The causes of malnutrition are multi-factorial. However, the immediate cause of this condition is inadequate intake and poor utilization of nutrients due to inadequate or poor quality foods (Tomkins et al. 1989; Mosha and Svanberg 1990; Williams 1933). Usually, children identified with mild or severe protein energy malnutrition (PEM) are referred to hospital-based or community-based rehabilitation centers where they receive feeding supplements while continuing with medical care for the complications associated with PEM. The common food used for rehabilitation is 'energy food' made from reconstituted dried skim milk (DSM) with vegetable oil and sugar added to increase energy density (King and Burgess, 1993). The DSM is imported by the government as part of its public social support service. Shortage of DSM to feed the large number of malnourished children in rehabilitation centers, rural and urban households, orphanages, street children centers and refugee camps has been a major problem in Tanzania. Research conducted in FY 03 and FY 04 demonstrated that inexpensive, shelf stable, culturally acceptable foods capable of preventing malnutrition and rehabilitation of malnourished children can be produced from cereals and beans grown in Tanzania. Increasing bean utilization and making more nutritious diets available at affordable cost is pertinent in insuring food and nutrition security to both adults and children.

In the U.S., excess food and poor food choices, low physical activity, and long life spans have shifted the major causes of death to 'chronic diseases;' heart disease, cancer, stroke, diabetes and obesity. In developing countries where cancer rates are currently low, changes in traditional diets due to widespread urbanization and global marketing are causing rapid increases in cancer rates as well. Cancer treatment is very costly and places a heavy burden on the health care system. The only rational alternative, argued by some, is to prevent cancer. Extensive research (World Cancer Research Fund 1997; Armstrong and Doll 1975; Doll and Peto 1981; National Academy of Sciences 1982, 1989; WHO 1990) has identified dietary components that enhance or decrease cancer at various sites in the body. In a few instances, clear cause and effect have been established. Evidence that eating beans might help keep colon, breast and prostate cancer low comes from one epidemiological study and two animal studies (Correa, 1981; Hangen and Bennink, 2002). The WCRF/AICR expert panel (World Cancer Research Fund, 1997) recommended, "Given the nutritional content of pulses and their importance in plant-based diets as rich sources of protein and of bioactive microconstituents that may protect against cancer, high priority should be given to epidemiological and experimental studies in which pulses are carefully identified and measured and their relation to disease risk established."

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Install and commission a new food production facility at SUA. Evaluate the quality and acceptability of bean-cereal products produced at SUA.
- Evaluate the efficacy of bean-cereal blends to promote growth.
- Evaluate the efficacy of navy beans to inhibit colon cancer in an obese-diabetic model of colon cancer.
- Determine if the anti-colon cancer properties associated with eating black beans is contained in an alcohol extract of the bean and if so, do oligosaccharides contribute to the anti-cancer activity.

Research Approach, Results and Outputs

Establishing a new food production facility: A building was constructed at Sokoine University of Agriculture (SUA) to house food processing equipment and a food packaging unit. Food processing equipment were purchased and installed in the new facilities. These facilities were used to produce foods utilized in the supplementary food study (Objective 2) during FY 06, and will be used for the feeding projects in FY 07. An extruder, hammer mill, dehuller, mixer, and scales were purchased, installed, and commissioned. The processing facility is now fully functional and will greatly enhance the teaching and research capabilities of the Food Science and Nutrition Department at SUA.

Formulations and processing conditions for two composite food products - maize-bean-sardine and cassava-maize-bean-sardine were finalized. The resultant products were evaluated for proximate composition, cooking doneness and organoleptic quality/acceptability. Crude protein was determined by the Kjeldahl method (21) using the factor of 6.25 to convert nitrogen to protein.

The maize-bean-sardine and cassava-maize-bean-sardine products are fully cooked, high-protein, highly nutritious foods that are well accepted by mothers. The nutritional and sensory attributes were also measured and recorded. Based on the results, the two foods were utilized for rehabilitation of undernourished children.

Evaluate the efficacy of bean-cereal blends to promote growth: In many parts of Tanzania, severely undernourished children lack food that is capable of rehabilitation (correcting growth deficiencies). A feeding study was initiated to evaluate the efficacy of the two processed composite foods produced to support normal growth and to rehabilitate undernourished children. The subjects were selected based on the weight, height, and general health records at the Maternal Child Health Clinic in the Mvomero district. Once the immediate medical problems (dehydration, diarrhea, parasites) were corrected and the children were ready to be discharged, the study was explained to the caretakers who were willing to participate in the study. The ability of the two composite foods to support normal growth was tested with children presenting normal growth patterns at the Maternal Child Health Clinic. The normal growth subjects were randomly selected from surrounding villages.

The supplementary foods were very effective in reducing the problem of malnutrition as shown in Figures 1-3. All of the children (19) classified as severely underweight gained sufficient weight in two months to be classified as moderately underweight. As shown in Figure 1, the number of children in the underweight categories decreased dramatically and there was a corresponding increase in the number of children classified as having normal weight for age. This phenomenal increase in weight in such a short time illustrates the potential for "catch-up growth" in young children when essential nutrients and energy are provided. The degree of underweight and stunting indicates that under nutrition was a chronic long-term condition rather than severe acute under nutrition that gives rise to wasting. As would be expected from the results shown in Figure 1, the extent of wasting (Figure 2) was decreased due to rapid weight gain.

Increase in stature is a much slower process than gain in lean body mass. Even so, feeding the bean-based supplements resulted in definite increase in height in two months. The extent of stunting in all categories decreased (Figure 3). This is most easily seen in the increase in the number of subjects that achieved normal height for age classification.

Evaluating the efficacy of navy beans to inhibit colon cancer in an obese-diabetic model of colon cancer: Epidemiologic studies suggest that obesity and diabetes increase the risk of developing colon cancer. However, there is no well established animal model to study the influence of diabetes and obesity on colon carcinogenesis. The researchers of this component received a grant from NIH to determine if a transgenic, obese, diabetic mouse would be an appropriate model for studying the influence of obesity and diabetes on colon cancer. It was hypothesized that navy beans would inhibit colon cancer because it was shown previously that feeding navy beans reduces colon cancer in a non-obese, non-diabetic rat model and because there was an inverse relationship between reoccurrence of colon polyps and consumption of bean soup and baked beans in a recent study conducted by NIH (26).

Results of this study indicate that mice of this transgenic strain become obese at an early age. By the time the mice were placed on their respective diets, they were already very obese. Feeding navy beans did not reduce further deposition of body fat. This was not surprising since the only known prevention of obesity in this model is daily injections of leptin or adrenalectomy. There is no known dietary treatment to prevent obesity in this model. Blood tests showed that the mice were diabetic and there was no difference in diabetes due to dietary treatment. Since obesity leads to insulin resistance, it was not surprising that blood glucose levels were similar for the two groups.

Six of the 40 mice (15%) fed the control diet and 5 of the 40 mice (12.5%) fed the navy bean diet had well defined macroscopic tumors. This small difference in tumor incidence is not significant. However, there were numerous smaller lesions that are currently undergoing pathologic examination and there were more small lesions in the mice fed the control diet than in mice fed the diet containing navy beans. We expect the final results to show that the navy bean diet was protective against colon cancer even in this aggressive model. However, we won't know definitely until all lesions have been classified by the pathologist.

Anti-colon cancer properties associated with eating black beans: Research of this component in previous years has shown on two occasions that eating black beans reduces chemically-induced colon cancer by 55-70% in an animal model of human colon cancer. Through these studies, the team has determined the plausible mode of anti-cancer activity associated with eating beans. The purpose of the research undertaken in FY 06 was to determine which component(s) of beans provide the anti-cancer activity. Identification of putative anti-cancer agents will improve "credibility" in the scientific community, stimulate research interest by scientists outside of the bean/cowpea community, and provide bean breeders with information to provide beans with superior health advantages.

Based on results of previous research with soy, the hypothesis of this investigation was that the majority, if not all, of the anti-colon cancer activity in beans is soluble in aqueous-alcohol. The aqueous-alcohol extract contains simple phenolics (benzoic and cinnamic acid derivatives), polyphenolics, saponins, oligosaccharides, and protease inhibitors with residual activity. All of these factors have been purported to have anti-cancer activity in various *in vitro* tests. Their individual or collective anti-cancer activity *in vivo* remains to be established. Oligosaccharides are considered to be the major flatulence factor in beans and therefore, many would like to remove oligosaccharides to produce "flatulence-free beans." However, oligosaccharides may actually help prevent colon cancer and this research was designed to determine the relative anti-cancer activity of oligosaccharides. The study is underway and the results will be reported in FY 07.

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Tables/Figures

Figure 1. Change in weight classification (weight for age of children fed bean-based supplementary foods.

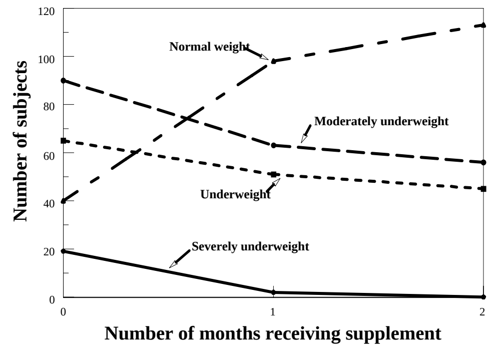


Figure 2. Change in wasting classification (weight for height of children fed bean-based supplementary foods.

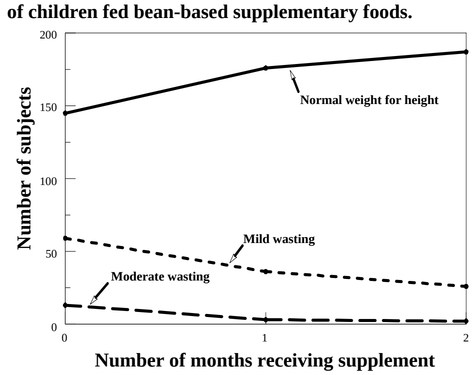
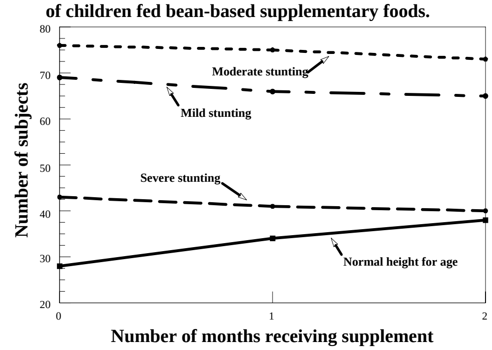


Figure 3. Change in stunting classification (height for age) of children fed bean-based supplementary foods.



ESA4-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Edaphic Constraints to Bean Production in Eastern Africa: The Selection of Bean Cultivars and Rhizobium Having Tolerance to Low N and P, and Ability to Grow at Acid pH

Principal Investigators and Institutions:
Peter Graham, University of Minnesota, U.S.; Robert Mabagala, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions:
Johnson M. R. Semoka and Susan Nchimbi-Msolla, Sokoine University, Tanzania; Ken Giller, Wageningen, Netherlands; Ken Grafton, North Dakota State University, U.S.; Phil Miklas, USDA U.S.; C. P. Vance and T. Michaels, University of Minnesota, U.S.; Steve Beebe, CIAT, Colombia; Mariangela Hungria, EMBRAPA, Brazil

Justification and Objectives

Phosphorus and nitrogen deficiency in soil are major problems worldwide, but of truly frightening proportions in Africa. Wortmann, et al. (1998) found P levels in soil to be limiting for plant growth in all but 11 of 95 bean sites evaluated, while all but two of these sites exhibited moderate to high N deficiency.

Amijee and Giller (1998) have studied this problem in Tanzania and have obtained >30% yield increases from P fertilization and inoculation of beans. Giller and Cadisch (1995) note that smallholders commonly apply less N and P than is removed in the grain; others note that rates of P depletion in soil in this region are from 3.5 to 6.6 kg P ha^{-1} yr^{-1}. P deficiency is also a major problem in Latin America and the Eastern U.S. Limitations in future availability of phosphorus fertilizers and problems of root health in Eastern Africa only exacerbate this problem.

N deficiency problems in Africa and Latin America are compounded by often-limited rates of N_2 fixation in beans, and by the greater need for P in plants dependent on nitrogen fixation for growth. More effective use of limited N and P reserves is needed. Improvement in both nitrogen fixation and P-use efficiency is possible as evidenced by studies already undertaken at Minnesota (Elisondo et al., 1999; Christiansen and Graham, 2002).

K. Giller (pers. comm.) suggests that the majority of soils in Eastern Africa have pH limitations for bean growth, with high Al and Mn concentration of significant, but lesser priority. Wortman et al. (1998) estimated that 52% of East African soils and 42% of Southern African soils are of pH 5.2 or less. Manganese toxicity is one of the principal factors limiting bean yield in Tanzania. Acid soils are also important constraints to crop production in the eastern U.S. and Canada, and in large areas of Latin America. Small farmers in much of Africa cannot afford to lime their soil. Acid pH has major effects on nodulation and nitrogen fixation in beans (Graham, 1981; Vargas and Graham,1988). These include death or displacement of the microsymbiont (Anyango et al., 1995; Hungria et al., 1997) and specific effects on the infection process (Munns, 1965).

Vargas and Graham (1988) have identified some bean cultivars and *Rhizobium* strains tolerant of acid pH, and have shown marked interaction between host and *Rhizobium*. Capixaba precoce, Preto 143 and Bico de Ouro are all Brazilian lines with outstanding tolerance (Vargas and Graham, 1988), while additional lines with acid tolerance have been reported in the studies of Wortman (1994) and more recent BILFA and low soil fertility CIAT nurseries.

R. tropici UMR1899, first identified by the U.S. PI in Colombia, is still widely used in inoculants in Brazil, the U.S. and Canada, in large measure because of its tolerance to acidity. However, most inoculant strains are not acid tolerant, and few other *tropici* strains have been tested. UMR1899 is one of three inoculant strains used in Tanzania, but is not favored (Msumali, pers.comm.), while overall less than 10% of farmers in Eastern Africa have ever used inoculants (Karanja et al., 2000). Unfortunately, there have been few recent studies on cultivar and strain interaction at acid-soil pH, and a new major focus on the problem is essential.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- To select bean cultivars and *rhizobia* with tolerance to low P and N levels in soil, and able to

nodulate and fix N_2 under such limiting conditions in Eastern Africa.
- To select bean cultivars and *Rhizobium* with tolerance to acid soil factors and able to nodulate and fix N_2 at acid pH.

Research Approach, Results and Outputs

Screening for differences in low P tolerance and ability to fix N_2 (Sokoine University): The accessions A785, VEF 88(40), MELENIO, BAT 477, AFR 708, ANT 22, DOR 714, previously reported in the studies of Mr. Sixbert Mourice as relatively low P tolerant under Tanzanian conditions, were evaluated for nodulation and nitrogen fixation with CIAT 1899 and a local *rhizobial* strain PV1. Nodulation was abundant, but fixation apparently limited, and all plants showed N deficiency. As the Leonard jars used were not apparently autoclaved, this could have been due to ineffective soil *rhizobia* present naturally in the sand used, or to problems with the inoculant strains used.

Grow out of Backcross - progeny from crosses between EL34 and Redkanner, Redhawk, Montcalm and Chinook (Minnesota): A breeding initiative to introduce genes for high N_2 fixation, and possibly enhanced P efficiency and utilization in plants dependent on N_2 fixation for growth was continued in 2006. F_3 rows derived by single seed descent from backcross populations of the cross of Montcalm x EL34 (Elisondo et al., 1999; crosses to Montcalm and back crosses, courtesy of Ken Grafton) were grown out under field conditions at Becker, MN in Summer 2006, but were badly affected by bacterial blight under the unseasonably hot and irrigated conditions, and no selection practiced. One-hundred and twenty-six unreplicated F_4 plants, inoculated with *Rhizobium* but otherwise not N fertilized, were then grown out in the glasshouse in late summer 2006 with a range in yield per plant from 1 to 27 g. Twenty of the apparently superior lines selected from this study are currently being evaluated under replicated conditions in the glasshouse, and will be further field tested next summer. Progress in this aspect of the project was affected by the illness and death of the PI's mother, and by maternity leave for Ms. Tlusty.

Differences in N_2 fixation among cultivars being evaluated for stress tolerance (Minnesota): Because many of the accessions identified for use in this project will only set seed under short day length conditions, we use the winter period to propogate seed in the glasshouse, and simultaneously to evaluate for differences in these accessions for nodulation and nitrogen fixation when dependent on *Rhizobium* for N. Forty cultivars were tested under replicated conditions in 2005, with G3513, Tio Canela, Tacana, RAB655, G21212, BAT304, Porrillo sintetico, Carioca, and VAX 1 giving good yields when dependent on N_2 fixation for growth. A further 40 accessions are currently under test with Je.Ma., A785, CIM9314-36 and G19227A showing vigorous growth when dependent on N_2fixation, and DB186, AND871, G2863 and Carbanzillo Zarco clearly chlorotic and apparently weak in fixing ability.

Characterization of genes up-regulated under P stress: Collaboration with G. Hernandez (CCG-UNAM) and C. P. Vance (University of Minnesota) continued in 2006, with differences in gene expression for nodules and roots of cultivar Negro Jamapa grown under normal and low P levels shown. More than 20 groups of genes from four legume species and *Arabidopsis thaliana* were identified as statistically over represented in EST contigs from P-stressed bean tissues, with 52 *P. vulgaris* candidate genes belonging to 19 categories induced by P-stress response. Nodule and root samples from plants tolerant and sensitive to acid pH have also been collected from hydroponically grown plants, and will also be tested for differences in gene expression.

Screening of bean lines and Rhizobium for tolerance to acid soil factors: The hydroponic system initiated last year has been further refined, and now uses plastic trays covered with mesh screens to support the growing seedlings. HOMOPIPES buffer at 1mM is used to provide some pH buffering control below pH 5.0, and pH is adjusted each day. Micronutrient supply has been modified, and individual air pumps are utilized to aerate for each 14L tank. As in previous years, 2 mL (109 cells mL-1) of liquid cultured UMR1899 was added to inoculate each tray at two days after freshly germinated bean seedlings had been transplanted into the trays. The aerators were turned off for 12 hours after inoculation to facilitate *rhizobial* attachment and infection. Appearance of nodules is monitored from seven days after inoculation. At 28 days, bean plants were assayed for nodule number and weight, plant weight and root length. In experiments undertaken in 2006 Yeguare, G3513, Tacana, BAT 304 and Capixaba precoce showed good nodulation at pH 4.5, with additional cultivars added to that list in 2006. An evaluation currently underway is testing Tacana, BAT 477, Rio Tibagi, G3513, BAT 304, Yeguare and Capixaba precoce for growth, speed and extent of nodulation and nitrogen fixation at pH 4.5, 4.9. 5.3 and 5.7. Plans are to use root and nodule samples from plants grown at pH 4.9 and 5.7 for cDNA production and for macro array studies similar to those being undertaken with P supply.

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ESA5-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Development of Cost-Effective and Sustainable Seed Multiplication and Dissemination Systems for Improved Bean Cultivars that Meet the Needs of Limited-Resource Bean Farmers

Principal Investigators and Institutions:

Carol Miles and David Holland, Washington State University, U.S.; Flavianus Magayane and Dismas Mwaseba, Sokoine University of Agriculture, Tanzania; Charles Masangano, Bunda College of Agriculture, Malawi

Collaborators and Institutions:

James Bokosi and Vincent Mwale, Bunda College, Malawi; Phil Miklas, ARS Prosser, Washington, U.S.; James Myers, Oregon State University, U.S.; Jennifer Wagner, Washington State University, U.S.; CIAT; Ralph Waniska, Texas A&M, U.S.; Agnes Mwangwela, Malawi; Susan Nchimbi-Msolla and Anna Temu, Sokoine University of Agriculture, Tanzania; Total Land Care; Concern Universal; TOSCI; CARE, Magu; LVIA, Dodoma; World Vision, Hai; Irente Farm, Lushoto; District Councils in Magu, Dodoma, Lushoto and Hai Districts

Justification and Objectives

Through support from the Bean/Cowpea CRSP, three new bean varieties have been recently released in Malawi, BCMV-B2, BCMV-B4 and BC-D/0 19, and two varieties were released in Tanzania in 2006. Keys to successful, rapid adoption of new varieties are: 1) sensitization of farmers and marketers to variety attributes prior to or immediately following variety release; and 2) adequate quantities and quality of readily available seed at affordable prices.

To improve seed dissemination in these countries, NGOs and donor organizations have begun to actively promote smallholder seed multiplication and marketing programs. Through these programs, smallholder farmers learn to employ best management practices for seed production, seed saving, and marketing. In addition, farmers receive a small portion of seed of new, improved varieties to plant and maintain. In support of these seed multiplication programs, Bunda College and Sokoine University have been providing seed and extension brochures with cultural information on improved bean varieties to these programs. A major constraint, however, is lack of infrastructure and farmer training to support quality seed production within the seed multiplication programs which jeopardizes the sustainability of these programs. In addition, there is insufficient production of certified bean seed to meet the annual demand of the multiplication programs.

In the U.S., new technologies developed by the Bean/Cowpea CRSP have generally been targeted towards larger-scale production systems. Small-scale producers, many of who are women (90% of women farmers in the U.S. are small-scale producers), have not necessarily benefited from these innovations. Dry beans are ideally suited for small-scale direct market production because they are relatively easy to grow, handle and store, and they provide farmers with crop diversity at the end as well as at the beginning of the market season when there tend to be crop shortages. Niche market varieties, heirloom or colored/patterned varieties, are most desired because they are considered a high value crop.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Establish participatory research on-farm trials in Malawi and Washington to evaluate variety performance, to improve feedback to breeders and to promote an effective bean breeding and selection process.
- Survey bean use patterns and preferences of farmers in Malawi, survey bean use patterns and preferences of farmers and market vendors in Malawi and Washington, and in the U.S. evaluate cooking time of heirloom varieties and new niche market varieties.
- Investigate the effectiveness of seed multiplication programs (including Bunda and SUA) to produce seed of newly released Bean/Cowpea CRSP varieties to increase availability of the seeds at affordable prices to rural communities.
- Investigate the effectiveness of different extension institutional arrangements and approaches in increasing the adoption of CRSP varieties.
- Assess the genetic variability of heirloom varieties in the U.S. through PCR assays.

Research Approach, Results and Outputs

Participatory on-farm trials: In Malawi, highly significantly yield differences (P<0.001) were observed among dwarf and climber bean lines and across locations in two management systems (Table 1). Lines were generally tolerant of major diseases such as BCMV, CBB and ALS in Ntchenachena and Ntchisi, but in Matapwata, AND 659, a climber, was severely susceptible to CBB. Stability of the entries across seasons varied significantly, and yields of entries in the second season were generally lower than in the first. Of the climbers, CAB 19, 5P/5 and DC 86-244 were the most stable across seasons and locations. Of the dwarfs, SDDT-54-C5, PC490-D8 and DOR 715 were the most stable.

Qualitative data shows that farmers select a variety based on yield potential, time to maturity, taste and grain color (Table 2). Farmers are primarily concerned with their own consumption needs before they consider market demands. Buyers tend to use grain color for selecting the beans they buy. Almost 2000 people attended a field day at Bunda College on April 8, 2006 where 12 Bean/Cowpea CRSP varieties were highlighted. The then Minister of Agriculture and Food Security, Honorable Uladi Mussa was the Guest of Honor. The 12 varieties were also displayed at the Labor Day celebrations attended by 5,000 people where the State President, His Excellency Dr. Bingu Wamutharika, was the Guest of Honor. A Television Malawi documentary was produced and a copy was provided to the management Unit and the EEP team.

In Washington, yield parameters differed significantly among bean varieties and years. Of the heirloom varieties, the 100-bean weight of Soldier, Calypso and Molasses Face was significantly greater than the overall mean. Maine Yellow Eye and Calypso were low yielding while Pinto was high yielding. Pinto was the earliest heirloom entry to be harvested and Molasses Face was the latest. Results were presented at four grower conferences (approximately 150 participants in total) and three university/extension classes (approximately 120 participants in total) in Washington and Oregon. In January 2006, the use of WSU threshing and seed cleaning equipment was demonstrated at the Organic Seed Conference in Oregon (150 participants). Three growers have created their own equipment based on WSU designs. A web page, http://sustainableseedsystems.wsu.edu/, has been developed to describe dry bean varieties appropriate for niche markets.

Bean use preferences: In Malawi, a total of 338 household heads were interviewed from Nkhotakota (64) Salima (49) Ntcheu (59) Dedza (104) and Mzimba (62). Of this population, 206 of the respondents (61%) were bean growers, and 81% of the household heads were male and 19% were female. All the households that grew beans used part of their production for household consumption while half (180 households, 53%) sold part of their production. In focus group discussions farmers indicated that major characteristics of interest were: 1) high yield; 2) early maturity; 3) marketability; 4) easy to cook; and 5) palatability. Data on market surveys is still being analyzed but initial findings indicate bean preferences at Jenda Market are different from other markets studied in the Central Region. In all markets, all vendors sold a red kidney type bean. It commanded the highest price and was the most popular bean type in three out of four markets. The majority of vendors (>75%) sold Kalima (Table 3). Kalima was most popular at Jenda Market and commanded the second highest price there. Kalima may rank second overall following Phalombe (red kidney), and Nanyati (sugar bean type) may rank third. Kalima was found in most of the markets in Ntcheu District but was not officially introduced there. Kalima was likely introduced by vendors who purchased it from Chimbiya (50 km away) and other parts of Dedza. Results also indicate that Kalima has spread into Mozambique as there is a large exchange of beans between that country and Ntcheu District. Bean prices are much higher at Mwansambo Turn Off Market, an area where beans are not traditionally grown.

In Washington, customers inquired from the farmer-suppliers about the nutritional value of different varieties (primarily protein), cooking time (fast cooking is preferred), and best use for each variety (soups, casseroles, etc.). Water absorption by beans stored for one and two years was slower than fresh dry beans. Freshly harvested dry beans were faster cooking, while beans that were stored for one year were significantly slower cooking. Significant differences in cooking time were observed among entries. Entries that had the fastest cooking time overall were W614737 (17.2 min.), Molasses Face (18.4 min.), and Navy Pea (20.4 min.), while Cardinal (34.7 min.), USCR-14 (35.1 min.), and 95:8186C (36.1 min.) had the slowest. Three of the slowest cooking entries were in the Cranberry market class.

Seed multiplication: Surveys of farmers participating with seed multiplication programs have been completed in Malawi and data are currently being analyzed. Seed was provided to participating farmers for the study of seed multiplication programs and data is being collected and analyzed but there are no results to report as yet.

Effectiveness of Extension Approaches: Surveys indicated that most extension offices and staff had not seen the brochure on CRSP bean varieties even though they had been distributed to these offices. Due to the high turnover in staff – almost none of the staff we interviewed had been working in the offices when the brochures were originally distributed. Extension offices do not file information or keep records of information they receive or distribute. Of the farmers contacted, only one said he had seen a brochure. All the people interviewed indicated that the brochures could be useful for the following reasons: to learn new practices; to identify beans found in the area; there is too little information on beans, and the brochures could fill a knowledge gap; increase interest in beans; create awareness of new varieties; the brochure on diseases can help extension workers and the farmers identify pests and ways to treat them; remind staff and up-date their knowledge; extension staff can use the brochures when they teach farmers; and provide important information about cooking time.

Genetic diversity of heirloom bean varieties: A total of 26 major bands were visualized across 44 individuals and groupings A and B (Fig. 1). Overall, there were minimal differences between the A and B groups with a similarity co-efficient range of .94 to 1. Maine Yellow Eye, Othello, Peregion, Pinto, Red Mexican, and Soldier all indicated a similarity co-efficient of 1 between A and B groups. Other genotypes with an exact (1) similarity co-efficient were Maine Yellow Eye and Soldier, PI 353479 and W614733, and PI 549776 and W614733. The PI accessions did not show any differences between each other, nor with W614733, for the markers used in this study. Orca, UI-239, and USRM 20 indicated the greatest number of dissimilarities (0) with other genotypes. A dendrogram produced by cluster analysis divided bean individuals into Andean and Mesoamerican branches. Within the Andean branch, 5 of the 9 heirloom varieties were clustered - Maine Yellow Eye, Soldier, Brown Dutch, Calypso, and Magpie - along with niche market variety Red Soldier and all four African accessions, PI 353479, PI 549776, W614733, and W614737. Heirlooms Pinto, Red Mexican, Peregion, and Navy Pea all clustered in the Mesoamerican branch.

Tables/Figures

Table 1. Mean yield of bean lines under researcher designed farmer managed (RDFM) trials and under farmer designed farmer managed trials (FDFM).

Type of bean	Line	Group mean yield under researcher designed farmer managed trials (kg/ha)	Group mean yield under farmer designed farmer managed trials (kg/ha)
Dwarf	DOR 715	1267.8	799.8
	BCMV B2	920.6	864.8
	APN 130	876.8	737.6
	SDDT -54-C5	725.8	573.2
	DC 96-95	696.2	659.2
	PC 490-D8	692.2	962.2
	F6BC (19)	610.6	870.4
Climbers	DC 86-244	1048.6	654.2
	RWV 1046	883.0	656.0
	RWV 1042-2-3	757.1	699.6
	AND 659	749.4	595.0
	CAB 19	748.2	769.6
	5P/5	726.9	727.4
	BCMV B4	622.0	702.8

Table 2. Bean characteristics that farmers look for when selecting bean seed.

Characteristic	Weighted frequency of 1st choice	Weighted frequency of 2nd choice	Weigted frequency of 3rd choice	Weighted total score	Rank
High yield	90	24	8	122	1
Time to maturity	27	34	6	67	2
Taste of bean	30	18	11	59	3
Grain colour	33	16	0	49	4
Grain size	30	2	1	33	5
Resistance to diseases	6	16	0	22	6
Better market price	3	8	5	16	7
Cooking fast	0	8	7	15	8
Resistance to pests	0	4	1	5	9
Resistance to drought	0	0	0	0	10
Resistance to heavy rains	0	0	0	0	10

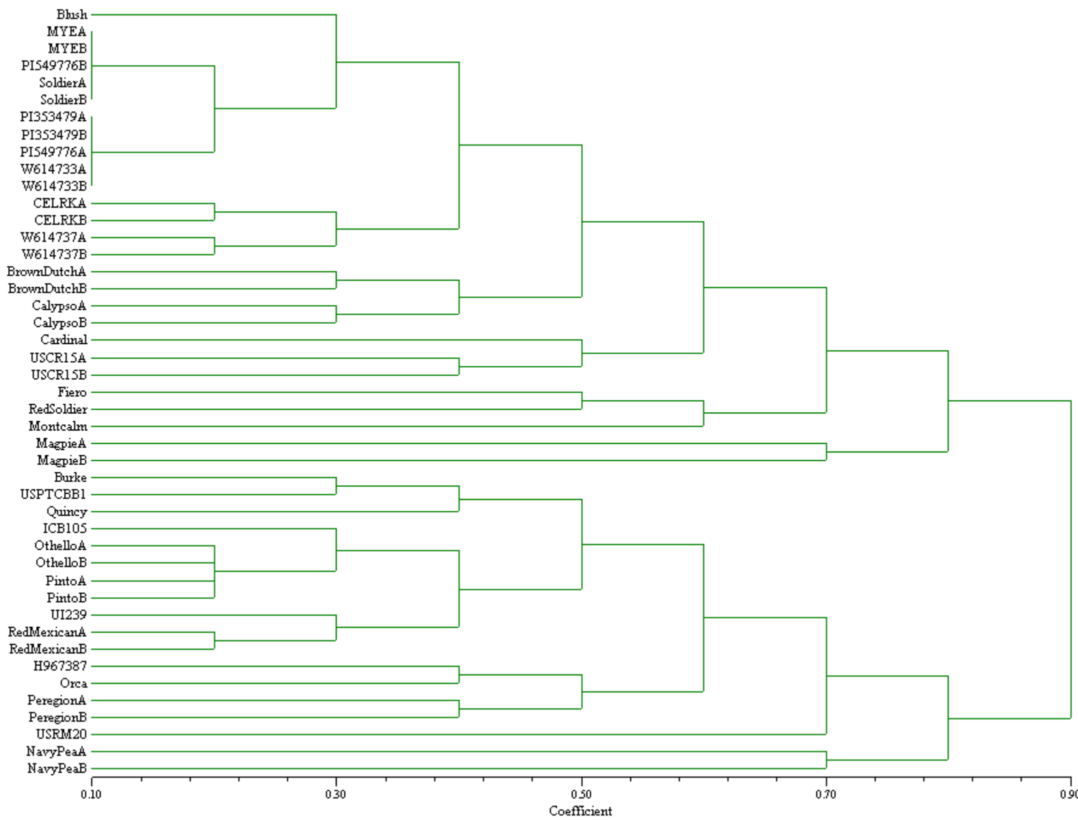
Note: Weighted frequencies for 1st choice were computed by multiplying the actual frequency by 3
Weighted frequencies for 2nd choice were computed by multiplying the actual frequency by 2
Weighted frequencies for 3rd choice were computed by multiplying the actual frequency by 1

Table 3. Results of a market survey in four bean markets for selected bean varieties in Malawi.

	Market							
	Chimbiya[2]		**Lizulu[3]**		**Mwansambo[4] Turn Off**		**Jenda[5]**	
Bean Types/varieties[1]	**Number of Vendors**	**Avg Price (MK)**	**Number of Vendors**	**Avg Price (MK)**	**Number of Vendors**	**Avg Price (MK)**	**Number of Vendors**	**Avg Price (MK)**
Kalima	24 (83%)	35	26 (76%)	68	0	0	30 (100%)	78
Phalombe/Thyolo (Red Kidney)	29 (100%)	40	34 (100%)	79	8 (100%)	98	2 (7%)	70
Nanyati (Sugar type)	27 (93%)	35	18 (53%)	73	6 (75%)	87	16 (53%)	82
Khaki (Nasaka type)	9 (31%)	30	14 (41%)	59	2 (25%)	75	10 (33%)	75
Kayela (white)	4 (14%)	30	11 (32%)	45	8 (100%)	90	16 (53%)	78

[1]Bean types may not be pure varieties. The only exception could have bean kalima but in some cases farmers confused it with another bean variety called maluwa.
[2]Chimbiya market is in Dedza District of Lilongwe ADD. Dedza District is one of the major bean growing areas in Malawi where Kalima bean variety was introduced through Concern Universal, an International NGO
[3]Lizulu Market is in Ntcheu District of Lilongwe ADD. Ntcheu District is a major bean growing area but Kalima Beans have not officially been introduced
[4]Mwansambo Turn Off is in Nkhota-kota District in Salima ADD along the Lake Malawi Shore. Nkhota-kota District is not a major bean growing area, however one NGO, Total Land Care (an International NGO) is working in the area and introduced winter cropping of Kalima beans in 2005 and results show that the variety is doing very well.
[5]Jenda Market is in Mzimba District under Mzuzu ADD in the Northern Region of Malawi. Jenda Market is in a major bean growing area where kalima beans were introduced by Action Aid, an International NGO

Figure 1. Dendrogram produced by cluster analysis divides 29 bean entries into Andean and Mesoamerican branches**.**



ESA6-A1

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

Develop Bean Cultivars for East and Southern Africa with Enhanced Resistance to Diseases and Insects

Principal Investigators and Institutions:
James Myers, Oregon State University, U.S.; Philip Miklas, U.S. Department of Agriculture--Prosser, U.S.; James Bokosi, Bunda College of Agriculture, Malawi; Susan Nchimbi-Msolla, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions:
Charles Masangano, Bunda College, Malawi; Catherine Madata, and D. Kabungo, ARI, Uyole, Tanzania; Robert Mabagala and Robert Misangu, Sokoine University, Tanzania; Carol Miles, Washington State University; U.S.; Flavianus Magayane and Henry Laswai, SUA, Tanzania; Joseph Mligo, ARI-Llonga; Sosthene Kweka and Ngulu, ARI-Selian; Geoffry Kananji, Chitedze, Malawi; Deidre Fourie, ARC, Grain Crops Institute, South Africa

Justification and Objectives

Bean (*Phaseolus vulgaris* L.) yields are about 400 to 500 kg/ha for smallholder farmers in sub-Saharan Africa. Many problems contribute to low yield including farmer dependence on local landraces that have low yield potential, are susceptible to diseases and pests and not able to tolerate environmental stress (low fertility and pH, drought, heat and flood stress). Bean breeding for East and Southern Africa is a challenge since bean production can be found in 14 different agro-ecological zones (Wortmann et al., 1994) of which seven are in Tanzania and two in Malawi. Because of the differences in latitude and day length, bean varieties developed in one country are not necessarily adapted to conditions in other countries in the region. It is imperative that technical support be provided to multiple bean breeding programs to develop varieties of various market classes that satisfy both local and regional market demands and possess desired agronomic traits conferring high yield potential and pest resistances.

Common Bacterial Blight (CBB, caused by *Xanthamonas campestris* pv. *phaseoli*) resistance is probably the most important biotic constraint to bean production in East and Southern Africa (Anonymous, 2000), and is important in the more humid growing regions of the U.S. Potential sources of CBB resistance from various germplasm sources need to be evaluated and incorporated into elite African lines. Other important diseases including anthracnose (ANT caused by *Colletotrichum lindemuthianum*), angular leaf spot (ALS caused by *Phaeoisariopsis griseola*), bean common mosaic necrosis virus (BCMNV), rust (caused by *Uromyces appendiculatus*), and halo blight (HB caused by *Pseudomonas syringae* pv. *phaseolicola*) continue to limit bean yields throughout Eastern and Southern Africa.
The Mexican Bean Weevil (*Zabrotes subfasciatus*) and the common bean weevil (*Acanthoscelides obtectus*) are serious storage pests of beans both in Africa and worldwide. Affordable integrated pest management technologies such as resistant varieties are needed to ensure a safe and secure food supply. Research is needed to introgress genes for bruchid resistance into cultivated beans from wild common bean and related species.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Evaluate promising bean lines with ALS and BCMNV resistance in on-farm field trials and multiply seed.
- Evaluate bean lines in preliminary and advanced yield trials for populations obtained from the hybridization program and the introduced germplasm.
- Evaluate lines from inter-specific hybridization for bruchid resistance.
- Obtain germplasm and make crosses and advance materials from crosses of elite materials to incorporate disease resistance into adapted varieties.

Research Approach, Results and Outputs

Evaluation of promising bean lines: In Malawi, breeders' seed of the three newly released varieties (BCMV-B2, BCMV-B4, and BC-D/O (19) was increased/multiplied during winter crop season under irrigation. At least 50 kg of breeder's seed is available for each variety. The seed multiplication component has also produced 1000 kg of BCMV-B2, 200 kg BCMV-B4, and 250 kg BC-DO (19) as foundation seed.

In Tanzania, two new bean varieties, 'Mshindi' and 'Pesa,' were officially released in 2004. Seeds of these two newly released varieties are now being multiplied at Msimba Foundation Seed Farm and at Sokoine University of Agriculture (SUA).

In Tanzania, cooking trials were performed in the laboratory on 13 advanced lines plus four checks (Kablanketi, SUA 90, Rojo and Canadian Wonder) using a Matson cooker. Significant variation ($P< 0.05$) in cooking time was observed among the lines tested. Local variety 'Kablanketi,' used as a parent for fast cooking, had the shortest cooking time (20 minutes) while the other local check 'Canadian Wonder' had the longest cooking time (73 min.). Among the tested lines, line EG10R11, EG21R30 and EG10R5 had the shortest cooking times; 27.7, 28.0 and 28.7 minutes, respectively.

Germplasm evaluation for resistance to diseases and abiotic stresses: Malawi- Lines of interest (e.g., Multiple Disease Resistant Beans (MDRBs), UC-Davis materials, and MAS lines developed in the U.S.) were included in the Preliminary (PBYT) and Advanced Bean Yield Trials (ABYT) and evaluated for agronomic characteristics and disease resistance. Preliminary trials were planted at three locations while advanced trials were conducted at five locations.

The Preliminary Trial-1 (PTI) included 36 determinate lines and 23 lines from MDRB (Malawi), nine from MAS (USDA-Prosser), two from F8BC3 (UCD), one CBB germplasm, USDK-CBB-15, (UNL), and a released variety, Kalima. These lines were evaluated at three sites (Bunda, Ng'onga, and Ntchenachena). Data on yield, reaction to diseases, days to physiological maturity (DPM), and seed size (SS) was collected. Results at Bunda showed that yield ranged from 215 to 1484 kg/ha with a mean of 741 kg/ha. Five top entries were F11 MDRB (A) 9, F12 MDRB (A), F5 PS 04-148 (A), F5 04-072 (B)-3, and PS 04 120(A)-3). All yielded over a ton. They also showed good resistance to ALS and BCMNV but had variable reaction (2 to 7) for CBB. Days to physiological maturity (DPM) and seed size (SS), in g/100 seeds, ranged from 67 to 74 and 25 to 44 (unadjusted) respectively. Yield performance at Ng'onga ranged from 242 to 786 with a mean of 550 kg/ha. The five top yielding at Ng'onga included F12 MDRB (A)-120, F12 MDRB (A) 8-1, F11 MDRB(A) 18, F5 PS 04 120(A)-11and F5 PS 04 120(A)-3. ALS and CBB were the two major diseases and the reaction of the five top entries ranged from 2 to 6. DPM and SS for these five entries ranged from 60 to 92 and 37 to 48 (unadjusted) respectively. Yields at Ntchenachena ranged from 451 to 1456 kg/ha with a mean of 954 kg/ha. The five top yielding entries were, F5 PS 04 120(A)-11, F5 PS 04 120(B)-3, F5 PS 04-122(D)-7), F7 MDRB (E) 15, and F9 BC3 D/N 41. ALS and CBB were two major diseases at this site and the reaction of the five entries ranged from 3 to 6. DPM and SS ranged from 69 to 79 and 37 to 48 (unadjusted) respectively. A total of 14 entries (7 MDRB, 6 MAS, and 1 F8BC3) from PT1 have advanced to ABYT1.

Thirty-six of the entries in PTII (indeterminate lines) included 15 MDRB, 6 MAS, 3 BC3, and 12 other lines (including local released varieties). The five top yielding lines at Bunda were F10 BC3 D/N 15, F11 MDRB (E) 10, Kanzama, Kamtsilo, and 6D/12. The yield performance of all lines ranged from 209 to 1144 with a mean of 499 kg/ha. CBB was the main disease problem and the reaction of the five top entries varied from 2 to 7. Yield performance at Ng'onga ranged from 206 to 873 kg/ha with a mean of 386 kg/ha. The five top yielding lines were F12 MDRB (A) 120, F12 MDRB (A) 8-1, F11 MDRB (A) 18, F5 PS 04 120(A)-11and F5 PS 04 120(A)-3. ALS and CBB were two serious diseases and these five lines gave varied reactions from 2 to 6. DPM and SS ranged from 74 to 79 and 30 to 43 respectively. A total of 10 entries (6 MDRB, 2 MAS, 1 BC3, and one other line) from PTII have advanced to ABYT2.

Advanced Bean Yield Trial–I (ABYTI) was comprised of 15 MDRB and 10 other entries. These were evaluated at four sites (Bunda, Ng'onga, Dedza, and Champhira). The results indicate that yield performance at Bunda ranged from 414 to 1342 kg/ha with a mean of 637 kg/ha. These five top yielding entries were F10 MDRB(A) 8, DG 226, UCD 0234, F11 MDRB (A) 13, and Kalima. The five entries showed good resistance to ALS, CBB, and BCMV/BCMNV except the check, Kalima showed some susceptibility to CBB with a reaction of 5. The yield performance at Ng'onga ranged from 254 to 673 with a mean of 383 kg/ha. The five top yielding lines at this site included F10 MDRB (B) 25, F7 MDRB (E) 9, DG226, F11 MDRB (A) 5-1, and F10 MDRB (A) 8. Main disease was CBB and the reaction of the five lines ranged from 3 to 5. DPM and SS ranged from 67 to 72 and 24 to 42 respectively. Yield at Dedza ranged from 116 to 484 with a mean of 316 kg/ha. The five top yielding entries were UCD 0244, F11 MDRB (A) 15, F10 MDRB (B) 10, BCMV B9, and UCD 0233. All the five lines gave good resistance to ALS, CBB, and BCMV/BCMNV. DPM and SS ranged from 66 to 75 and 30 to 40 respectively. Yield performance at Champhira ranged from 422 to 1076 kg/ha with a mean of 605 kg/ha. The five top yielding entries included F10 MDRB (B) 25, F11 MDRB (A) 15, DG 226, F12 MDRB (A) 9, F10 and MDRB (A). All five top lines showed good resistance to ALS and BCMV/BCMNV but were susceptible to CBB. DPM and SS ranged from 68 to 76 and 29 to 40 respectively. Four entries (DG 226, UCD 0233, F9 MDRB (A) 8, and F9 MDRB (B) 25) have been advanced to NBYT1.

Advanced Bean Yield Trial-II (ABYTII) had seven MDRB, six BC3, and 12 other entries. Yield performance at Bunda ranged from 93 to 776 kg/ha with a mean of 328 kg/ha. The five top yielding entries included DC 86-279, DC 86-215, F12MDRB (A) 1, F9 BC3 D/N 5, and DC 86-263. All five lines showed good resistance to ALS, CBB, and BCMV/BCMNV. DPM and SS for these five lines ranged from 71 to 78 and 21 to 37 respectively. Yield performance at Ng'onga ranged from 150 to 432 kg/ha and mean yield was 252 kg/ha. The five top yielding entries were F7MDRB (E) 32, 7P/4, 2D/9, Namajengo, and F8 BC3 D/N 29-1. All five lines showed good resistance to ALS, CBB, and BCMNV except 7P/4 which had a 5 for CBB. DPM and SS ranged from 75 to 78 and 27 to 37 respectively. At Dedza the yields ranged from 71 to 332 kg/ha with a mean of 105 kg/ha. The five top yielding entries included F9BC3 D/N 10, F7 MDRB (E) 32, 45-3/1, IZ 309-1, and F8 BC3 D/N 29-1. All five lines gave good resistance to ALS, CBB, and BCMNV. DPM and SS ranged from 83 to 85 and 21 to 37 respectively. At Champhira, yields ranged from 182 to 480 kg/ha with a mean of 321 kg/ha. The five top yielding entries were F7 MDRB (E) 32, F7 MDRB (E) 31, Namajengo, F9BC3 D/N 10 and F12 MDRB (A) 35. CBB was the major disease problem and the reaction of the five entries ranged from 3 to 7. DPM and SS ranged from 77 to 84 and 25 to 37 respectively. Five lines (2D/9, F8 BC3 D/N 10, IZ 309-1, F6 MDRB (E) 22, and F8 BC3 D/N 29-2) have been advanced to NBYT2.

National Bean Yield Trail-1 (BYTI) was comprised of four UCD, three MDRB, and nine other entries. These were evaluated at five sites (Bunda, Ng'onga, Dedza, Champhira, and Ntchenachena). Yield performance at Bunda ranged from 213 to 887 kg/ha with a mean of 532 kg/ha. The five top yielding entries were MCM 4008, F10 MDRB (B) 36, UCD 0239, F10 MDRB (B) 24, and Wartburg. ALS and CBB were two diseases posing a major problem. All five lines were susceptible to ALS but showed good resistance CBB and BCMNV except UCD 0239 which had 6 for CBB. DPM and SS ranged from 71 to 76 and 28 to 38 respectively. At Ng'onga the yields ranged from 218 to 520 kg/ha with a mean of 349 kg/ha. The five top yielding entries were MCM 4008, F10 MDRB (B) 24, Napirila, Kabalabala, and DC 96-69. These entries gave very good resistance to ALS and BCMNV but fairly susceptible to CBB. DPM and SS ranged from 64 to 67 and 27 to 36 respectively. Yield performance at Dedza ranged from 84 to 332 kg/ha with a mean of 105 kg/ha. The five top yielding entries were UCD 0239, Wartiburg, UCD 0235, F9 BC3 D/N 13, and F10 MDRB (B) 24. The five lines were resistant BCMNV and susceptible to ALS but had variable to CBB ranging from 3 to 6). DPM and SS ranged from 73 to 75 and 29 to 35 respectively. Yield performance at Champhira ranged from 484 to 829 kg/ha with a mean of 676 kg/ha. These five entries were resistant to ALS and BCMNV but susceptible to CBB. DPM and SS ranged from 67 to 72 and 41 to 45 (unadjusted). Yield performance at Ntchenachena ranged from 689 to 1496 kg/ha with a mean of 1152 kg/ha. The five top yielding entries were F10 MDRB (B) 36, UCD 0239, F10 MDRB (B) 28, UCD 0236, and UCD 0237. All five entries showed good resistance to ALS and BCMNV but had varied reaction (3 to 7) for CBB. DPM and SS for these five lines ranged from 67 to 80 and 37 to 48 respectively (unadjusted). Four entries (MCM 4008, F10 MDRB (B) 36, UCD 0239 and F10 MDRB (B) 24) have been advanced to on-farm trials. Eight entries have been dropped-off.

NBYTII comprised 2 MDRB, 1 BC3, and 13 other lines. Yield performance at Bunda ranged from 545 to 1088 kg/ha with a mean of 775 kg/ha. The five top yielding entries were DC 86-279, DC 86-215, F12 MDRB (A) 1, F9BC3 D/N 5, and DC 86-263. All five entries showed good resistance to ALS, CBB, and BCMNV. DPM and SS ranged from 83 to 89 and 22 to 33 respectively. Yield performance at Ng'onga ranged from 127 to 472 kg/ha with a mean of 259 kg/ha. The five top yielding entries were 5P/6, Namajengo, 12D/2, BCMV B20, and 14K/2. The entries were resistant to ALS and BCMNV but susceptible to CBB. DPM and SS for these five entries ranged from 67 to 72 and 26 to 31 respectively. Yields at Dedza ranged from 96 to 377 kg/ha with a mean of 197 kg/ha. The five top yielding entries included Namajenga, 4G/7, 34-4/6, PC 524-C1, and PC 260-C1. Reaction to ALS and CBB varied from 2 to 5 while all five entries were resistant to BCMNV. DPM and SS ranged from 69 to 74 and 27 to 37 respectively. Yield performance at Champhira ranged from 136 to 417 kg/ha with a mean of 251 kg/ha. The five top yielding entries were 12D/2, PC 260-C1, DC 86-230, PC 524-C1, and F12 MDRB (A) 17. The entries were resistant to both ALS and BCMNV but susceptible to CBB. DPM ranged from 70 to 81 while SS varied from 23 to 45 g/100 seeds. Yield performance at Ntchenachena ranged from 425 to 882 kg/ha with a mean of 627 kg/ha. The five top yielding entries were F9 BC3 D/N 5, 5P/6, F12 MDRB (A) 17, 12D/2, and BCMV B20. DPM ranged from 73 to 87 and SS from 23 to 29 g/100 seeds. All five entries showed good resistance to all three diseases (ALS, CBB, and BCMNV). Four entries (PC 260-C1, 12D/2, DC 86-215, DC 86-279, and F8 BC3 D/N 5) have been advanced to on-farm trials.

In summary, many potentially useful lines, including MDBR lines developed by Bunda College of Agriculture, MAS lines developed through marker-assisted selection at USDA-Prosser, and BC3 lines from the UC-Davis program are moving through preliminary, advanced, and national bean yield trials in Malawi. The top five performing lines during the 2006 growing season include 12D/2, DG 226, F10MDBR(A) 8, F10MDBR(B) 24 F10MDBR(B) 36, F7MDRB(E) 32, MCM 4008, PC 260-C1, and UCD 0239. MAS lines are still in preliminary trials, with the F5 PS 04-120 series producing many promising lines. Of material closest to release, four entries from the National Bean Yield Trial for bush types (MCM 4008, F10 MDRB (B) 24, UCD 0239 and DC 96-69) and four entries from the counterpart climbing trial (F12 MDRB (A) 17, 12D/2, PC 260-C1, and PC 544-C1) will go into on-farm evaluations.

Tanzania- At Sokoine University of Agriculture (SUA), bean lines evaluated for CBB showed variation in disease scores (Disease rating 1-9 with 1 being highly resistant and 9 highly susceptible). Line PSO4-901-16 and the VAX 5 and VAX 6 showed to have high resistance to CBB (1-3). The backcrossed F_3 lines for ALS were evaluated. About 25 single plants showing resistance to ALS were selected for further evaluation in the screen-house. In addition, 16 bean lines (non-segregating/fixed) were evaluated in the screen-house for BCMV. Varieties SUA90 and Masai red were used as resistant and susceptible checks respectively. Seven bean lines [PC03-551—A-2 (2), PC03-570-3(1), PC03-570C-(1), PC03-570-C4(2), PC03-570-2 (1), PC03-570 C2 (1) and PC03-570-A2 (1)] were highly resistant to BCMV while the rest were either resistant or moderately resistant to BCMV.

An advanced trial of 13 Kablanketi backcrossed lines was evaluated at the Selian Agricultural Research Institute for yield and disease reaction. All Kablanketi backcrossed lines performed better in terms of yield than the parents Rojo, Kablanketi and SUA 90. The five best lines in terms of yield were EG 10R43, EG 10R5, EG 21R3, EG 10R53 and EG 10R49; 1068, 1054, 995, 958 and 836 kg/ha, respectively. Most of these lines were resistant or moderately resistant to ALS. All were resistant to CBB and BCMV with score of 1-3 (Using CIAT scale of 1-9).

Among 10 bean lines from a drought nursery evaluated under non- water stress and water stress conditions, lines DN 1007, DN 1006, DN 37 and DN 36 performed well in terms of yield in both regimes. These lines will be evaluated for disease reaction among other factors in advanced yield trials.

An F_3 segregating population from SUA was screened at Uyole for resistance to anthracnose, ALS and other diseases. This population was derived from crosses to Miklas MAS selected lines for anthracnose resistance. Bean anthracnose infections were quite mild during the season and the few infected plants (16%) showed resistance reactions 1-3. Nevertheless, almost all the entries were highly susceptible to ALS disease which appeared quite serious during the season.

In Oregon, 107 BC_2F_5 inbred lines from the inter-specific cross OR91G/PI255956 (*P. vulgaris/P. coccineus*) were increased in the field in 2006. A portion of the seed from these lines along with *P. coccineus* parents will be sent to Tanzania for testing for ALS, Ascochyta, and ANT resistance.

Evaluate inter-specific lines for bruchid resistance: In the effort to transfer resistance to bean weevils from a wild tepary bean accession G40199, a 33-35 KDa storage protein thought to be closely associated with lectin-like seed proteins as transferred. Most of the hybrid lines demonstrated introgression of the novel lectin-like protein profiles of 33kDa that were associated to the arcelin-like (ARL), alpha-amylase inhibitor like (alpha-AIL) and phytohemagglutinins (PHA) seed proteins found in *P. acutifolius*. Genomic DNA sequences deduced from tepary beans G40199 and their interspecific hybrids reveal the co-segregation of the seed protein to ARL-2, alpha-AIL and PHA-L genes of tepary bean. The 33kDa protein fragment and other closer protein bands from the tepary bean G40199 were isolated and subjected to protein sequencing using in-gel digested peptide sequencing. Several peptides were revealed in the protein profiles, among the peptides generated were a perfect match to the amino acid sequences of the arcelin genes of tepary bean, arcelin-like (ARL2) and phytohemagglutinins (PHA). No peptide matched the alpha amylase inhibitor like alpha-AIL which is among the proteins expressed by bean seeds containing the complex arcelin – phytohemagglutinins – alpha amylase inhibitor (APA) locus.

BC_2F_2 inter-specific hybrids of the cross ICA Pijao x G40199 were used as bridge parents to transfer the novel tepary bean protein into 'Rojo' using the backcross method. Three backcross generations were generated with the selection of backcross lines based on the presence of the lectin-like seed storage protein from wild tepary bean and the DNA based gene-specific primers for the presence of the three APA genes. Some Rojo backcross lines that do not contain *phaseolin* were used for incorporation of the novel lectin-like proteins from tepary beans. The strategy is to develop seeds with a segregation of arcelin 2 and novel proteins that replace the major seed protein *phaseolin*. Two backcrosses to the arcelin 2 *phaseolin* null Rojo were performed using the bridge parents of inter-specific hybrids (ICA Pijao x G40199). $BC_2F_2{:}_3$ seeds have been developed and will be subjected to *A. obtectus* feeding trials at OSU.

Seeds from 167 BC_2F_2 lines from the cross ICA Pijao x G40199 were screened for resistance to *A. obtectus* in Malawi by the National Program in Chidetze. The results indicated that seeds containing the novel protein demonstrate a delay in days to adult emergence and reduced emergence of F_1 adults. These results need to be repeated, however, using non-segregating families of $BC_2F_2{:}_3$ for the presence or absence of the seed protein. Very few lines from these materials were found to express the same level of resistance as the wild parent G40199 despite the presence of the novel lectin-like protein from tepary bean in their seeds. This suggests that the novel seed protein may not be the only factor conditioning resistance to the weevils. It is hypothesized that these proteins alone or in conjunction with other proteins or polypeptides may be among the factors contributing to resistance to bruchids in tepary bean accession G40199.

From a natural infestation of *A. obtectus* in OSU green bean breeding program, a bruchid colony has been successfully established for evaluating arcelin containing materials in Oregon. Bruchid screening is currently being conducted at OSU of non-segregating populations of inter-specific hybrid seeds for backcross lines from ICA Pijao, and Rojo $BC_1F_2{:}_3$ containing the introgressed novel tepary bean seed protein.

An additional generation of advance of the Arl-2 and Arl-4 Rojo backcross lines was performed, with selection to fix *phaseolin* null with the appropriate arcelin allele. This material will be provided to the SUA breeding program in December of 2006. Some of this material has already been supplied to Jim Beaver in the LAC breeding program, and germplasm of the new ICA Pijao with tepary resistance will be made available to LAC and Africa programs after the genes for resistance have been stabilized.

ESA6-A2

Bean/Cowpea Collaborative Research Support Program
East and Southern Africa Regional Project

The Use of Marker-Assisted Selection to Improve Selection Efficiency in East and Southern Africa and U.S. Programs

Principal Investigators and Institutions:
James Myers, Oregon State University, U.S.; Philip Miklas, U.S. Department of Agriculture--Prosser, U.S.; James Bokosi, Bunda College of Agriculture, Malawi; Susan Nchimbi-Msolla, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions:
Robert Mabagala, SUA, Tanzania; Wilson Musuku, Bunda College, Malawi; Catherine Madata, Uyole ARI, Tanzania; Deidre Fourie, ARC-Grain Crops Institute, Potchefstroom, S. Africa; Bert Vandenberg, University of Saskatoon Canada; Ken Grafton, North Dakota State University, U.S.

Justification and Objectives

While improved varieties have been developed in Tanzania and Malawi by the Bean/Cowpea CRSP, additional efforts are needed to develop multiple disease and pest resistant materials by pyramiding useful traits. Current varieties generally have resistances to Bean Common Mosaic Virus (BCMV) and Bean Common Mosaic Necrosis Virus (BCMNV), rust, and in some cases, Halo Blight (HB). The focus of the Tanzania and Malawi breeding programs now is on adding resistance to Angular Leaf Spot (ALS), Common Bacterial Blight (CBB), and root rots. These diseases are similar in that resistance is quantitative, making it difficult to achieve rapid progress. However, recent progress in identifying molecular markers (especially for CBB) has increased the efficiency of breeding for these diseases. For other diseases such as anthracnose, the genetics of resistance have been elucidated, but the best sources of resistance have not been widely used.

Selection of markers linked with known resistance genes and Quantitative Trait Loci (QTL) can accelerate development of multiple resistant varieties. A number of molecular markers for common bean have become available with recent research efforts on a number of diseases (Miklas, 2005). There are, for example, three molecular markers for genes for BCMV, two for bean golden mosaic virus, one for beet curly top virus, six each for anthracnose and rust, three for white mold, two for ALS, and seven QTL for CBB. Not all loci are appropriate for broad spectrum disease resistance in Africa. In addition, some markers are polymorphic only in one center of origin or between centers of origin. For example, the Ur 5 block of genes is holding up well to rust races found in Africa, but other genes used individually break down. The SCAR marker SI19 is associated with the Mesoamerican origin of the Ur 5 block, and is lacking in Andean germplasm. This inter gene pool polymorphism can be exploited to transfer Ur 5 into the large-seeded Andean types that are widely preferred in East and Southern Africa.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Continue crosses for marker-aided selection of CBB, BCMNV, rust and anthracnose into elite African materials.
- Cross lines with HB resistance to develop RIL populations for marker identification.
- Screen RIL populations for root rot resistance.

Research Approach, Results and Outputs

Crosses for marker-assisted selection: A total of 360 BC_3 F_4 progeny lines were generated by marker-assisted backcrossing for SU91 and SAP6 markers linked with QTL for CBB resistance. These lines were subjected to both greenhouse pathogen testing and field testing for reaction to CBB in Makhathini, South Africa in 2006. A majority of the lines suffered from severe halo blight infection which emphasizes the need for multiple disease resistance in African varieties. Nonetheless, 130 BC_3F_5:$_6$ lines were harvested for further evaluation of field reaction to CBB. In addition, white kidney germplasm with high levels of CBB resistance due to SAP6 and SU91 QTL were developed for U.S. breeders.

Some of the promising CBB resistant lines above were used in crosses with sources of halo blight resistance to initiate development of breeding lines with resistance to both bacterial blight diseases. F_2's have been generated from crosses between LY-90, Nasaka, Uyole-96, Uyole-98, Kablanketi, and Maluwa as recurrent parents and Edmund, PI150414, and Kranskop-HR1 as halo blight resistance donor parents. Resistant F_2 will be backcrossed to the recurrent parents. This represents a traditional backcrossing effort to improve halo blight resistance which is necessary due to the lack of genetic markers. First backcrosses were completed with Rojo (Edmund and PI150414) and the F_2's became available for screening and further backcrosses in December 2006.

Advanced BC_3F_2 populations with putative Co-42 gene introgressed by MAS were screened by the pathogen in the greenhouse (by Kelly at MSU). Eight $BC_3F_{2:3}$ progenies were identified possessing the anthracnose resistance gene, which were subsequently increased in the field in Prosser, WA.

Similar BC_3F_2 populations were screened for presence of the Ur-5 and Ur-3/Ur-11 rust resistance genes by the pathogen in the greenhouse (by Steadman at Univ. of Nebraska). Sixty-five of the $BC_3F_{2:3}$ lines with resistance were sent to South Africa for further pathogen testing to confirm resistance to African race isolates. During MAS backcrossing it has been noted that plants selected with SK14 marker for Ur-3 gene have exhibited vigor problems associated with dwarf lethality. This association, if confirmed, between Ur-3 and lethality when present in an Andean background will hinder deployment of this gene in African germplasm.

Direct pathogen screening with BCMNV strain NL-3 (K) identified BC_3F_2 plants fixed for the bc-3 gene in large red, red mottled, purple speckled, yellow and sugar types. F_3 progenies from the resistant plants have been distributed for further evaluation and selection in Tanzania and Malawi in 2006. In addition, 23 $BC_3F_{2:3:4}$ lines with bc-3 resistance were increased in the field at Prosser, WA, to generate additional seed for distribution to ESA breeders. The success of the increase indicates that certain African materials can be successfully grown in the U.S. For selected lines, the presence/absence of the hypostatic I gene will eventually be determined by marker-assisted detection using the SW13 marker.

A RIL population developed by Miklas is being used in collaboration with CIAT (M. Blair) to search for a more applicable marker linked with bc-3 in cis-orientation, but to-date no markers have been found. However, the population was useful for characterizing resistance to Clover yellow vein virus which appears to be linked in coupling with the bc-3 gene.

Outputs: Advanced backcross lines (~130 BC_3F_6) derived by MAS and pathogen testing with common bacterial blight resistance and separate lines (~23 BC_3F_4) with resistance to BCMV and BCMNV in six major East African market classes; advanced backcross populations (65 BC_3F_3) derived by MAS and pathogen testing for rust resistance which await pathogen testing against African rust isolates. Eight BC_3F_4 lines similarly derived with Co-42 gene for resistance to anthracnose, which await distribution to ESA breeders. Traditional backcrossing of halo blight resistance into African recurrent parents initiated with one parent Rojo has advanced to the BC_1F_2 generation. White kidney germplasm with resistance to CBB conditioned by SAP6 and SU91 linked QTL developed for the U.S.

Development of RIL populations for marker identification: Six RIL ($F_{5:6}$ or $F_{6:7}$) populations segregating for the different halo blight resistance genes Pse-1, Pse-2, Pse-3, Pse-4, pse-5, and QTL have been generated (Canadian Wonder (CW)/A53, CW/A52, CW/UI-3, CW/A43, CW/Tendergreen, and CW/PI 150414). Screening of the six RIL populations with differential races of the pathogen has been completed. Genetic analysis of the resistance segregating in the populations is being conducted. A partnership with Canadian researchers (B. Vandenberg, K. Brett) was initiated for tagging and mapping the resistance QTL segregating in the CW/PI 150414 RIL population.

Genes for resistance to halo blight were placed on the core linkage map. The Pse-1 gene from UI-3 was linked with three SCAR markers and placed on linkage group B10. A gene derived from BelNeb-RR-1 with reaction similar to Pse-1 was tagged with a SCAR marker and mapped to linkage group B4. Thus, the genes from UI-3 and BelNeb-RR-1 thought to be the same were actually independent. Recent allelism tests in the F_2 generation for BelNeb-RR-1/UI-3 cross support presence of two independent dominant genes conferring resistance to the same races 1, 5, 7, and 9. The Pse-? gene from BelNeb-RR-1 appears to consist of a block of tightly linked genes conditioning resistance to different races of the pathogen. The Pse-? gene putatively maps in the Minuette/OSU5630 RIL population to B4 but only confers resistance to Race 1 whereas the Pse-? gene in BelNeb-RR-1 confers resistance to races 1, 5, 7, and 9. A new discovery was the broad-based resistance of Pse-2 gene in A43 differential to Races 2, 3, 4, 5, 7, 8, and 9. The Pse-2 gene, similar to Pse-3, conditions an HR response to Races 3 and 4. A SCAR marker linked with the Pse-2 gene has been developed but its map location has not been confirmed. The recessive resistance to Race 8 thought to be conditioned by pse-5 is actually conditioned by a gene completely linked with Pse-2 and perhaps is a gene block at this locus.

Outputs: Six RIL populations generated and characterized for halo blight reaction; four previous RIL populations Raven/I9365-31, BelNeb-RR-1/A55, Minuette/OSU5630, and Montcalm/G122 characterized for disease reaction to the core set of nine differential pathotypes (races); three halo blight resistance genes located on the core linkage map; SCAR markers developed for MAS of the Pse-1, Pse-?, and Pse-2 genes, and the broad based resistance of Pse-2 to 7 or 9 differential races of the pathogen represents a new discovery.

Single crosses (~20 F_1) generated between Rojo and different sources of resistance to halo blight CAL 143, Edmund, PI 150414, and HR-Kranskop to initiate introgression of a broad base of halo blight resistance into African germplasm have been advanced to the F_2 generation, and resistant F_2 plants were backcrossed to the recurrent parent to generate ~20 BC_1F_1 for the next cycle of screening the BC_1F_2 with resistance for backcrossing to the recurrent parent.

Screen populations for root rot resistance: A total of 197 lines, including checks, were grown in a root rot trial at the Vegetable Research Farm, Prosser, Washington. Material consisted of B7030, B7126, B7239, and B7732-39 series lines (BBL crosses to FR266, a root rot resistant kidney line), two DM4NY lines, NY5517, RR4270, two SB lines, two WIS RR lines, GF series (RIL population developed from the cross Goldcrop x FR266), and the GW series (RIL population from the cross Goldcrop x WIS 46 RR). Evaluations were made in late summer and early fall on root rot resistance, plant growth habit, and pod fiber. Root rot resistance was measured on a 1-9 scale, with 1 = very light surface infection and 9 = roots mostly dead and plants stunted. Plant growth habit was rated as either type I (determinate upright bush) or type III (indeterminate trailing plant). Pod fiber was scored as high, medium, or low. Each line was replicated in two plots, and the resistant (RR6950) and susceptible (5446) checks were replicated in 11 plots.

The GW population is being used to map quantitative trait loci associated with resistance to root rot. Forty-one GW lines were included in the 2006 root rot trial (the remaining 17 lines in this population were planted for seed increase) and we have data on the entire population (n=58) for the year 2005. This will allow us to perform QTL analysis using mapping and bulk-segregant screening. To accomplish this, DNA has been extracted and quantified from the entire GW population and screening of microsatellite (SSR) markers for mapping is beginning.

A second population under development (RR6950/OSU5446) was advanced by a single seed descent from the F_4:F_5 in the field in 2006.

Building on Latin America and Caribbean Project's Accomplishments

The Latin America and Caribbean Basin Regional project (LAC) of the Bean/Cowpea CRSP is comprised of six components involving five U.S. lead universities who are collaborating in research and training activities with national agricultural research programs and universities in many countries in the region. Following a value-chain approach, research foci range from enhancement of demand and market opportunities for beans and value-added bean products, health and nutritional impacts of beans, gender and participatory bean breeding, genetic improvement for improved adaptation to low fertility soil, development of sustainable disease management strategies and genetic improvement of beans for both lowland and highland production regions including enhanced disease resistance utilizing tools of modern molecular genetics. Scientific achievements, outputs and impacts of the LAC Regional Project during FY 06 are summarized and highlighted in this Section.

U.S. AND HC INSTITUTIONS PARTICIPATING IN THE LATIN AMERICA/CARIBBEAN REGIONAL PROJECT

Cornell University

Michigan State University (MSU)

Pennsylvania State University (PSU)

Purdue University

University of Nebraska (UN-L)

University of Puerto Rico (UPR)

Centro para el Desarrollo Agropecuario y Forestal (CEDAF), Dominican Republic

Centre de Recherche et de Documentation Agricole (CRDA), Haiti

Escuela Agricola Panamericana (EAP), Honduras

Instituto de Ciencia y Tecnologia Agricolas (ICTA), Guatemala

Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador

Instituto Nicaraguense de Tecnologia Agropecuaria (INTA), Nicaragua

Universidad de Costa Rica (UnCR)

University of West Indies (UWI), Jamaica

LAC1-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Assessment of Constraints to Expanding Bean Supply in Central America

Principal Investigators and Institutions:
Richard Bernsten, Michigan State University, U.S.

Collaborators and Institutions:
Juan Carlos Rosas, EAP, Zamorano, Honduras; Jim Beaver, University of Puerto Rico, U.S.; Abelardo Viana Ruano, Guatemala; Roy Black and James Kelly, Michigan State University, U.S.; Peter Jones, CIAT; Juan Carlos Hermandez, INTA/MAG, Costa Rica; Scientists associated with the National Bean Programs in Central America

Justification and Objectives

To document impact and gain insight regarding traits that need to be incorporated into future varieties, bean scientists require continued feedback regarding the on-farm performance of newly-released bean varieties. Periodic farmer-level surveys will be carried out to collect data required to monitor the performance of improved varieties compared to traditional varieties.

Throughout Central America, farmers have limited access to improved bean varieties. In order to relax this constraint to higher yields, private/commercial seed production and distribution must be developed. Feasibility studies will be carried out to assess the potential to contract small farmers to produce high quality seed and contract input dealers to market this seed.

To establish future research priorities, scientists require a holistic understanding of the region's bean-farming systems, characteristics of the bean subsector, and key environmental, abiotic, and biotic constraints to increasing bean productivity. These data (expert opinion and GIS databases) will be collected from national bean program scientists, Bean/Cowpea CRSP PIs, and CIAT scientists, and will be used to compile a Bean Atlas of Central America, the Caribbean and México (which will include basic data for Canada and the U.S.).

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Characterizing the dispersion of abiotic and biotic constraints in the Americas (Bean Atlas).
- Assessing constraints to increasing bean production, productivity, and marketed surplus in Guatemala.
- Assessing the impact of participatory plant breeding in Honduras.
- Assessing the adoption of improved bean varieties in Costa Rica.

Research Approach, Results and Outputs

Bean Atlas: During FY 06, dot maps were created to show the relationship between bean-growing regions in the Americas and various agro-climatic factors and abiotic and biotic stresses; and socioeconomic data were compiled to document the role of beans in each country's agricultural economy. Dot maps have been created for most factors that are important for characterizing bean growing environments in Central American countries. In addition, dot maps have been created that show the distribution of the bean production areas in Argentina, Brazil, and Ecuador.

Socioeconomic Data: For all countries in the Americas, data have been collected to document recent trends in socioeconomic characteristics, land use, area planted to the 10 major crops, harvested bean production area and yield, bean imports and exports (totals and by country of origin/destination), and the principal growing seasons in each country. These data have been used to create tables and charts (.jpg, .gif, .htm files) that display trends in these data. Country-level data for bean production, area, imports, and exports have been aggregated to create charts that show each country in the Americas share of the total. Photos of all major market classes grown in the region have been formatted into .jpg files and data have been compiled to show the major market classes grown in each country of the Americas. For Central American countries, data showing recent bean varietal releases has been formatted in .htm. A directory of, and contact information for, bean program leaders has been compiled for most countries.

Additional dot maps are being created for the remaining countries. Once these dot maps have been completed, the dot maps and the socioeconomic data will be compiled into www pages for each country of the Americas.

Assessment of constraints to increasing bean production, productivity, and marketed surplus in Guatemala: Black beans (*Phaseolus vulgaris*) are the main bean type consumed in Guatemala. Due to their important role in the diet of the great majority of the Guatemalan population, most of dry bean research is focused on black beans. However, black bean prices tend to be lower than for other less consumed bean types. As a result, farmers looking for higher profits are increasing their production of beans of other market classes (e.g., small red, white) and non-*P. vulgaris* dry bean species (e.g., *P. coccineus*, *P. dumosus*). Species of non-*P. vulgaris* ("piloy") are cultivated primarily in the highlands–planted in May and harvested in December or January, and are sold in both highland markets and open air markets in Guatemala City. Just as dry bean research has focused more on *Phaseolus* spp. than on other non-*Phaseolus* types, market research and reports available by the Guatemalan Ministry of Agriculture also only seek to provide timely price monitoring data on black, small red and white market classes. Market information on "piloys" is non-existent, despite their importance to farmers and consumers, especially those in the Guatemalan western and central highlands. This study collected and analyzed information on the "piloy" market class sold by vendors in local markets where traded.

Characteristics of Non-Common Beans: Vendors refer to non-common beans by their common names. In most of the western/central highlands, they are known as "piloy" and in few markets in the central highlands as "furuna." While grain size vary from medium-to-large, colors range from solid black or solid red to red with black speckles or black with white speckles. Vendors reported that consumers prepare them in special dishes for special occasions, in combination with pork and other local spices (e.g., ground roasted pumpkin seed). Most consumers eat them regularly--once a week to once a month. Consumers value quality based on freshness, absence of broken beans, and sorting of color. Vendors' displays emphasized these characteristics by showing the most red, or the blackest "piloy" in the biggest sizes, although vendors indicated that during low-production months (June-November) all sizes are sold consistently.

Market Trends: The relative prices of common beans vs. "piloys" varied among markets. In some regions "piloys" were more expensive, while in other regions their price was the same as or higher that common beans. Seasonal availability of "piloys" is determined by the rainy season--beans planted in May are harvested from the first week of December to the last week of January. About 89% of the vendors interviewed offer "piloys" 10 months a year. However, as supplies decline from June-November, prices double--from a mean low price of Q2.84/lb to a mean high price of Q5.14/lb. Assuming that growers with access to irrigation can plant a few months earlier, the June-November season could represent a good market opportunity where prices are high. While prices were relatively uniform among venders in a single municipality market, they varied greatly among departments. Vendors could not provide detailed information as to why this was the case. In general, average prices were highest in markets far away from the major production areas, due to the presence of more intermediaries. For example, the highest mean price (Q7.0/lb.) was observed in the Department of Chimaltenango. Buyers in Chimaltenango bought from wholesalers, who gathered and sorted "piloys" from scattered growers in the Department of Solola. In contrast, the mean price of "piloys" in Solola was only Q2.37/lb.

Vendors' Supply Sources and Characteristics: The Departments of Solola and Totonicapan supply around 36% of "piloys" traded in the highlands. Vendors' purchases of common and "piloy" beans are cash transactions. Supply transactions for "piloys" are largely between grower and retailer (71%), as growers bring it early on market day. The rest is traded by wholesalers located within the open markets' bean trading section. In contrast, vendors mainly obtain common beans from intermediaries. On average, vendors purchased (cash only) "piloys" once a month and tended not to store them for longer than two months--despite the venders assertion that "piloys" can be stored for an average of five months before storage grain quality deteriorates (i.e., corrugated seed coat). Vendors reported making an average profit of 7% on "piloy" sales—which suggests at least 70% of farmers supplying directly to wholesalers receive the benefits of the fluctuating market prices. Since off-season "piloys" could be an alternative for some farmers with irrigation capability, this markup over purcase prices are key for further analysis.

Socioeconomic Characteristics of Vendors: While common beans and "piloys" are primarily sold by vendors with a permanent booth in the municipal open market, they are also sold by street venders. Most venders were women (64%), with an average age of 38 years, compared to 44 years for men. Typically, the vendors had limited education. Among the sample, all of the vendors sold both beans and a variety of other products (e.g., spices, other grains).

Research Implications: This initial study to profile the non-common bean industry in Guatemala highlights several opportunities for increasing the incomes of "piloy" vendors, wholesalers, and producers. First, the high difference in prices across departments between on and off seasons could represent profitable opportunities for small farmers with access to irrigation for off season production willing to enter into more commercial production systems of "piloys." Second, the disparity of prices across departments during on and off seasons hints opportunities for wholesalers in low-price areas to increase their distribution capacity to areas with high prices where more constant supply may promote higher consumption rates of "piloys." Finally, to-date, no research has been conducted to identify and address farm level constraint to increasing the productivity of "piloys." Given the strong consumer demand and the high price that these species command, ICTA should initiate a farm-level survey designed to assess/prioritize production constraints and consider the feasibility of developing a research/breeding program to address these constraints.

Assessing impacts of participatory plant breeding (PPB): In Honduras, village-based research groups (CIALs) have been established in many communities throughout the country. Each CIAL identifies specific research activities to pursue and all CIAL members participate in all of these initiatives. CIALs which have identified PPB as one of its activities implement this activity under the supervision of an NGO.

Key informant Interviews: Key informant interviews were conducted with staff associated with the National Bean Program and to gain a better understanding of the history of both PPB and conventional plant breeding (CPB), the costs and benefits of each methodology, and their strengths and weaknesses. In addition, key informant interviews were carried out with staff from the NGOs which were managing the PPB project.

Farmer Surveys: Fieldwork was carried out during FY 06 in two study areas—Yorito in Yoro Department and Lago de Yojoa in Santa Barbara and Comayagua Departments--located in the Middle North and Middle West parts of Honduras, respectively. Initially, visits were made to the office of the NGO managing the PPB project in each of the study areas--FIPAH (Fundacion para la Investigacion Participativa con Agricultores de Honduras en Yorito) and PRR (Programa de Reconstruccion Rural in Lago de Yojoa) to present the study to the participating farmers/NGO staff, pre-test the questionnaire, gain additional insights about the history of CIALs and PPB, identify the CIALs to work with, and select a sample of farmers/respondents. In each location, all CIALs which had been working on beans PPB were selected. However, as more farmers in Yorito had participated in the PPB project, 75% of the Yorito participants were selected vs. 87% in Lago de Yojoa. Also, in each location an equal number of non-PPB farmers (not members of a CIAL) were selected as a control group. The total sample included 58 PPB participants and 57 non-PPB participants.

Preliminary Results: In the past, farmers in the study area have had opportunities to participate in a variety of agricultural projects. During the past five years, 38% of the PPB farmers had participated in another agricultural project before joining the CIAL, whereas about 40% of the control group had previously participated in an agricultural project—suggesting that both groups of farmers are similar in terms of their interest in participating in agricultural projects.

Varieties bred using PPB techniques are released by the CIALs. Since the PPB project was initiated, CIALs have released three varieties and bred two additional varieties which are in the process of being released. Farmers' awareness of these varieties varied greatly among respondents. Among the PPB farmers, 91% knew the name of at least one of these varieties, 28% could name two, and 40% could name three of these varieties. In contrast, among the control group, only 30% knew the name of one PPB variety, 35% could name two, and none could name three of these varieties. These results suggest a need to give greater priority to increasing awareness among farmers who are not members of the CIAL regarding the availability of PPB varieties.

A major goal of PPB is to provide farmers with training in bean production-related activities. During the past five years, 93% of the PPB farmers had received some training, vs. only 12% of the control group. With respect to specific knowledge about how to make bean crosses, 10% of the PPB farmers and 4% of the control group had a vague idea and while 9% of the PPB farmers and none of the control group could describe in detail how bean crosses are made. Among all respondents, only 4.3% had actually made bean crosses, 11.3% had made maize crosses, and none had made crosses of another crop. Among respondents who had made bean crosses, 60% were PPB farmers and 40% were from the control group. These results suggest that the project has done a good job of providing bean-related training for PPB farmers, but more effort should be made to encourage other farmers to participate in the CIAL's training activities. While it may appear that there is a need for more training in how to make bean crosses, this is not one of the goals of the PPB project.

Unless farmers are aware of the benefits of planting clean bean seed, they will continue to plant farmer-saved grain as seed. Among the sample, farmers' knowledge of the differences between sowing grain vs. seed (i.e., consequence of sowing grain vs. seed on yield) also varied. Of the PPB farmers, 98% identified at least one benefit and 59% reported >two benefits; whereas in the control group 90% identified one benefit but only 21% reported >two benefits. Farmers' knowledge about activities required to produce high quality bean seed (i.e., absence of disease, heavy grains, filled pods, higher yield, uniform seed) also varied among respondents. Among the PPB farmers, 91%, 57%, and 34% identified 1, 1-3, and >3 activities, respectively. In contrast, among the control group, 72%, 65%, and 7% identified 1, 1-3, and >3 activities, respectively. These results suggest that farmers involved in PPB, compared to the control group, are both more aware of the benefits of planting clean seed and know more about the field management practices which are required to produce clean seed.

A goal of the PPB project is to produce seed of PPB varieties and make them widely available to other farmers in the community. Among PPB farmers, 33% had sold seeds of PPB varieties, 28% had given seeds to other farmers, 9% had bought PPB seeds, and 38% had received (for free) seeds of PPB varieties. In contrast, among the control group, 4% had sold seeds of PPB varieties, 9% had given it to other farmers, 14% had bought PPB seeds, and 19% had received (for free) seeds of PPB varieties. These results suggest that a greater effort is needed to increase seed interchange—both within the community and across communities—in order to encourage adoption of the PPB varieties. Greater diffusion is constrained by the fact that only limited quantities of PPB varietal seed are available. Thus, there is a need to increase the amount of seed produced for the "Releasing Day," so more of the farmers who participate in this event can obtain a free sample of the PPB varieties.

Adoption of Improved Bean Varieties in Costa Rica: In 2004, an adoption study was carried out in the Southern Brunca region of Costa Rica, designed to document the adoption of recently released improved bean cultivars (i.e., Bribri- 2000, Cabecar- 2003, Telire, 2004). A complementary study is currently being conducted in two localities of the North Huetar region (Upala and Los Chiles), two of the main bean-production zones in the North Huetar region, where 879 bean producers are located. A total sample of 199 farmers are being surveyed--stratified across 14 communities in the localities of Upala (Pueblo Nuevo, La Victoria, Jomusa, Villa Hermosa, La Union, San Jose and San Ramon), La Cruz (Piedras Azules) and Los Chiles (Cuatro Esquinas, Medio Queso, El Amparo, San Pablo and Los Chiles). The number of farmers surveyed in each community ranges from 12 to 18. A questionnaire, similar to the one used in the 2004 adoption study conducted in the Southern Brunca region, is being used to collect data from the sample of farmers about their bean production activities in both the primera and postrera seasons during the past three years. Data being collected includes area planted in beans by individual farmers, varieties grown, year of adoption, production, advantages/disadvantages of planting improved varieties, and socioeconomic information on farmers. These data will be analyzed in three steps, using descriptive statistics, a logistic function of adoption to identify factors that determine the probability of adoption, and calculation of the probability of adoption for the identified factors and reported in the FY 07 annual report.

LAC1-A2

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Enhancement of the Sustainability of Bean Production Systems Through Technology and Policies that Improve Production Management

Principal Investigators and Institutions:
Scott Swinton, Michigan State University, U.S.; Eduardo Peralta, INIAP, Ecuador

Collaborators and Institutions:
Julio Lopez, EAP-PROMIPAC, Nicaragua; Alredo Rueda, EAP, Zamorano, Honduras; Cristian Subia, INIAP, Ecuador

Justification and Objectives

Common bush beans (*Phaseolus vulgaris*) constitute the mainstay of both household diets and crop cash income in the Chota and Mira river valleys of northern Ecuador. Intensive bean production during two seasons per year on 10,000 ha in the region relies upon heavy pesticide use, typically on a prophylactic, calendar spray basis. Research on Ecuadorian potato production at higher altitudes in the same region has highlighted the hidden economic costs of health risks from misuse of pesticides (Crissman, et al., 1994, 1998; Yanggen et al., 2003). Exploratory research suggests that pesticide use on beans there may exceed necessary levels by 70% (Gately, 1995). These preliminary findings suggest that pesticides are a major source of cash input costs, and potentially also a significant source of health costs to Ecuadorian bean producers.

INIAP has already begun participatory research encouraging the adaptation and adoption of integrated pest management (IPM) methods in the Chota and Mira river valleys of northern Ecuador (INIAP, 2001). The IPM program focuses on the two major bean diseases, rust ("roya" or *Uromyces appendiculatus*) and anthracnose ("antracnosis" or *Colletotrichum lindemuthianum*), and three major insect pests, whitefly ("mosca blanca" or *Trialeurodes vaporariorum*), spiders ("ácaros") and thrips ("trips"). Progress toward adoption of new methods depends importantly on an understanding of the logic and values behind current pest management methods. Moreover, the efficacy of new pest management approaches and the resultant profitability and health effects on bean growers depend not only on the bean crop, but also on effects of rotation crops.

Beans in Nicaragua also face serious pest management challenges. The major pests facing bean growers are: (1) diseases, including web blight ("*mustia hilachosa*" or *Thanatephorus cucumeris*) and angular leaf spot ("mancha angular" or *Phaeoisariopis griseola*); (2) insect pests, including slugs ("babosa" or *Vaginilus plebelus* fisher), caterpillars ("*gallina ciega*" or Phyllophaga spp.) and bean pod weevils ("*picudo*" or *Apion godmani*; *Apion aurichalceum*); and (3) weeds, notably purple nutsedge ("*coyolillo*" or *Cyperus rotundus* L.). Integrated pest management (IPM) is widely expected to reduce the misinformed use of pesticides in beans and other crops, and hence pesticide-related health risks. After conducting traditional IPM extension programs for seven years in Nicaragua and three years in El Salvador, the IPM Project in Central America (PROMIPAC) began to use farmer field schools (FFS) to accelerate diffusion in 2001. By the end of 2003, 42 FFS had been implemented with around 960 farmers. Preliminary results show that FFS graduates increase their IPM knowledge by 40%, and facilitators report that farmers rely more upon natural enemies and have decreased the use of pesticides (PROMIPAC 2003). Due to significant resources invested in IPM extension via both FFS and other methods, there is considerable interest in whether these programs have been effective at combating poverty and reducing the health and environmental risks associated with pest management.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Reducing pesticide risk in bean systems of the Chota Valley, Ecuador.
- Analyze IPM technology adoption data among bean growers in Nicaragua.

Research Approach, Results and Outputs

Reducing pesticide risk in bean systems in Ecuador: During FY 06, the CRSP and INIAP analyzed data from 48 bean-producing households that were monitored for all cropping activities in FY 05. This analysis is being developed into an INIAP bulletin on the evolution of bush bean production over the past 15 years, with particular focus on pest management and associated risks to farmer's health.

Late in FY 06, the CRSP and INIAP began work on a survey of 132 farms to estimate the economic impacts (including impacts on farmer's health) of bean varieties resistant to bean rust and anthracnosis diseases that INIAP has released in recent years, with special focus on the Chota and Mira river valleys. The survey sampling frame of farms in 30 bean-producing communities is stratified by the presence of INIAP-bred disease-resistant bean varieties, with and without direct intervention by INIAP staff. Planning of the study, village-level sampling, questionnaire design, and questionnaire testing were completed during FY 06. The survey analysis aims to predict the rate of future adoption of disease resistant varieties, as well as household-level changes in profitability and fungicide exposure risks. Consolidating this information, MSU and INIAP will in FY 07 develop an impact analysis using the economic surplus approach.

Analysis of IPM technology Adoption Data in Nicaragua: The FY 04-05 impact assessment of the farmer field school (FFS) approach to training Nicaraguan bean farmers about integrated pest management (IPM) revealed that the field schools are effective at inducing adoption of IPM methods, especially insect scouting, botanical insecticides, and yellow sticky traps. Although farmers were largely aware of pesticide risks to human health, only farmers exposed to IPM training could recognize beneficial insects (a necessary condition for protecting these environmental assets). Despite widespread adoption of IPM practices, farmers exposed to field school training used pesticides that were no less toxic than other farmers, and their reported incidence of pesticide poisoning was no lower than among farmers exposed to other extension IPM approaches. The study also found that NGOs extending IPM methods differ substantially in their success at increasing farm incomes and reducing pesticide risk exposure. NGOs that are larger and have a longstanding commitment to agricultural pest management are more effective than smaller ones with less experience in agricultural pest management.

CRSP trainee Ricardo Labarta completed his Ph.D. dissertation based on the Nicaragua research (Labarta, 2005). He and PI Scott Swinton diffused the results of the Nicaragua study to different audiences through research presentations given at the 5th National IPM Symposium, St. Louis, April 4, 2006 (Labarta and Swinton 2006b, 2006c) and the International Association of Agricultural Economists (IAAE) 2006 annual meeting, August 12-18, 2006, Brisbane, Australia (Labarta and Swinton 2006a).

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LAC2-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Enhanced Bean Utilization in the U.S. and Central America

Principal Investigators and Institutions:
Suzanne Nielsen, Purdue University, U.S.; Ana Ruth Bonilla, University of Costa Rica, Costa Rica

Collaborators and Institutions:
Richard Bernsten, Michigan State University, U.S.; Wilfredo Dominguez, Zamarano University, Honduras

Justification and Objectives

Research in the past on bean nutrition and utilization has focused largely on nutrient bioavailability (especially on protein, starch, and mineral bioavailability), cooking time and using germination or fermentation processing technologies to develop bean-based weaning foods. Some efforts on these aspects of bean utilization remain relevant, especially in discussing with bean breeders as they screen germplasm for various traits. However, increased effort is warranted on bean-based ingredients and final products, using appropriate processing technologies. Product development work is essential to enhance the utilization of beans, making beans more available as food ingredients and as new food products. This has potential for impact, especially for the many large urban areas of the Latin American and Caribbean (LAC) region. Inexpensive bean-based, value-added products with long shelf-life have excellent market potential in LAC. Because of the cancer-fighting constituents of beans and the nutritional benefits known to be associated with beans (the health benefits associated with beans will be one focus of the nutrition project), bean-based products have great potential in the U.S. Research proposed on bean utilization must include consideration of market potential, nutritional value and consumer acceptance. Such work will create an interest in the private sector for beans as ingredients and processed products, leading to commercialization of products and increased consumption of bean-containing products.

This report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Continue to identify opportunities for development of bean-based ingredients and products.
- Assess consumer acceptance, nutritional value, physical properties and economic potential of bean ingredients and products.

Research Approach, Results and Outputs

Development of bean-based ingredients and products: As a result of the survey conducted in FY 05 in Honduras, product development efforts at Purdue focused on a bean and corn-based tortilla. Another product, a bean dip, is in the preliminary stages of product development. A focus group will be used to evaluate several bean dip prototypes, before further development and sensory panel evaluations in the U.S. and Costa Rica.

Because of consumer acceptability of the bean-based cookies as determined in earlier studies, further studies in Costa Rica were done to evaluate different bean treatments to allow for a claim as a functional food. Sensory evaluation was also performed. In preliminary studies on another product, bean pasta was shown to have a good acceptability among people with good nutritional and healthy habits. Because of that, a study was designed to develop pasta (farfallel) as a functional food.

Consumer acceptance, nutritional value and economic potential of bean-based ingredients and products: *Bean-corn tortillas*- At Purdue University, bean-corn tortillas were formulated using mashed cooked beans with masa flour, water, and other ingredients. "Masa" is the standard alkaline-treated corn used to make tortillas in Central America. Ingredients for cooking the beans included water, onions, green pepper, fresh garlic, and salt. The ingredients used to make the bean-corn and the corn tortillas are given in Table 1. The tortillas were formulated to create an acceptable product, but also keeping in mind the marketing value of being able to make nutrient content claims for the product (as defined by the Food and Drug Administration), specifically for protein, fiber, iron, and folic acid. Two tortillas containing approximately 50% by weight of either red (Lebaron) or white (navy, Seahawk) dry beans and the other 50% by weight of masa flour were developed and tested by several sensory evaluation panels to rate the acceptability.

Prior to doing acceptance tests of the bean-corn tortilla, a focus group of panelists from Central American

Abstracted from FY 06 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

countries was conducted at Purdue University to obtain suggestions for modification of a prototype of the tortilla made with red beans and masa flour. These suggestions resulted in modifications in the amount of gum and salt, weight of dough used to make the tortilla, and the time and temperature of cooking. A final suggestion to modify the color resulted in making another type of tortilla with white beans and masa flour.

Acceptance tests were conducted on the three tortilla types (red bean-corn, white bean-corn, and corn) utilizing three groups of panelists: people at Purdue University, students at Zamorano University, and village visitors to Zamorano University. Five attributes were evaluated using a nine-point hedonic scale: appearance, color, flavor, texture, and overall liking. Overall the tortilla made with white beans and masa flour had a similar level of acceptability compared to the corn tortilla (control) for the Zamorano University students and visitors. However, the people from Purdue University preferred the tortilla that contained white beans. Also, Purdue panelists gave lower scores for texture, flavor and overall acceptability for the tortillas than did the other two groups of panelists. The tortilla made with red beans and masa flour had the lowest acceptability for all panelist groups.

To determine if the color of the tortilla could influence the scores given to other attributes such as flavor, texture, and overall liking, a small study was conducted with Latin American people at Purdue University. Three types of comparisons between means of the panelists' scores were done for each of the attributes evaluated for the three tortilla types, when panelists either looked at the tortillas (i.e., using white light) or did not look at the tortillas (i.e., using red light, and covering tortillas with aluminum foil). Results showed that looking at the samples did not influence the scores given for flavor, texture, or overall liking. The differences in scores for each attribute between tortilla types could be due to other factors such as mouthfeel, aftertaste, etc. While the bean-corn tortillas developed and tested showed promise from the sensory panels, they would need to be improved because results of the acceptance tests showed that they do not have an extremely favorable rating.

The bean-corn tortilla developed with either red or white beans could be a low cost and highly nutritious bean-based food product. The formulation used would allow for nutrient claims of a good source of fiber and iron and an excellent source of folate. Based on some facts and assumptions about costs of ingredients, direct production costs per tortilla for a corn vs. bean-corn tortilla in the U.S. would be $0.009 vs. $0.021, and in Honduras it would be $0.010 vs. $0.017.

Bean and wheat cookies: The evaluation of bean treatments for the production of bean and wheat cookies was completed in Costa Rica in FY 06. The objective was to evaluate the effect of different bean treatments on consumer acceptability and the characteristics of bean-wheat cookies as a functional food. The bean treatments evaluated were: soaked ground beans, raw bean flour and cooked bean paste. Trypsin inhibitor and alpha-amylase inhibitor activities were evaluated to determine if the baking process was adequate. The RDS, SDS, RAG, SAG, dietary fiber, resistant starch, and antioxidant capacity were evaluated to determine the potential of the cookies as a functional food.

The baking process was adequate to eliminate trypsin inhibitor as well as alpha-amylase inhibitor activities. The partial substitution of bean for wheat flour decreased the amount of RDS and increased the amount of SDS. Also, the bean-wheat cookies showed higher values of resistant starch and dietary fiber than wheat flour cookies. This is very important for people who need to reduce weight, because foods with higher dietary fiber levels and lower values of RDS produce satiety for longer periods of time. Also, lower values of RAG and higher values of SAG are an indication of lower glycemic index products. Resistant starch and dietary fiber also were higher in the bean-wheat cookie than the wheat cookie. The partial substitution of wheat flour for beans in cookies increased the antioxidant capacity of the cookies from 10.9 to 26-30.8 mol of Trolox/g of cookie, as is basis.

To determine consumer acceptability, an affective analysis with 105 persons was done. The cookies evaluated were prepared with 1:1 wheat flour and different bean (dry base) treatments (raw bean flour, soaked bean gruel, and cooked bean paste). The cookies were evaluated by 57 women and 48 men between 17 and 50 years old. The panelists were regular cookie consumers and had no sensory evaluation experience. Consumer liking or disliking preference was evaluated using a 14 cm scale with the observation "I dislike it very much" at the left end, and "I liked it very much" at the right end. Every consumer evaluated the three different samples. The consumers were grouped in four segments according to their preferences. Segment 2 consisted of 16 persons who gave similar scores to all three types of cookies. The rest of the segments of consumers were more discriminative. All four segments of consumers gave the highest scores to cookies made with raw bean flour.

Bean and semolina pasta: The objective of this research was to develop bean and semolina pasta with good nutritional properties. A preliminary study was done formulating fresh pasta with a 25% and 50% semolina substitution for bean flour. Resistant starch and trypsin inhibitor contents were evaluated. The results showed that an increase in the bean substitution increased the resistant starch content in the developed pastas. Trypsin inhibitor was destroyed by the pasta cooking process. At the present time, a M.S. student is in the process of evaluating the contents of resistant starch, RDS, SDS, dietary fiber, antioxidant capacity, presence of oligosaccharides, trypsin inhibitor, and alpha-amylase inhibitor. Also, a study with consumers on the pasta concept will be done.

Bean-rice chips and cookies: The bean-rice chips were evaluated for the following carbohydrate components: RDS, 21% ± 1.5%; SDS, 25.4% ± 1.8%; resistant starch, 24% ± 0.7%; and total starch, 54.2% ± 2.3%. Antioxidant capacity also was measured at 31.6 ± 3 ORAC (mol of Trolox/g of chip, as is basis). Also, antioxidant activity was determined for bean-rice cookies (additional to last year's evaluation) with a resulting value of 36.7 ± 3.4 (mol of Trolox/g of cookie, as is basis).

Marketing study: The project with the rural women's association (Asociación de Mujeres de San José del Amparo) has started slowly because the group is trying to obtain some financial support to improve their infrastructure. The project is in conjunction with a non-profit organization (Coordinadora de Mujeres Campesinas) working with rural women to develop small businesses. The association is located in the Northern Costa Rican bean-growing area. A marketing study was performed in this region where the women's group is located. The study indicated that cookies in general are consumed by the entire family. Results showed that consumers would most likely buy cookies in supermarkets, then in small grocery or cafeteria-like places, and lastly in the school. One of the problems the women would face in marketing the product is the high consumption of cookies produced by multinational companies. The study also pointed out the importance of the distribution channel for a successful enterprise.

The University of Costa Rica through the Technological Transfer Office is working to license the bean products to women cooperative groups. At the present, two brands have been registered, “Pintochips” for the bean-rice chips and “Pinticas” for the bean-rice cookies. Through this model, the University of Costa Rica is trying to protect the developed products for transfer to small-scale women producers.

Evaluation of different analyses for the bean matrix: The protocol utilized for measurement of antioxidant capacity was the ORAC assay (oxygen radical absorbance capacity). Carbohydrate-based protocols were used for assay of rapidly digestible starch (RDS), slow digestible starch (SDS), rapidly available glucose (RAG), and slow available glucose (SAG). Both types of analyses are important to claim that the developed product have health benefits as functional foods.

Effect of Hard-to-Cook Phenomenon on the Content of Simple Phenolic Acids and Antioxidant Activity of Beans: Researchers within the Bean/Cowpea CRSP and elsewhere have been studying the anti-cancer benefits of beans. These anti-cancer benefits have been attributed to the following components of beans: folate, fiber, flavonoids (anthocyanins), lignin, tannins, phytic acid, hydroxycinnamic acid related compounds, and benzoic acid related compounds. At least several of these components also have been linked to the hard-to-cook (HTC) phenomenon of beans, which occurs when beans are stored under high temperature and high humidity condition, resulting in greatly increased cooking times. Specifically, phytic acid, hydroxycinnamic-related compounds, and benzoic acid-related compounds have antioxidant activity, and have been linked to both the HTC phenomenon and the anti-cancer benefits of beans. Therefore, the content and antioxidant activity of these acids was measured in select varieties of black (T-39), red (Lebaron), and white beans (navy Seahawk), stored under normal conditions and under high temperature-high humidity conditions to create the HTC phenomenon. These free and bound phenolic acids were extracted from beans, then quantitated by high-performance liquid chromatography (HPLC) with an electrochemical detector, and the antioxidant activity measured using the Trolox equivalent antioxidant capacity assay (TEAC).

Results showed that storage conditions to create the HTC phenomenon did not affect equally the content of free, alkaline, and acid hydrolysable phenolic acids and their antioxidant capacities from all bean varieties. Most affected were the free and acid hydrolysable phenolic acids of black beans, probably caused by crosslinking of the phenolic acids with proteins or carbohydrates. Increases in the concentration of p-coumaric, ferulic and sinapic acid were identified by HPLC analysis within the free phenolic acids for all three bean varieties (data not shown). In general, the total content of phenolic acids was highly correlated to the antioxidative activity, and this correlation was much higher between the total content of free phenolic acids and the antioxidant activity ($r = 0.88$ for both control and HTC beans), rather than for alkaline or acid hydrolysable phenolic acids. Based on the results of this study, the black beans could represent the best source of phenolic compounds with good antioxidant capacity among the varieties tested. This variety had the highest antioxidant capacity for all three fractions of the phenolic compounds.

Tables/Figures:

Table 1. List of ingredients used to make corn-beans and corn tortillas.

Tortilla Type	Ingredients	Amount (grams)
Corn-beans tortilla[a]	Dry beans	100
	Masa flour (MASECA)	100
	Carboxy methyl cellulose (CMC)	0.45
	Water to dissolve CMC	110
	Salt	3
	Water to dissolve salt	40
Corn tortilla[b]	Masa flour (MASECA)	100
	Carboxy methyl cellulose (CMC)	0.15
	Water to dissolve CMC	110
	Salt	1.5
	Water to dissolve salt	20

[a] Yield 12 tortillas.
[b] Yield 6 tortillas.

LAC3-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Increasing Knowledge on the Nutritional and Health Benefits of Beans and Cowpeas as Related to Reducing the Incidences of Cancers and Chronic Diseases

Principal Investigators and Institutions:
Maurice Bennink, Michigan State University, U.S.; Helen Jacobs, University of West Indies, Jamaica

Collaborators and Institutions:
Maria Jackson and Sharon Hooper, University of West Indies, Jamaica; Kathleen Barrett, Michigan State University, U.S.

Justification and Objectives

Many countries in the Caribbean region have experienced an unprecedented epidemiological transition in the last 35 years. During this transition, total food availability has greatly improved, but much of the increase in caloric intake is due to fat. Increased caloric and fat intake has led to a dramatic rise in heart disease, stroke, diabetes, obesity and cancer (i.e., chronic diseases). Age standardized cancer mortality in the English-speaking Caribbean is comparable to the U.S. Cancer is the second leading cause of death in the U.S. and accounts for 23% of all deaths; thus, cancer represents tremendous personal and national burdens to both societies. Unfortunately, the economies of Caribbean countries have not improved much and the majority of the population cannot afford cancer treatment. Therefore, cancer prevention is the only feasible public health approach for most countries in the LAC region.

Extensive research has identified dietary components that enhance or decrease cancer at various sites in the body. In a few instances, clear cause and effect have been established. Also, during the past two decades, several consensus reports by large groups of experts in the area of diet and cancer have been published. The WHO (1990) and WCRF/AICR (2001) reports included very general recommendations concerning pulse (legume) consumption to reduce cancer development. The WHO recommended daily consumption of 30g of pulses (including nuts and seeds) to reduce occurrence of chronic disease (heart disease and some types of cancer). The WCRF/AICR recommended that 45-60% of the energy in the diet should come from starchy or protein rich foods of plant origin to minimize cancer development. Pulses (legumes) are included in this category. It is estimated that appropriate diet choices, weight control and exercise could reduce cancer incidence by 30-40%.

The WCRF/AICR expert panel made the following recommendation, "Given the nutritional content of pulses and their importance in plant-based diets as rich sources of protein and of bioactive microconstituents that may protect against cancer, high priority should be given to epidemiological and experimental studies in which pulses are carefully identified and measured and their relation to disease risk established." The colon cancer study by Hangen and Bennink (2002), funded by the Bean/Cowpea CRSP, and the research activities conducted by this component are clearly in line with the WCRF/AICR recommendation.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Evaluate the efficacy of navy beans to inhibit colon cancer in an obese-diabetic model of colon cancer.
- Evaluating anti-cancer constituents for beans in Jamaica.
- Continue the prostate cancer case-control study.
- Determine if the anti-colon cancer properties associated with eating black beans is contained in an alcohol extract of the beans and if so, do oligosaccharides contribute to the anti-cancer activity.

Research Approach, Results and Outputs

The study to evaluate the efficacy of navy beans to inhibit colon cancer and the study to determine the anti-colon cancer properties associated with eating black beans were cross-cutting research activities conducted under the ESA3 and the LAC3 components. Results and outputs of these two studies in FY 06 are reported in the ESA3 Highlight Report.

Evaluating the anti-cancer constituents for beans in Jamaica: *Extraction of phenolic compounds from* *beans:* Two g of dried, cooked, and ground bean powder (see cooking description below) was mixed with 50% methanol:49% water:1% acetic acid (v/v), placed in a sonication bath for 30 minutes, centrifuged at 3000 x g for 10 minutes, and the supernatant collected. The pellet was extracted three more times with 70%, 90% and 100% methanol containing 1% acetic acid. Supernatants were combined, concentrated by roto evaporation, and brought to 10 ml with 80% methanol.

Hydrolysis of bean phenolics: Esters and glycosides were cleaved from the aglyconnes by hydrolyzing with base and acid. Duplicate 1 ml samples of the bean extract were hydrolyzed using base and another set of duplicates were hydrolyzed with acid. The alkali hydrolysis cleaves ester bonds, whereas the acid cleaves glycosidic bonds liberating simple phenolics or aglycones. o-Coumaric acid was added as an internal standard since it was not found in any of the bean extracts. After hydrolysis, bean extracts were applied to a conditioned C18 Sep Pak, washed with water, and phenolic aglycones were eluted with 80% methanol.

Diets and animals: Navy beans, black beans, pinto beans, and small red beans were used to prepare diets. The beans were cooked in large steam kettles until soft, oven dried immediately and ground. Seven-hundred and forty g of dried bean powder was added per 1 kg of diet. Diets were identical in protein, fat, fiber and total calories and contained all nutrients required by growing rodents. Male Sprague Dawley rats (n=58), 10 weeks in age, were housed singly in hanging wire cages. Room temperature was maintained at 22 °C and had a 12 hour light:dark cycle. Animals were allowed free access to food and water. After one week on the control diet, the animals were randomized by weight into one of five diets; control (modified AIN-93G), black bean, navy bean, pinto bean or red bean. After two weeks on the designated dietary treatment, rats were sacrificed and plasma was collected.

Analysis of phenolic compounds in plasma: Glucuronic acids and sulfate esters of phenolic compounds were hydrolyzed by incubating 1 ml of plasma with 40 µl of Helix pomatia for 17 hours at 37°C (4,000 units of ß-glucuronidase and 200 units of sulfatase activity). After hydrolysis, plasma samples were applied to a conditioned C18 Sep Pak, washed with water, and phenolic aglycones were eluted with 80% methanol.

High Performance Liquid Chromatography (HPLC) analysis: HPLC analysis utilized a quartenary gradient pump, an auto-injector and an eight-channel ESA Coularry Electrochemical Detector. The detector channels were set at –200 mV and from 200 to 800 mV, increasing in increments of 100 mV. Separation of phenolic compounds (acid and base hydrolysates of beans and enzymic hydrolysates of plasma) was performed using a Luna C18 Column, (250 x 4.60 mm, 5 µm particle size). Column temperature was maintained at 37 ºC. The mobile phases were: solvent A- 2% Acetonitrile in 30mM of phosphate buffer, pH 2.3; solvent B- 70% Acetonitrile in 30mM of phosphate buffer, pH 2.3; and solvent C-90% Acetonitrile: 10% water. The gradient was: 0-30 minutes, 0%-26% B; 30-65 minutes, 26%-65% B; 65-70 minutes, 0%-100% C; 70-75 minutes, 0%-100% A. The column was equilibrated with 100% A for 15 minutes prior to the next injection. The flow rate was 1ml/minute and the injection volume was 20 µl. All samples were filtered through a 0.45µm nylon filter prior to HPLC analysis.

Standards: Based on the literature, 22 phenolic compounds were considered potentially present in beans. The HPLC gradient described above allowed separation of 20 of the compounds while two of the 22 compounds could not be separated.

Phenolic compounds in beans: Electrochemical profile, spectral characteristics at 260, 280, 320, and 360 nm, and retention time were determined for each standard and then used to putatively identify and quantify phenolic compounds in beans and plasma. The phenolic compounds identified in all four bean extracts were protocatechuric acid, p-hydroxybenzoic acid, (+)-catechin, vanillic acid, caffeic acid, syringic acid, p-coumaric acid, ferulic acid and sinapic acid (Table 1). Isovanillic acid was also identified as being present in all beans, but the quantities present were too low to allow accurate quantization. Ferulic acid was the predominant phenolic compound present in all beans. The flavonol quercetin was detected in the black and red beans, while kaempherol was identified in pinto and red beans. The peaks representing these flavonols, although identified, have yet to be confirmed. It should be noted that methods utilized may not detect the anthocyanins known to be present in raw black beans.

Analysis of plasma from rats fed diets that were 74% beans showed only minor quantities of compounds corresponding to phenolics identified in cooked beans. These peaks were too small to accurately quantify. The procedures utilized are capable of detecting low nanomolar concentrations of phenolic compounds. Therefore, bean phenolicis are present in circulating blood at exceedingly low concentrations. A peak representing an unknown phenolic compound was detected in the plasma of rats consuming pinto and small red beans.

Prostate cancer case-control study: The prostate cancer cases-control study initiated in FY 04 in Jamaica continued to enroll subjects with the ultimate goal of enrolling enough subjects and cases to provide statistical power of 0.9 and C.I. = 90%.

A total of 723 persons attending urology clinics or private physicians' offices were screened for potential involvement in the study. Among those screened, 169 subjects were identified as cases (histological confirmation of prostate cancer) and 126 subjects were classified as controls (PSA <2.0 μ/L). The mean age of cases was somewhat higher (67.3 ± 8.0 years) than that of the controls (57.4 ± 10.9 years). Examination of the data by age-groups shows the expected trend of increasing number of cases with increasing age (Table 1). In contrast, among the controls we find a decreasing number of persons available as matched controls. This highlights the difficulties encountered in matching cases in the older age groups. Dietary records were collected and will be analyzed in FY 07.

Literature Cited

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Tables/Figures

Table 1. Descriptive data for Cases and Controls enrolled in the study entitled, "Prostate Cancer in Jamaica: The Contribution of Diet and Lifestyle."

	Cases	Controls
Number	169	126
Age: years		
Mean ± SD	67..3 ± 8.0	57.4 ± 10.9
Age groups: % (n)		
<50	2.5 (4)	32.5 (38)
51-60	18.9 (32)	30.8 (36)
61-70	36.7 (62)	20.5 (24)
70 or older	42.0 (71)	16.2 (19)
PSA levels: percentiles		
25^{th}	11.9	0.50
50^{th}	24.1	0.80
75^{th}	101.0	1.30

LAC-CC1-A2

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Gender and Participatory Research in the Improvement of Bean Varieties (*Phaseolus vulgaris* L.) and Seed Production Systems in the Andean Highlands of Ecuador

Principal Investigators and Institutions:
Anne Ferguson, Michigan State University, U.S.; Eduardo Peralta, INIAP, Ecuador

Collaborators and Institutions:
Diane Ruonavaara and James Kelly, Michigan State University, U.S.; Nelson Mazon, Angel Murillo and Carlos Monar, INIAP, Jose Isacaz, FAO-Pesa-Ecuador

Justification and Objectives

In Ecuador, women and ethnic minorities lack access to improved bean varieties and related technologies and have inadequate knowledge and skills to produce and market high quality bean seeds. This activity promotes research and outreach that recognizes the importance of women and minority groups in the production and consumption of beans in Ecuador and takes into account the new circumstances that women and ethnic minorities face due to increased globalization of trade and accompanying economic insecurity. The dual goals of this project are to: promote the participatory development of new varieties, agronomic practices and technologies that address the needs of women and ethnic minorities in a shifting economic and social context, and enhance and systematize methodologies of participatory plant breeding and gender analysis.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Participatory evaluation with women and ethnic minority groups of lines and varieties of bush and climbing beans with genetic resistance to biotic and abiotic factors.
- Improve the artisan local seed production and distribution systems for quality bush and climbing bean seeds in the area of the project.
- Identify and document best practices and other experiences of participatory research and evaluation working with men and women of marginalized communities.

Research Approach, Results and Outputs

Participatory evaluations of lines and varieties of bush and climbing beans: In FY 06, the INIAP CRSP project continued to support existing CIALs in the varietal evaluation process to ensure that the participatory evaluation remained dynamic and became permanently embedded into how the community carries out varietal selection of beans. The project was expanded to other areas of Ecuador where bean production is important and that have been equally neglected by both private and public sector groups. The areas to which the work for FY 06 expanded included Pallatanga in Chimborazo province, El Corazon in Cotopaxi province, and Chillanes and Santa Fe in Bolivar province.

Promising lines were evaluated in three communities in the valley of Intag, province of Imbabura during the last agricultural cycle. In the valley of Intag, beans are the second most important agricultural commodity produced and are planted during two seasons. The main varieties planted are red and purple mottled bush beans. Seven varieties and promising lines were planted for evaluation including five red mottled varieties (INIAP-Yunguilla, Paragachi, INIAP-Concepción, AND-1005, Yunguilla x Mil Uno, s23), one yellow variety (INIAP-Canario del Chota) and one white variety (INIAP-Fanesquero.) The trial consisted of three repetitions, one in each location (Monopamba, 1216 m.; Santa Rosa, 1100 m y Peñaherrera, 1400 m.).

Data on each variety was collected relating to rust (scale 1-9: 1=resistance, 9=susceptible), vigor (scale 1-9: 1=very vigorous, 9=no adaptive), days to flower (DF), number of pods (participatory evaluation), quality of seed, yield per plot, and projected yield per hectare. The varieties exhibiting strong resistance to rust in the two communities were INIAP-Canario del Chota, INIAP-Concepción and Yunguilla x Mil Uno, s23. Varieties evaluated in Monopamba, demonstrated better adaptation than in Santa Rosa; the varieties demonstrating best adaptation were Yunguilla x Mil Uno, s23 and INIAP-Fanesquero. Varieties demonstrating precocity were INIAP-Fanesquero e INIAP-Concepción.

In Monopamba, the varieties with highest pod set per plant were Y x M,s23; INIAP-Yunguilla, INIAP-Canario del Chota and AND-1005. In Santa Rosa, the varieties INIAP-Yunguilla, INIAP-Canario del Chota e INIAP-Concepción showed highest ratio of pods per plant. In Monopamba, varieties were also evaluated for seed quality with the varieties or lines of Y x M,s23; INIAP-Yunguilla, INIAP-Canario del Chota, INIAP-Concepción and AND-1005 excelling.

In Monopamba, the best yielding varieties were INIAP-Paragachi, AND-1005, INIAP-Yunguilla and Y x M,s23 while in Santa Rosa, Paragachi, INIAP-Concepción y AND-1005 showed the highest yield. The average from the two communities demonstrated that Paragachi and AND-1005 were the highest yielding.

Based on yields, adaptation, and seed quality, agriculturalists (both men and women) in the valley of Intag selected the four varieties - AND-1005, Y x M,s23; INIAP-Concepción and INIAP-Canario del Chota - to evaluate in the next agricultural cycles.

Eight varieties of bush beans- six red mottled, one yellow and one white variety - were evaluated at Chayahuan (1780 m) in the Pallatanga valley, province of Chimborazo, Chayahuan. This area is the most important bean-producing region of the country given the area planted to beans and the diversity of both bush and climbing bean varieties planted. In Chayahuan, one repetition of 24 m2 was planted to evaluate general agronomic characteristics and yield per parcel and projected yield per hectare. According to the general agronomic evaluation, the varieties Paragachi x JE.MA., sel 1; INIAP-Concepción, INIAP-Paragachi, INIAP-Canario del Chota showed the best adaptation. While Y x M,s23 Y x M,s23 came in second place and INIAP-Canario del Chota came in third. Varieties showing the highest yield were Paragachi x Je.Ma., sel 1; Paragachi, INIAP-Yunguilla and INIAP-Concepción.

In Pallantanga, agriculturalists selected the INIAP-Canario del Chota, Paragachi x Je.Ma., sel 1 and INIAP-Concepción for adaptability, disease resistance and yield. These materials will be multiplied during the next production cycle. In the province of Bolivar, using a participatory evaluation approach, two promising lines of bush beans were tested, one a red mottle (AND-833) and the other a yellow Canary (Canario Imbabura). Agriculturalists' selection criteria for these varieties follow in Table 1.

Improving the artisan local seed production and distribution system: In the communities of Santa Lucía, La Concepción, El Tambo and San Clemente, the CIALs multiplied seeds from varieties selected by CIAL members. Seed multiplication of INIAP-421 Bolívar and INIAP-426 Canario Siete Colinas also occurred at the Laguacoto Station, State University, Bolivar. Approximately 200 kg of each variety was produced.

A workshop on "Production and Management of Good Quality Beans Seeds" was held in Ibarra to reinforce the informal seed production system to provide good quality seeds and develop the capacity of CIAL members in the northern valleys of the country. The primary focus of the workshop was to present the basic cultural management principles to produce good quality seeds. Seventeen men and three women attended from eight communities including Santa Lucía, La Concepción, El Tambo, San Clemente, Pusir Grande, Urcuquí, Moraspungo, Perucho in the valley of Chota, Mira and Intag. Four technicians also attended, one independent, one from a NGO and two from INIAP.

Identify and document best practices and other experiences of participatory research and evaluation: One problem identified during the base-line study at the inception of the CIALS was the limited knowledge of agriculturalists on bean diseases and use of pesticides. Accordingly, a workshop entitled, "Identification and Management of Principle Diseases of Bush Beans in Ecuador," was held in Ibarra in May 2006. The objectives of the workshop were to enable participants: 1) to recognize and differentiate between symptoms of angular leaf spot, bacteriosis, rust, anthracnosis, powdery mildew and root rot, and 2) apply appropriate integrated management techniques to control these diseases in the field.

Eighteen women and three men from the communities of Santa Lucía, La Concepción, El Tambo, San Clemente, Pusir Grande and Urcuquí attended this workshop. The participants each received educational materials and posters illustrating the diseases and management techniques to distribute in their respective communities.

In the zone of Pallatanga, a workshop was held focusing on increasing consumption of beans. Pallantanga is an area of high bean production, but domestic consumption in homes and restaurants is low. The workshop entitled, "The Importance of Beans in the Diet and How to Prepare New Dishes with this Legume," was held in September 06 in the Municipal offices. Eighteen women and thirteen men attended from nine communities, local institutions and restaurants. The event covered the importance of beans in the agricultural system and their role in a healthy diet. Seven dishes were prepared and enjoyed by the participants.

Emerging conclusions from this Activity: Once agriculturalists (both men and women) are exposed to and evaluate new bean varieties, those that have desired characteristics are multiplied and distributed informally within the community and with other communities that express an interest in the variety. To strengthen and improve this process, it is very important to develop the capacity of agriculturalists to produce good quality bean seeds in order to maintain desired varietal characteristics and to ensure that seeds for planting are of high germination potential and vigor.

Participatory evaluation began in communities in the valleys of Intag and Pallantanga based on the varieties selected through participatory evaluation in the communities in the valleys of Chota and Mira. This work has allowed INIAP bean breeders and technicians to develop a more in-depth understanding of agriculturalists preferences for beans in the region.

The training on bean diseases and management practices for CIAL members (both men and women) has enabled farmers to better manage their bean crops and associated pests and most importantly, to reduce their dependency on agro-chemicals.

Tables/Figures

Table 1. Selection criteria of two promising lines of bush beans in the province of Bolivar.

Lines	Farmers' selection criteria
Andino – 833	Good yield (2344 (kg/ha), seed health, medium seed size, kidney-shaped. Very good appearance both green and dry stage; tender texture, maintains consistency when cooked.
Canario Imbabura	High yield (2500kg/ha), medium seed size, good over-all health, good yellow color (canary), good shine, round shape. Very good xxx green and dry; tender texture and maintains consistency when cooked. Excellent price in the market as a dry seed because of its color and shape.

Photograph 1. Evaluation of field trials of beans in the communities of Santa Rosa (Intag), and Pallatanga (Chimborazo) in 2006.

Photograph 2. Workshop (Ibarra, 2006) and poster on bean diseases.

Photograph 3. Members of the CIAL of La Concepcion during the workshop on "Production and Management of Good Quality Bean Seeds" (Ibarra, 2006).

LAC4-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Genetic Improvement of Bean Adaptation to Low Fertility Soil

Principal Investigators and Institutions:
Jonathan Lynch, Pennsylvania State University, U.S.; Nestor Felipe Chavez Barrantes, University of Costa Rica, Costa Rica

Collaborators and Institutions:
James Beaver , University of Puerto Rico, Puerto Rico; Stephen Beebe and Matthew Blair, CIAT, Colombia; Kathleen Brown, Pennsylvania State University, U.S.

Justification and Objectives

Poor soil fertility is a primary constraint to bean and cowpea production in developing countries. Recent advances in root biology make it possible to breed crops with greater nutrient efficiency and acidity tolerance. These traits can improve productivity, increase economic returns to fertility inputs, and potentially 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 improve bean production in the Central America/Caribbean region, focusing on improved genetic adaptation to low P availability and manganese toxicity.

Bean cultivars with better adaptation to suboptimal nutrient and water availability are one of the few alternatives for increased and sustained bean production by small farmers of the LAC region. Genotypic efficiency under low P in combination with tolerance to other abiotic (drought) and biotic (diseases) stresses as well as greater yield potential is required. There is limited understanding of the specific root traits that enhance P acquisition, their metabolic costs, genetic control, and potential agro-ecological impacts. This shortcoming constrains the ability of plant geneticists to select and breed superior genotypes as well as to predict the impact of such genotypes on bean production systems.

Manganese (Mn) toxicity is also an important constraint to bean production in the tropics. Bean genotypes vary substantially in their tolerance to Mn toxicity. Research is needed to systematically characterize bean breeding lines for sensitivity to high levels of Mn, to identify sources of Mn tolerance as well as to aid in the interpretation of field screening results in low fertility environments where Mn toxicity is often a serious but intermittent stress factor.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Identify bean genotypes capable of yielding 20-30% more than traditional varieties in low P soils, and deploy this germplasm through been breeding programs in Central America (primary focus) and Eastern Africa (secondary focus).
- Identify, validate, and genetically map phenotypic traits conferring phosphorus acquisition efficiency in beans.
- Evaluate bean breeding lines for Mn tolerance.

Research Results, Achievements and Outputs

Identify bean genotypes capable of higher yields than traditional varieties in low P soils: A low P plot was prepared at Zamorano, Honduras, during FY 06 for a multiline study to be conducted during the postrera season of 2006 by Amelia Henry, a Ph.D. student from PSU. A set of multiline trials was planted in October 2006 in farmer fields to complement the results of the multiline and low P/drought trial to be conducted simultaneously at Zamorano´s low P plot.

Of the families selected in 2005 for superior performance under no added fertilizer conditions, 149 were advanced to the F_5. These 149 selected F_5 families were evaluated during the Oct.-Dec. growing season in Honduras (FY 06) in two separate plots; a plot with no added fertilizer/moderate drought stress, and a second plot with moderate fertilization/drought stress. The selected 68 F_6 families with superior performance were tested at Zamorano under drought stress. The same group of 68 lines was sent to the University of Puerto Rico (UPR) for testing by J. Beaver´s graduate student at a low P field plot in the Isabela Station, and to CENTA (C.A. Perez) for testing under drought stress in El Salvador. Several of the best lines were also included into regional nurseries distributed throughout Central America.

In 2006, a set of 10 F_3 low P x drought tolerant populations (an average of 100 F_3 families per population) was sent to Costa Rica for evaluation under low fertility in Alajuela. Also, a set of 24 lines, which includes low P and drought tolerant genotypes used as parents for developing the populations indicated above, were sent to PSU for root traits characterization under greenhouse controlled conditions. A group of 62 advanced breeding lines and cultivars, including recently or nearly to be released cultivars and *P. vulgaris* x *P. coccineus* inter-specific lines were sent to PSU for root traits characterization. The 2006 VIDAC Rojo (93 advanced lines and 2 checks) and VIDAC Negro (59 lines and the local check) nurseries were sent to the UPR (J. Beaver) for testing under low fertility at the Isabela Station in Puerto Rico. In addition, a set of 20 small red and black advanced lines were sent to UPR for BNF testing at the same station in Puerto Rico.

The development of three inbred backcross populations, by crossing the commercial cultivar Amadeus (recurrent parent) with lines from the L88 population which were identified at PSU as being highly superior on several root traits associated with greater efficiency under low P/drought stresses, was initiated during 2006. The second backcross to the recurrent parent is ongoing. The goal is to develop commercial cultivars with superior performance to local cultivars under low fertility/drought conditions due to a combine set of root traits that increase plant efficiency under these stresses.

Define effects of root traits on erosion and nutrient cycling: Two sites were chosen in Veracruz, Costa Rica based on their low P availability, steep slopes, and long-term low-input management. Forty 3 x 5 meter plots were enclosed with sheet metal and fitted with runoff collection buckets. Six bean genotypes (L-88 RILs) and two local varieties (Bribri and DOR-364) were used, with four replicates per genotype. These genotypes were chosen as contrasting in P efficiency and root architecture in previous studies. An additional four plots each of Bribri and DOR-364 were given high P. After each rain event, runoff samples were collected by local farmers, filtered, and shipped to PSU for P and sediment analyses. Phosphorus contents of leaves, stems, and pods are being monitored over time. Preliminary results indicate that the amount of P eroded from a plot in the first two rain events of the season represents over 5% of the P that will be removed from the plot in the form of seed yield. Local interest in erosion and soil conservation was stimulated by this study and an informational field day for farmers was held at the experiment site.

Assess abiotic stress tolerance of multilines: This study tests the hypothesis that genetic multilines having contrasting root architecture are more tolerant of abiotic stress than monogenetic lines. Three sets of multilines with contrasting roots architectures were identified, and DNA primers were screened as genetic markers to differentiate genotypes in field samples. Multiple SSR markers have been identified that will distinguish and quantify plant tissue (root and seed yield) from distinct genotypes in three multiline sets. Fieldwork has begun at a main site in Zamorano as well as in six on-farm sites in Honduras varying in soil type and climate. Physiological measurements are being taken at the main site, including time domain reflectometry (TDR) measurement of soil moisture at two depths, soil and plant P content, and root distribution with depth. Replicated treatments of drought stress, low P, combined drought and low P, and adequate water and P are being evaluated at the main site.

Genetically map traits conferring P efficiency in beans: The objectives of this study were to identify quantitative trait loci (QTLs) for P accumulation and associated root architectural traits. Eighty-six F5.7 recombinant inbred lines (RILs) were developed from a cross between G19833 and DOR 364. A genetic map constructed with RFLPs, microsatellites, and PCR-based markers covering 1703 cM total genetic distance and all eleven linkage groups (LGs) was used for QTL analysis. Seventy-one RILs were evaluated in the field at high P (HP) and LP for P accumulation, total root length (RL), specific RL, and plant dry weight (DW), while all 86 RILs were evaluated in a hydroponic system in the greenhouse for tap, basal, total, and specific RL and plant DW. Phosphorus accumulation in the field correlated with root parameters measured in the greenhouse. A total of 26 individual QTLs were identified for P accumulation and associated root characters. Phosphorus accumulation QTLs often coincided with those for basal root development, thus, basal roots appear to be important in P acquisition. Independent QTLs were identified for basal and taproot development, and for specific RL. Distinct QTLs for greater specific RL had positive, null and negative effects on P accumulation. These results confirm the importance of root structure for LP adaptation and highlight the need for a more detailed understanding of root architectural traits for phenotypic as well as marker-aided selection of more P-efficient crops.

An additional study identified QTL for adventitious root formation in beans. Adventitious roots assist P acquisition, as they are localized near the soil surface where P is relatively abundant. RILs of G2333/G19839 were screened under high and low P conditions in the greenhouse and field. We observed phenotypic variation and transgressive segregation for adventitious root traits in both environments. Allometric analysis revealed that although the taproot and basal roots are closely linked to shoot growth, RILs differ substantially in biomass allocation for adventitious roots. A linkage map with 149 genetic markers and a total cumulative map length of 1175 cM was used to identify a total of 19 QTL across 8 of the 11 linkage groups. Together these QTL accounted for 19 to 61% of the total phenotypic variation for adventitious root traits in the field and 18 to 39% under greenhouse conditions. Two major QTL for adventitious rooting under low P conditions in the field were observed that together accounted for 61% of the observed phenotypic variation. We conclude that adventitious rooting under low P is a feasible target for bean breeding.

Genetic mapping of basal root whorl number in beans has begun, using RILs of G19833xDOR 364 and G2333xG19839. Both populations show two strong QTL for basal root whorl number that explain from 60 to 90% of phenotypic variation.

Identify and understand physiological traits conferring P efficiency in beans: Adventitious rooting contributes to P acquisition by enhancing topsoil foraging, but metabolic investment in adventitious roots may retard the development of other root classes such as basal roots, which are also important for P acquisition. In this study, the effects of adventitious rooting on basal root growth and whole plant P acquisition were quantitatively assessed in young bean plants. The geometric model 'SimRoot' was used to model root systems with varying architecture and C availability growing for 21 days at three planting depths in three soil types with contrasting nutrient mobility. Simulated root architectures, tradeoffs between adventitious and basal root growth, and P acquisition were validated with empirical measurements. Phosphorus acquisition and acquisition efficiency increased with increasing allocation to adventitious roots in stratified soil, due to increased P depletion of surface soil. In uniform soil, increased adventitious rooting decreased P acquisition by reducing the growth of lateral roots arising from the taproot and basal roots. Allocation to adventitious roots enhanced P acquisition and efficiency as long as the specific respiration of adventitious roots was similar to that of basal roots and less than twice that of taproots. When adventitious roots had greater specific respiration rates, increased adventitious rooting reduced P acquisition and efficiency by diverting carbohydrate from other root types. These results confirm the importance of root respiration in nutrient foraging strategies, and demonstrate functional tradeoffs among distinct components of the root system. This information will be useful in developing ideotypes for more nutrient efficient bean genotypes.

As hypocotyl borne roots appear later than other root classes, they may serve to functionally replace basal and primary roots lost to biotic and abiotic stress. Experiments were conducted in solution and solid media culture with treatments involving the removal of part of the bean root system (basal, hypocotyl borne or primary roots), P availability, and depth of seeding to test the hypothesis that there are compensation mechanisms among root classes to cope with the loss of part of the root system. The root system was highly plastic in response to root excision, which resulted in the maintenance of below-ground growth. In most cases, compensation among root classes was enough to maintain plant performance in both P-sufficient and P-stressed plants. Removal of a specific root class induced an increase in the growth of the remaining root classes. All root classes, but especially the primary root, contributed to the compensation mechanism in some way. Greater planting depth increased the production of hypocotyl borne roots at the expense of basal roots. Total root biomass maintained strict allometric relationships with total shoot biomass in all treatments. However, the pattern of this root regeneration was not uniform since the way the three root classes compensated each other after the removal of any one of them varied among the different growth media and P supply conditions. The resulting changes in root architecture could have functional significance for soil resource acquisition.

Plagio-gravitropic growth of roots strongly affects root architecture and topsoil exploration, which is important for the acquisition of water and nutrients. Research indicates that basal roots of *Phaseolus vulgaris* L. develop from two to three definable whorls at the root-shoot interface and exhibit position-dependent plagio-gravitropic growth. The whorl closest to the shoot produces the shallowest roots, while lower whorls produce deeper roots. Genotypes vary in both the average growth angles of roots within whorls and the range of growth angles, i.e., the difference between the shallowest and deepest basal roots within a root system. Since ethylene has been implicated in both gravitropic and edaphic stress responses, we studied the role of ethylene and its interaction with P availability in regulating growth angles of genotypes with shallow or deep basal roots. There is a small correlation between growth angle and ethylene production in the basal rooting zone, but ethylene sensitivity is strongly correlated with growth angle. Basal roots emerging from the uppermost whorl are more responsive to ethylene treatment, displaying shallower angles and inhibition of growth. Ethylene sensitivity is greater for shallow than for deep genotypes and for plants grown with low P compared to those supplied with high P. These results identify basal root whorl number as a novel architectural trait, and show that ethylene mediates regulation of growth angle by position of origin, genotype, and P availability.

A new kinematic approach was employed based on computer-aided image analysis to measure root growth and curvature. The primary difficulty in kinematic study of thick rooted species like beans is that the epidermal cells are not visible, resulting in images of roots devoid of any trackable patterns. The objective was to develop a method to study spatio-temporal patterns of growth of bean roots in a semi-automated way. Graphite sprinkled on the roots created random patterns that could be followed by a new image-analysis program we created, KineRoot, that tracked the displacement of the patterns created by the graphite particles in space and time. Using KineRoot, root growth and curvature of basal roots of common bean was measured using a kinematic approach. The local patterns of root growth and gravi-responding zones of the basal roots were identified and measured. Of interest were the velocity profiles within these zones and how these zones are affected by low P availability and ethylene treatment. Basal roots accelerated the growth rate of the upper whorls at the cost of lower growth rate in lower whorls in response to low P availability. Apart from root growth, one of the most important aspects of this study was to characterize the bending of the basal roots which leads to gravi-response and reflects shallowness or deepness of basal roots. Root curvature results from differential growth between upper and lower edges of the root, and the direction of this curvature varied over time, producing a waving motion. The results show that ethylene and MCP treatments do not alter local root curvature, but alter the span and duration of the bending of the root upward or downward which causes altered response to gravity, thereby producing shallow and deep roots respectively. This study shows new aspects of the plagio-gravitropic response of basal roots not previously observed.

Assess impacts of P efficient bean genotypes on intercrops: Field and greenhouse studies were conducted to test the hypothesis that P efficient bean genotypes having shallower basal roots may reduce the growth of associated intercrops such as maize and cucurbits via root competition. A greenhouse study using dual radio-labeled P in large soil containers failed to show such competition up to three weeks after emergence, but preliminary analysis of a field study with maize/bean intercrops taken to maturity showed reduced maize yield with P efficient genotypes.

Evaluate bean breeding lines for Mn tolerance: A Mn-sensitive by Mn-tolerant population with higher heritability value (Bribri x G3513) was advanced to the F_6 by single seed descent to develop a RIL population to study the genetics of Mn tolerance. A set of 106 F_6 families from this population were sent to PSU for Mn toxicity screening under greenhouse conditions. The population exhibited phenotypic variation for Mn toxicity symptoms. This analysis will be repeated in 2007 for QTL mapping.

LAC5-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Develop Improved Bean Cultivars for the Lowland Production Regions of Central America and the Caribbean

Principal Investigators and Institutions:
James Beaver, University of Puerto Rico, Puerto Rico, U.S.; Juan Carlos Rosas, Escuela Agrícola Panamericana, Honduras

Collaborators and Institutions:
Aurelio Llano, INTA, Nicaragua; Danilo Escoto, DICTA, Honduras; Carlos Atilio Pérez, CENTA, El Salvador; Juan Carlos Hernandez, INTA, Costa Rica; Emmanuel Prophete, CRDA, Haiti; Julio Cesar Villatora, ICTA, Guatemala; Feiko Ferwerda, University of Puerto Rico; Jonathan Lynch, Pennsylvania State University; Rick Bernsten, Michigan State University; James Steadman, University of Nebraska; Graciela Godoy, CEDAF, Dominican Republic; Eladio Arnaud-Santana, IDIAF, Dominican Republic; Tim Porch, USDA-ARS/TARS, U.S.; Phil Miklas, USDA, WA, U.S.; Steve Beebe, CIAT, Colombia

Justification and Objectives

Yield reduction and poor seed quality caused by web blight and common bacterial blight continue to be major factors limiting expanded bean production in the lowland, humid tropics and during the "primera" growing season of Central America and the Caribbean (CA/C). Recurrent selection is an effective strategy to accumulate favorable alleles for a particular trait. Interspecific crosses have been used to develop common bean lines with enhanced levels of common bacterial blight and BGYM resistance. Recent collaboration between Bean/Cowpea CRSP and CIAT scientists permitted the identification of *P. coccineus* lines with web blight and rust resistance. Recurrent selection and interspecific crosses are being used by the Bean/Cowpea CRSP Lowland Bean Breeding team to select bean breeding lines with enhanced levels of web blight resistance and more durable resistance to rust.

Drought and low soil fertility are the chief abiotic constraints to bean production in the CA/C region. Most of the beans in Central America are planted toward the end of the rainy season, when the crop can suffer from moderate to severe drought stress. Yield loss due to terminal drought is mostly a problem for small-scale farmers who produce beans under rain-fed conditions. These farmers use early maturity landrace varieties to escape the effect of limited rainfall. However, these short-season landraces are low yielding. Seed yield of recently released cultivars such as Tio Canela 75 are 20% greater than local landrace varieties, even though they are only slightly later (5-7 days) in maturity. Progress in the development of drought tolerant bean cultivars will require the use of a wider genetic base, including the transfer of *P. acutifolious* drought tolerant genes through interspecific hybridization and greater adaptation of lines to the predominant edaphic and biotic constraints.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Develop and release bean cultivars with improved adaptation to lowland agro-ecological zones in Central America, the Caribbean and the U.S.
- Increase web blight, rust, and BCNM and BGYM resistance in beans using recurrent selection, inter-specific crosses and marker-assisted selection.
- Increase resistance to terminal drought in bean lines for rain-fed bean growing areas in Central America and the Caribbean.

Research Results, Achievements and Outputs

Cultivar release with improved adaptation to lowland agro-ecological zones: Since its release in 2003, the small red cultivar "Amadeus 77" has become the leading improved cultivar planted in Honduras, Costa Rica, El Salvador and Nicaragua due in part to government promotional programs. In 2005/2006, the levels of adoption of Amadeus 77 and overall production increased markedly.

New bean cultivars have been developed using landrace cultivars as parents and participatory plant breeding (PPB) approaches. The candidate cultivars, projected for release in the near future, include two PPB improved "Sacapobres" lines for Costa Rica and two PPB improved "Estelí 150" lines for Nicaragua.

Several elite black-seeded breeding lines have been developed with excellent yield potential, desirable

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agronomic traits and resistance to BGYMV. The most promising black lines will be considered for release in Costa Rica, Nicaragua, Honduras or Haiti. EAP 9712-13 and DOR 390 were increased in Haiti for release in 2007. The CRSP project also assisted in the testing of black bean lines in the lowland regions of Guatemala in collaboration with the National Bean Program at the Instituto de Ciencias y Tecnología (ICTA) and the highlands project.

In an effort to breed lines of the highly desired small-red seed type, several inbred backcross (IBC) populations were developed by crossing Central American landraces such as "Paraisito," "Rojo de Seda" and "Sacapobres" with improved, disease resistant cultivars such as Tío Canela 75, Amadeus 77, and Carrizalito. A single backcross to the improved cultivars, followed by a single seed descent has been used to develop BC_1F_3 lines that have been selected for agronomic adaptation and seed type. Besides their testing in Honduras, some of these IBC populations were sent to El Salvador, Costa Rica and Nicaragua for evaluation and selection under their unique bean production conditions. Selection for yield potential and adaptation will be initiated at the BC_1F_4 generation using replicated trials. The most promising advanced generation ($BC_1F{>}_5$) lines will be tested in regional performance trials.

The yield components of a F_2 population derived from the cross EAP9503-32A x Hond 02-01were studied in Puerto Rico. EAP9503-32A is an indeterminate (Type 2) small red-seeded line from Zamorano and Hond 02-01 is a small red bean landrace that has an indeterminate growth habit (Type 4) and as many as 10 seed per pod. The yield components of $F_{2:3}$ lines will be evaluated to attempt to identify Type 2 or Type 3 growth habits with an increased number of seed per pod and greater seed yield potential. Advanced generation lines derived from this population will also be tested in Honduras by farmers using PPB approaches to determine if increased numbers of seed per pod has other advantages.

Increase disease resistance in beans using recurrent selection, inter-specific crosses and marker-assisted selection: Web blight- G35163, a cultivated *P. coccineus* landrace from Mexico expressed a high level of physiological resistance to web blight. CIAT bean breeder, Dr. Steve Beebe, had assisted the project by developing inter-specific crosses between G35163 and "ICA Pijao." The F_1 seed was planted in Puerto Rico during FY 06 to produce F_2 seed. Lines are being advanced to the F_4 generation and screened for web blight resistance in Puerto Rico and Honduras.

In Honduras, testing of the interspecific families from earlier crosses between *P. vulgaris* and *P. coccineus* (G 35066) continued in 2006, selecting materials with high levels of web blight resistance. The most web blight resistant interspecific lines will be used during FY 07 as parents in the third cycle of crosses for the recurrent selection program, and as sources of resistance to develop resistant cultivars in crosses with elite lines and cultivars which carry BGYM resistance, heat tolerance and excellent seed types.

Two cycles of recurrent selection have been completed to accumulate alleles for resistance to web blight using different sources such as Talamanca, BAT 93, MUS 83, MUS 132, MUS 181, MUS-N-8, MUS PM-31 and VAX 6. The most promising lines will be distributed in the CA/C region for testing during 2007.

Rust and Bean Common Mosaic Necrotic Virus (BCMN)-

Seed of BGYMV and BCNMV resistant white- and black-seeded bean breeding lines were multiplied in response to the recent arrival of BCMNV in Haiti. The performance of these lines is being evaluated on an ongoing basis in Haiti, Honduras, the Dominican Republic and Puerto Rico.

In Honduras, several small red and black populations were developed using the rust resistant sources mentioned above in crosses with the best elite lines and cultivars. F_3 families were screened in the field using inoculations of rust spores collected from susceptible plants in commercial bean fields and resistant bean breeding lines were selected. F_4 plants from these rust resistant families were screened with five rust SCAR markers SK14 (Ur3), SA14 (Ur4), SI19 (Ur5), SOAD12 (Ur7) and GTO (Ur11). Families which combined phenotypic resistance in the F_3 generation and presence of markers in the F_4 generation were screened again in the field during the 'postrera' season of 2006 using inoculation of rust spores.

BGYMV: Marker-assisted selection was used to identify white-seeded bean breeding lines with BGYM and common bacterial blight (CBB) resistance. In collaboration with Dr. Tim Porch (USDA-ARS) and Dr. Mildred Zapata (UPR), the CBB resistance was confirmed by inoculating the leaves and pods with two strains of the CBB pathogen. These lines are being evaluated in 2006 and 07 in Puerto Rico, Haiti and the Dominican Republic.

Multiple disease resistance: The Zamorano and UPR bean-breeding programs have sought to combine resistance to BGYM and BCNM with resistance to other important diseases such as common bacterial blight (CBB), rust and angular leaf spot (ALS). Small-red breeding lines derived from the cross Tio Canela 75/VAX 6 have been shown to exhibit a high level of resistance to Xap isolates from Honduras. Marker-assisted selection is being used to detect the presence of the SU91 and SAP-6 SCAR markers for CBB resistance and the SR2 SCAR marker for the presence of the bgm-1 gene and SCAR marker and the major QTL for BGYMV resistance. During the past two years, MAS is being used more intensively for the selection of promising multiple resistant breeding lines. These lines are being distributed to National Programs in the region for assessment of performance.

Crosses were made in Puerto Rico and Honduras to improve the rust resistance of small red beans by using Michigan State University breeding lines as sources of resistance. Populations developed from these crosses have been screened for general adaptation, agronomic value and seed type. Testing of breeding lines for multiple disease resistance including rust continued in 2006. Molecular markers are being used to select multiple resistant lines and/or to confirm the presence of specific rust resistant genes. The lines will also be field tested in Honduras using artificial inoculation of spores collected from commercial bean fields and nurseries at Zamorano infected with rust.

Lines with resistance genes from the accession G10474, selected from a group of 60 lines previously screened for resistance to ALS at CIAT, were identified as highly resistant in screenings conducted at Zamorano using artificial inoculation. Selected resistant lines are being used to broaden the genetic base of angular leaf spot resistance in bean cultivars for the CA/C region. Triple crosses of elite lines by the F_1 from the cross between resistant lines from Tio Canela/G06727 by the CIAT lines carrying the gene from G10474 were developed. F_4 families are being screened using artificial inoculum prepared at the Zamorano lab with ALS races isolated from Honduras. Populations developed by crossing the black-seeded cultivars from Guatemala Santa Gertrudis and ICTA Ligero with ALS resistant lines are being tested in Honduras and were sent to Guatemala for testing by ICTA researchers. In 2004, preliminary studies identified two RAPD markers associated to the resistance from the Andean accession G06727 to race 63-59. The SCAR markers SNO2 (for identification of the presence of the Mesoamerican Phg2 gene) and SH13 (for identification of the Andean Phg1gene) are being used for MAS to identify ALS resistant lines and cultivars for the CA/C region.

Angular leaf spot has become a problem for green-shelled bean producers in Puerto Rico. Jorge Venegas at Zamorano analyzed two isolates of the ALS pathogen from Isabela, Puerto Rico. The races were identified as being race 31-38 (isolate Pg-I1) and race 15-39 (isolate Pg-I2). Among the 12 angular leaf spot differentials, only G5686 (Andean) and the Mesoamerican lines Mex 54 and BAT332 were resistant to both isolates. Lines that combine Andean and Mesoamerican resistance genes are projected as sources of resistance genes for white bean improvement in Puerto Rico.

Small red, white and red mottled bean breeding lines were crossed with CIAT lines RAZ 105 and RAZ 75 that have bruchid [*Zabrotes subfasciatus* (Boheman)] resistance. Haitian graduate student, Gasner Demosthene, is assaying breeding lines from these crosses for the presence of arcelin, with the assistance of Dr. James Myers, Oregon State University.

Increase resistance to terminal drought in bean lines for rain-fed growing areas: Drought tolerant lines superior to BAT 477, resistant to BGYM and with good seed types were selected after one cycle of recurrent selection. Breeding lines derived from the second cycle of crosses between tolerant lines from the first cycle and other drought tolerant sources are being screened under drought. Superior lines from this drought recurrent selection program were included in the bean drought regional trial (ERSEQ 2006) that was evaluated in several countries in the region.

Twenty-four low fertility and drought tolerant lines were evaluated at Zamorano under low and high P conditions and tested under drought stress. The most drought tolerant lines as well as those lines that performed well under both abiotic stresses have been included as parents in various crosses. Single crosses between drought and low fertility tolerant lines have yielded progeny that perform well under both abiotic conditions. F_1 plants were also crossed to small-red landraces and elite cultivars. In collaboration with J. Lynch (Penn State University, advanced generation populations derived from these crosses were tested under low soil fertility and drought-stressed plots. Small red and black bean populations have been developed using the drought tolerant line L88-63 (J. Kelly, LAC6-A1) as a recurrent parent and the IBC method. BC_1F_2 and BC_1F_3 lines were tested under drought stress during the second season of 2005 and the dry season of 2006 at Zamorano. Selected black-seeded lines from these populations were sent to Guatemala for testing under drought conditions in the lowlands.

LAC5-A2

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Development of Sustainable Disease Management Strategies for Bean Rust and Web Blight

Principal Investigators and Institutions:
James Steadman, University of Nebraska, U.S.; Graciela Godoy-Lutz, CEDAF, Dominican Republic and Juan Carlos Rosas, EAP, Honduras

Collaborators and Institutions:
Lindsay Hansen, Maricelis Acevedo, Nancy Gonzalez, University of Nebraska, U.S. and Myrna Alameda, University of Puerto Rico

Justification and Objectives

Reduced yield and poor seed quality caused by disease is considered to be the most common constraint to bean production in Central America, the Caribbean and the U.S. In addition, fungicides used to control bean diseases such as rust and web blight increase production costs. Central America is a center of genetic diversity for both the common bean and its pathogens. Some of the most virulent pathotypes of the bean rust and web blight pathogens are found in Central America/Caribbean (CA/C). This diversity provides an ideal environment for plant pathologists to study pathogen variability and design strategies for resistance gene deployment. Mobile nurseries allow characterization of pathogen variability in the field and improved techniques have been developed for screening for web blight and rust resistance. In addition to studying virulence patterns in the field, the University of Nebraska-Lincoln (UN-L) and Dominican Republic (DR) scientists have unique and comprehensive collections of the rust and web blight pathogens that have permitted preliminary characterization of these pathogens using classical and molecular techniques. This research has led to the development of bean germplasm and cultivars for CA/C and the U.S. with enhanced levels of rust resistance.

The development of bean breeding lines with enhanced levels of web blight resistance and other disease management strategies is complicated by the existence of pathotypes of the web blight pathogen that vary in virulence patterns and in Anastomosis Groups (AG) that infer differences in epidemiology. New approaches are needed to develop bean breeding lines with higher levels of resistance to these important diseases.

The deployment of disease resistance genes is only one component of an integrated disease management strategy. Researchers in the Dominican Republic have demonstrated that cultural practices such as a fallow period followed by the synchronous planting of beans can reduce the incidence of Bean Golden Yellow Mosaic (BGYM). Researchers in Ethiopia report lower levels of rust infection when beans are intercropped with maize. Vegetative mulch is used in Central America to reduce the spread of web blight. In the U.S., disease free seed is used to control common bacterial blight and Bean Common Mosaic Necrosis (BCMNV). Because the effectiveness of specific disease management techniques is often site-specific, different strategies will be needed for the diversity of cultivars, planting dates, cultural practices and levels of technology used for bean production in CA/C.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Develop resistance gene deployment strategies for rust and web blight compatible with integrated disease management systems through molecular marker-assisted selection.
- Develop molecular markers for bean pathogens to study virulence patterns and co-evolution of the host and pathogen and guide resistance gene deployment.

Research Results, Achievements and Outputs

Resistance gene deployment for Rust and Common Bacterial Blight: Multiple disease resistant great northern bean lines developed cooperatively with Michigan State University and USDA-ARS were registered in the Crop Science Journal. These six lines have resistance to all races of bean rust stored at USDA-Beltsville and all known strains of Bean Common Mosaic and Bean Common Mosaic Necrosis viruses combined with erect growth habit, desirable seed and good yield. A Common Bacterial Blight (CBB) resistant great northern bean with superior seed quality, partial avoidance to white mold, two rust resistance genes and good yield was released cooperatively with USDA-ARS. Surveys for bean rust pathogen races/pathotypes found data to support stable resistance from the Ur-3 rust resistance gene found in newer great northern, pinto, black and red bean seed classes in the U.S. high plains. However, new rust resistance genes are needed for highly variable and virulent pathotypes found near wild *Phaseolus* species in the Middle American areas of subdomestication such as Honduras.

Remotely sensed data were evaluated for monitoring the initiation and spread of common bean rust caused by *Uromyces appendiculatus*. Airborne Imaging Spectrophotometer of Applications (AISA) provided aerial image data on a field of common bean (*Phaseolus vulgaris*) with Bill Z pinto and Beryl great northern cultivars inoculated with the rust pathogen. Ground truth consisted of a rust severity survey during the AISA overflight. In a previous greenhouse/laboratory hyperspectral measurement study, the ratio of near infrared to red edge was the most sensitive of four tested indices. Using this index and rust and no rust severity classes, accuracy assessment was 68%. Thus, remote sensing, e.g., satellite-based sensor system, of a rust pathogen is possible. However, the detection was possible only after symptoms had developed. Also, the chlorophyll content changes associated with pathogen infection and estimated by the ratio of near infrared to red edge could be associated with any chlorosis, not just that caused by a rust or other pathogens. Higher positional accuracy imagery and GPS data are needed to improve the accuracy of the index.

There is a lack of information about the specificity between the common bacterial blight (CBB) pathogen *Xamthomonas campestris pv. phaseoli* (Xcp) and its presumed fuscous blight variant *S. fuscans* subsp. fuscans (Xff) and major quantitative trait loci (QTL) and/or alleles in *Phaseolus vulgaris* conferring resistance. This makes the task of identifying genetic changes in host-pathogen interactions and the grouping of bacterial strains difficult. This in turn affects the choice of pathogen isolate(s) used for germplasm screening and complicates breeding for CBB resistance. In a project initiated in 2002, the feasibility of identifying a set of common bean genotypes to differentiate the CBB pathogen based on low vs. high compatible reactions was assessed. We also examined virulence differences of Xcp and Xff originating from different regions of the world. From 36 common bean genotypes, 12 were selected for further screening with 69 Xcp and 15 Xff strains from around the world. Candidate strains for physiological races of the CBB pathogen were identified. Nine Xcp strains (123 Colombia, 95 Argentina, 95-04, 95-39, K3A, SX124, G24, 84-5, B-705) and five Xff strains (1158A, 1158B, 0794, SX119, SX127) were able to differentiate host resistance based on low vs. high compatible reactions using a uniform inoculation method. This is the first report, to the best of our knowledge, where clear differential expression was shown with the CBB pathogens on common bean *P. vulgaris*. The Xff strains showed higher virulence than Xcp strains having the same geographical origin. African strains had the highest virulence. The largest Xcp strain variation in virulence exists in the Caribbean and South American countries. Pathogenic variation was greater with Xcp than Xff strains. Based on virulence levels, Xcp and Xff strains did not cluster according to their geographical origin. This virulence data indicate significant differences between geographical regions and effectiveness of resistance genes, although VAX 4 has broad resistance over all geographic regions. Thus, resistance QTL need to be deployed based on virulence data within specific bean growing regions.

A total of 53 lines and cultivars from East Africa were screened with select races for rust resistance genes Ur-3, Ur-5 and Ur-11. Sixteen of these lines/cultivars had one or more of the resistance genes and are being backcrossed into cultivars with acceptable plant and seed traits for East Africa. Also, 176 small red breeding lines were screened for resistance to *U. appendiculatus* pathotypes prevalent in Honduras as well as bean common mosaic and bean common mosaic necrosis viruses. These small red seed class lines also have combinations of resistance to bean golden yellow mosaic, angular leaf spot and/or common bacterial blight, providing promise for more stable yielding cultivars in the future.

Study of virulence patterns and co-evolution using molecular markers: Rust- Collection of wild *Phaseolus vulgaris, P. coccineus and P. lunatus* as well as domesticated *P. vulgaris* and *P. coccineus* leaves with bean rust fungal spores have been made and studied over the past three years. Isolates collected in 2003 identified on the 12 international bean differential genotypes were phenotyped into 34 unique pathotypes according to their reaction on these genotypes. The most frequent pathotype was found in all 11 geospacially separated host populations. Nearly all populations had at least one unique pathotype. In 2005, the most frequent pathotype was found in 9 of 13 populations and again most populations had at least one unique pathotype. In 2003, the number of pathotypes per population ranged from 13 to 3, but in 2005 the range was only 9 to 3. The data from these two years does not support the hypothesis that the high phenotype diversity of the pathogen on its wild host, which was found to be susceptible to most pathotypes, selected for the more virulent pathotypes collected in farmer production fields. However, *P. coccineus* plants in these wild populations have a high level of rust resistance, as do some of the *P. vulgaris* landraces, and thus selection for the higher virulence recorded in Honduras could result from this interaction.

The AFLP technique has been used for screening a group of 39 *U. appendiculatus* isolates from Honduras. These isolates represent the two most distinctive virulence groups of the bean rust pathogen. One group is composed of isolates that are only virulent or mostly virulent on the differentials of Andean origin (Andean specific) and the second group is composed of isolates that are virulent on differentials of both Andean and Middle American origin (non-gene pool specific). Of 20 fluorescent labeled primer sets initially tested for screening, ten primer sets with the highest number of repeatable, easy to score polymorphic DNA bands will be chosen for the final analysis. Analysis of the AFLP banding pattern of the 39 isolates has shown that *U. appendiculatus* isolates with identical virulence patterns on the 12 differential lines can be distinguished using the AFLP technique. However, the AFLP phenotype groups have not correlated with the virulence pattern grouping. This does not agree with a published USDA study using disparate bean rust pathotypes that found a relationship between the elongation factor l-alpha sequence polymorphisms and Andean vs. non-specific virulence patterns. There is a strong Andean resistance gene susceptibility phenotype for the pathotypes of *U. appendiculatus* isolated from wild *P. vulgaris*, other *Phaseolus* species and landraces irrespective of year. Gene flow may explain the lack of phenotype/genotype relationships as the long interaction time would blur the separation of genotypic groups, but we do not have an explanation for the Andean origin resistance gene failures in a Middle American common bean sub-domestication region.

Web Blight (WB)- In 2005, the first part of the research on the genetic variability of the web blight (WB) pathogen was completed. Web blight is still a major disease affecting common beans in the LAC region and is spreading in bean growing areas in Eastern Africa. Based on phylogenetic analysis of the ITS-5.8 S rDNA region of 68 *Rhizoctonia solani* WB isolates from 11 countries in LAC, we confirmed that WB is caused by a least five genetically distinct groupings. This is a very unique example of one disease caused by various subgroups of *R. solani*. An interesting finding from our study is the widespread distribution of similar genotypes in geographically distant countries. We hypothesize that these WB isolates have been spread over time and space by seed. In a published research article, we reported that virulent isolates are transmitted via asymptomatic as well as symptomatic seed of white and colored common bean seed. In order to determine if seed and not other inoculum types, such as sclerotia or basidiospores, are responsible for the spread, we need to use markers other than the ITS-5.8S rDNA region to examine these isolates. Thus, in the summer of 2006, we looked for polymorphisms in the entire genome of isolates collected 10 years ago and compared them to the DNA sequences of isolates collected in the same locations in 2005 and 2006. This work is also part of the research of Ms. Nancy Gonzales, a doctorate graduate student at UN-L. The sources of the WB isolates have been limited to two countries, Honduras and Puerto Rico, where most of the WB breeding is currently done.

This work was started with isolates from the WB collection. So far three Micro-satellite markers and Universal Rice Primers (similar to RAPD primers but more precise) have been used to determine if the pathogen population is composed of individuals of clonal or outbreeding origin by using several genetic models. So far only two Micro-satellite markers (GACA)4 and (GTG)4 and two Universal Rice Primers UPR2R and URP6R have been informative. Preliminary analysis by UPGMA analysis indicates that isolates of the same subgroup cluster together. New isolates from Puerto Rico have been obtained from seeds and leaves collected in the 2006 summer and fall field trials, respectively. Unfortunately, when 50 asymptomatic seeds collected in the WB trials in June at Isabela, Puerto Rico, were plated on 1% water agar only six *R. solani* isolates were amplified with specific primers for WB *R. solani* subgroups. Only one isolate of AG-1-1A, two of AG-1-1F and three of AG-4 were found. The first three isolates have been associated with WB symptoms elsewhere in LAC but not at Isabela. The AG-4 isolates are associated with root rot of bean seedlings. The remaining 46 bean seed yielded another important bean pathogen *Macrophomina phaseolina*. Even though *M. phaseolina*, the causal agent of charcoal rot of many hosts, was not the focus of this investigation, it was interesting to isolate this fungus only from the seed not infected by *R. solani*. This is another example of asymptomatic common bean seed as an efficient carrier of a fungal pathogen.

Eighteen isolates of *R. solani* were also recovered from symptomatic leaves collected in September 2006 at the Isabela Station. Based on cultural appearance these isolates are more likely to be placed in AG-1-IE after characterization by specific primers. Depending on how much variability is found, the isolate information should have important implications on methods and germplasm selection for WB resistance breeding and disease management. This work could also be used as a model to address the spread of WB in Africa where it appears that the disease is spreading to areas not previously affected. Occurrence of the disease in Africa has caught the attention of bean researchers at CIAT, Colombia, who believe that WB will become as devastating as BGYMV was a decade ago (S. Beebe, personal communication).

As a result of the phylogenetic analysis of the WB isolates, 68 sequences of the ITS rDNA region will be published at the NCBI Genbank. With the availability of online programs such as MEGABLAST that can be used to compare nucleotide sequences to sequence databases and to calculate the statistical significance of sequence matches, it will be possible to compare these isolates to other *R. solani* that cause web or sheath blight in other important crops like soybeans and rice. MEGABLAST is part of the BLAST package which can be used to infer functional and evolutionary relationships between sequences as well as help identify members of gene families. This CRSP team started searching for similarities in DNA sequences of isolates from Jamastran and Los Limones, Honduras. The results showed a 99% sequence identity match with WB isolates from Panama and Puerto Rico (previously published by G. Godoy-Lutz in the Genbank) but surprisingly 100% identity match with eight isolates that cause aerial blight of soybeans in Brazil. These soybean isolates have been tentatively placed in the AG-1-IA subgroup by researchers in Brazil even though they did not match the original tester isolates belonging to IA and published in the Genbank. It appears that once our sequences are published, some of those isolates will have to be reclassified based on information on the new subgroups. WB isolates of AG-1-IE are similar to those associated with sheath blight of rice in Louisiana according to a recent study by Dr. Shiro Kuninaga of the University of Hokkaido, Japan, and collaborator in the WB pathogen genetic variability work. The hypothesis that *R. solani* isolates that cause WB on beans are unique and constitute a separate population of various distinct subgroups might not hold true for isolates in subgroup AG-1-IE.

LAC5-A4

[9]Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Multiplication, On-Farm Evaluation and Dissemination of Improved Bean Cultivars for Central America and the Caribbean

Principal Investigators and Institutions:

James Beaver, University of Puerto Rico; Juan Carlos Rosas, Escuela Agricola Panamericana-Zamorano, Honduras

Collaborators and Institutions:

Aurelio Llano, INTA, Nicaragua; Danilo Escoto, DICTA, Honduras; Carlos Atilio Periz, CENTA, El Salvador; Juan Carlos Hernandez, University of Costa Rica, Costa Rica; James Steadman, University of Nebraska, U.S.; Emmanuel Prophete, Ministry of Agriculture, Haiti; Eladio Arnaud-Santana, IDIAF, Dominican Republic; Rick Bernsten, Michigan State University, U.S.

Justification and Objectives

The LAC lowland bean breeding team has developed and released improved cultivars such as "Amadeus 77," "Carrizalito," "JB-178" and "Morales" that have improved disease resistance and tolerance to abiotic stress. Previous experience with the release of "Tio Canela 75" in Honduras suggests that the impact of the release of an improved bean cultivar can be enhanced if the release is complemented with an effort to multiply and disseminate seed to as many farmers as possible. This effort can be conducted in collaboration with government extension agencies and local NGOs in order to distribute seed throughout the country. Farmers will be asked to compare the performance of the recently released cultivars with the bean variety that he/she is currently using. Interviews with the farmers during and after the growing season will provide the bean breeding team with valuable information concerning the attributes of the recently-released cultivars. If a large number of farmers decide to plant the improved cultivar the following growing season, the Bean/Cowpea CRSP will have evidence that the bean breeding program is benefiting the intended stakeholders.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Multiplication, on-farm evaluation and dissemination of improved bean cultivars for Central America and the Caribbean.

Research Results, Achievements and Outputs

The LAC lowland bean breeding team has several promising bean breeding lines at or near the final stages of development (Table 1). During FY 06 and FY 07, seed of these promising bean breeding lines will be multiplied and distributed to farmers in Central America and the Caribbean for on-farm testing. Small red and black foundation seed for Central America will be produced in Honduras at the Escuela Agrícola Panamericana, whereas IDIAF in the Dominican Republic will multiply most of the seed for the Caribbean. Both institutions have good facilities for the production and processing of bean seed. Land transportation will be used to ship foundation seed lots to Haiti, El Salvador and Nicaragua. The "Sacapobres" improved bean lines will be increased in the Fabio Baudrit Station, Alajuela, Costa Rica. To facilitate their dissemination, the recently released varieties "INTA Precoz" and "CENTA Pipil" will be increased in collaboration with researchers at CENTA, El Salvador and INTA, Nicaragua, respectively. Project personnel will collaborate with government extension agencies and NGOs to distribute the seed to farmers within each country. A portion of the funds will be used in Haiti to strengthen the bean seed program and for on-farm testing. A small amount of funds will be used for the production and shipment of BGYMV resistant light red kidney bean lines to Jamaica. Dr. Wayne McLaughlin (University of the West Indies, Mona Campus) will contact a Ministry of Agriculture official to arrange for the on-farm testing of the light red kidney lines in Jamaica. During FY 07, farmers who received seed of the bean lines during the previous year will be surveyed to determine if they plan to continue to plant the improved bean line. The survey will also attempt to identify the reasons why the farmer made the decision to plant or not to plant the bean line.

Validation trials and variety release processes were facilitated by increased efforts to produce and distribute seed in Honduras, El Salvador, Nicaragua and Costa Rica, in the Central America Region, and in Puerto Rico, Dominican Republic and Haiti, in the Caribbean region. Several promising small red, black, white, great northern and red mottled lines were validated intensively in the LAC countries participating in the project (Table 1). These validation trials included multiple locations on-farm testing in the main bean production regions. This project provided support and technical assistance to produce seed for the releases of the heat tolerant, BGYM resistant line PRF9653-16B (cultivar name CENTA Pipil) in El Salvador; and the early maturity, BGYM resistant line MPN103-137 (cultivar name INTA Precoz) in Nicaragua, that were released in these countries in FY 2006.

Also in FY 06, several small red bean lines were validated in farmer fields and are being considered for release during the upcoming year. For example, as part of the validation process in Honduras, more than 400 on-farm tests have already been conducted with the lines SRC2-1-18 and MER2226-41, which are being promoted with their cultivar names Cardenal and DEORHO, respectively. Several on-farm tests were conducted in the Brunca and North Huetar, the two main bean production regions in Costa Rica, with two improved Sacapobres lines (MPCR202-26-1 and MPCR202-30-2) derived from the cross Sacapobres x Tio Canela 75. In addition, two white bean lines, Great Northern grain type developed by the cross of the cultivar Blanco de Costa Rica (line PAN 68) x Bribri, were validated in Costa Rica where this grain type has a niche market. In Nicaragua, validation trials were conducted with promising lines SRC1-12-1-182, MPN102-11 and MPN102-54. In El Salvador, the lines under validation were SRC2-18-1 and PPB11-20MC. In FY 07, most of these small red lines and at least one white-seeded line in Costa Rica are expected to be released in these countries. The main features of these lines are BGYM resistance, broad agronomic adaptation, greater yield, and excellent grain commercial quality.

In Honduras, the Bean/Cowpea CRSP project provided support to a government program that is distributing improved seed as part of a technological package. The goal of the program is to reach nearly 30,000 small-scale farmers. During FY 06, the Zamorano Seed Unit produced more than 2,000 quintales of certified seed of the bean cultivars Amadeus 77 and Tio Canela 75 for the government's program. Similar initiatives are being implemented by government agencies in El Salvador and Nicaragua targeting a significant number of small-scale farmers with seed of recently-released bean cultivars.

Six black bean breeding lines (DPC1 to DPC6) with BGYM and BGNM resistance were evaluated on farms in the Dominican Republic. In the absence of disease pressure, these lines yielded as well as "Arroyo Loro Negro." During the upcoming year, seed harvested from the on-farm trials will be multiplied in the San Juan de la Maguana valley in collaboration with the farmers= association CAU. The most promising line will be considered for release in the Dominican Republic. Foundation seed stocks of the DPC lines will also be made available to the Seed Program of the Ministry of Agriculture in Haiti.

In December 2005, the Bean Program of the National Seed Service in Haiti initiated a new strategy for promoting the production of improved cultivars by local farmers= groups. This approach required the following steps:

1. The identification of existing well-organized farmers' groups.
2. The realization of training seminars before the beginning of the planting season.
3. The "loan" of improved seeds to the farmers' groups.
4. The recuperation of the loaned seeds.
5. The identification of possible buyers for the produced seeds.

A total of 240 farmers have been trained, some have received a full complement of three training sessions (Bean Agronomy and Seed Production Techniques, Seed Processing and Seed Quality Control), and over 150 hectares of land have been planted for bean seed productions. The bean varieties planted were 'Morales,' a white-seeded variety with resistance to BGYM virus, and 'ICTA Ligero,' an early, maturing black-seeded variety with resistance to the BGYM. One metric ton of Morales, previously produced by the National Seed Service, and eight metric tons of ICTA Ligero were distributed in FY 06 to farmers in Haiti.

Impressive results were obtained in Dubreuil, an irrigated area in the Southern Department of Haiti. In Dubreuil, the local extension personnel participated in the various training sessions and consequently provided excellent technical assistance to the farmers. Yields of 1.5 metric tons per ha of bean grain were recorded there and the farmers have expressed their satisfaction. Seed "reimbursements" of the "loaned" seeds were excellent and the operation was deemed a success. The farmers have asked for the operation to be repeated for the coming growing season.

In the other areas, success was more moderate. Both Morales and ICTA Ligero had different plant development characteristics than the local lines and the presence of technical support was considered to be critical for the success of the bean plots. In the end, the farmers have all agreed that the improved varieties yielded better than the local populations and all have asked for the seed production programs to be repeated.

Efforts to motivate farmers to market their improved seeds by themselves have not been as successful. A sizable portion of the seeds produced have been sold to other farmers impressed by the high yield potential of the improved varieties, and some 30% of the seeds have been bought by an international program, but 50% were sold for bean consumption. Future training in marketing will be offered to the most successful groups in order to strengthen their ability to commercialize their seeds. A program of demonstration plots in neighboring areas may help this goal.

Local seed production by farmers' groups may represent an efficient way to distribute improved bean varieties in Haiti and make them available to farmers in a shorter period of time. However, a sustained support of the farmers' groups will be required, especially for marketing and business management.

In December 2006, the Haitian National Seed Service plans to introduce the black-seeded line 'Arifi Wurite' into their program, while maintaining Morales and ICTA Ligero. Other improved lines, notably PR9745-232, a red mottled line with resistance to BGYMV from Puerto Rico and DPC-3, a black-seeded bean line from the Dominican Republic with resistance to BGYMV and BCMNV and SRS drought tolerant lines from Honduras are currently being increased by the National Seed Service and will be proposed to the farmers' groups as soon as a minimal quantity of one metric ton of seeds for each variety is available. A possible means to improve the sustainability of the seed program in Haiti is the sale of basic seeds, instead of loans to farmers.

In Puerto Rico, seed of PR0690, a white bean breeding line with BGYMV, common bacterial blight resistance and heat tolerance, and PR0301-181, a white bean breeding line with BGYM, BCNM and rust resistance, have been multiplied. These lines will be evaluated on farms during FY 07. PR0690 produced seed yields significantly greater than Morales in two trials planted at the Isabela Substation in FY 06.

William Suarez, a graduate student in the Department of Agronomy and Soils at the University of Puerto Rico developed a database using 2003 and 2004 bean seed sales at the Isabela Substation. The periods of January-March and October-December were identified as the months of greatest demand of bean seed. Farmers from the municipalities of Isabela, Aguadilla and San Sebastián purchased the greatest amount of bean seed. A validation study of the "Morales" bean variety was conducted using results from 20 on-farm trials planted from September of 2004 to August of 2005. Seed yield of Morales was lower during the summer months due to high temperatures and abundant rainfall. Angular leaf spot, caused by *Phaeoisariopsis griseola,* was the most common disease in bean plantings where symptoms often appeared before the blooming. Among the characteristics that farmers emphasized about the Morales bean variety are the high yield, homogenous maturation and resistance to pest and diseases which resulted in a high index of acceptance (83%).

The determinate cowpea variety "Gorda" was formally released in Puerto Rico. Gorda performed as well as breeding lines from IITA in field trials conducted at the Isabela Substation. Gorda, which has a typical black-eyed seed type, is generally used in Puerto Rico for the production of green-shelled peas. It also has potential as a cover crop or as forage. Basic seed stocks of Gorda are maintained by the UPR seed program. Seed samples of Gorda have been sent to Haiti, the Dominican Republic and Honduras.

Tables/Figures

Table 1. List of cultivars and promising bean breeding lines at or near the final stages of development.

Line	Seed Type	Trait(s)	Target Countries
PRF9653-16B-3 (released in FY 06 as CENTA Pipil) SRC2-1-18 and PPB11-20MC	Small red	BGYMV, heat tolerant, seed type	El Salvador
SRC2-18-1 (cultivar name: DEORHO) and MER 2226-41 (cultivar name: Cardenal) SRC1-12-1-8 and SRS 56-3	Small red	BGYMV resistant, drought tolerant, landrace seed type	Honduras
MPN 103-137 (released in FY 06 as INTA Precoz) SRC1-12-1-182, MPN102-11 and MPN102-54	Small red	BGYMV resistant, drought tolerant, landrace seed type	Nicaragua
MEB2232-28 and MEB2232-29	Great Northern white	BGMYV resistant, erect architecture and good yield	Costa Rica
EAP9712-13	Small black	BGYMV resistant, early maturity, drought tolerant, seed type	Honduras (Aifi Wuriti) and Haiti
MPCR202-26-1 and MPCR202-30-2 (improved "Sacapobres" lines)	Small red	BGYMV resistant, tolerant to low fertility, landrace seed type	Costa Rica
DPC1 to DPC6 (XRAV-lines)	Black, small red	BGYMV (*bgm*), BCMV and BCMNV (*I*+*bc3*) resistant, commercial seed type	Guatemala, Haiti the Dominican Republic
PR0690	White	BGYMV (bgm), common blight resistance	Haiti, Dominican Republic, Puerto Rico
PR0301-181	White	BGYMV (bgm), BCMNV (*bc3*) and rust '(*Ur-5*) resistance	Haiti, Dominican Republic, Puerto Rico
PR9745-232 (Formally released as improved germplasm in the Dominican Republic and Haiti	Red mottled	BGYMV (*bgm*), BCMV (*I*) resistance	Haiti, Dominican Republic
PR9847-8 PR9847-12	Light red kidney	BGYMV (*bgm*), BCMV (*I*) resistance	Jamaica, Puerto Rico

Table 2. Farmer training sessions have been held in Haiti during 2005 and 2006.

Haitian Department	Locality	Time Period	Topic	Number of Farmers
Southern	Dubreuil	November 2005	Bean agronomy and seed production techniques	90
Artibonite Valley	Borel	December 2005	Bean agronomy and seed production techniques	60
West	Petit Goave	December 2005	Bean agronomy and seed production techniques	30
Artibonite	Gonaives	December 2005	Bean agronomy and seed production techniques	30
North	Dondon	January 2006	Bean agronomy and seed production techniques	30
South	Dubreuil	February 2006	Seed processing	90
Artibonite	Gonaives	February 2006	Seed processing	30
Artibonite Valley	Borel	January 2006	Visit of bean plots	30
West	Petit Goave	March 2006	Visit of bean plots	30
Artibonite Valley	Borel	March 2006	Seed processing	30
South	Dubreuil	April 2006	Seed quality control	60
Artibonite Valley	Borel	April 2006	Seed quality control	30
South	Dubreuil	April 2006	Seed quality control	60

LAC6-A1

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Development of Improved Bean Cultivars for Highland Production Regions

Principal Investigators and Institutions:
James Kelly, Michigan State University, U.S.; Eduardo Peralta, INIAP, Ecuador; Julio Villatoro, ICTA, Guatemala

Collaborators and Institutions:
Matthew Blair, CIAT; James Beaver, University of Puerto Rico; Angel Murillo, INIAP, Ecuador; George Abawi, Cornell University, U.S.; Juan Carlos Rosas, EAP, Honduras; Esteban Falconi, INIAP, Ecuador; Jorge Acosta, INIFAP, Mexico; Emmanuel Prophete, CRDA, Haiti

Justification and Objectives

Rust is a serious production problem in Ecuador with bean yield losses ranging from 30 to 50% in susceptible cultivars. In recent years at elevations between 1,400 to 1,600 masl, angular leaf spot (ALS) and common bacterial blight (CBB) have become serious production problems necessitating attention in the breeding program. The sequential planting of susceptible varieties antagonizes many of these disease problems. Anthracnose also continues to be a major constraint to bean productivity in Ecuador and Guatemala and other highland areas in Latin America. Abiotic stresses such as drought, negatively affect >70% of the bean production area in the LAC region, and can be intensified by high temperatures, shallow infertile soils and root rotting pathogens. The genetic base of current bean varieties grown in Ecuador is narrow and future improvement will depend on increasing the genetic diversity of current varieties. Since Ecuador has a wide range of diverse ecological production zones, local adaptation is an essential trait among successful varieties.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Strengthen bean breeding programs in Ecuador and Guatemala with expanded emphasis on nurseries to evaluate performance, adaptation, disease resistance, understanding consumer markets, and stronger collaborative ties with CIAT and LAC CRSP colleagues in the lowland tropics.
- Broaden the genetic base of the regional drought screening nursery and evaluate the nursery at sites in Ecuador and Guatemala.
- Introgress new resistance sources into local bean germplasm.

Research Results, Achievements and Outputs

Strengthen bean breeding program in Ecuador: The bean breeding program in Ecuador focused on two major objectives in 2006: 1) to conduct field trials to evaluate adaptation and resistance to various economically important diseases so as to broaden the genetic base of local germplasm for biotic and abiotic factors; and 2) to continue the collection of samples of anthracnose, rust, ALS and root rotting pathogens to determine genetic variability and provide sources of inoculum for disease screening in the greenhouse. Three sets of backcrosses and three-way crosses to introduce anthracnose, rust and ALS resistance are being advanced. New sources of resistance continue to be evaluated for reaction to different pathogens at Tumbaco and at locations in the Mira and Choto Valleys. In the case of anthracnose, screening has been restricted to the greenhouse with specific known races collected from different production regions of Ecuador. Isolates of *Colletotrichum lindemuthianum*, *Fusarium solani*, *F. oxysporum*, *Phaeisariopsis griseola*, *Pseudomonas*, *Rhizoctonia solani*, *Thanathephorus cucumeris*, *Uromyces appendiculatus*, and *Xanthomonas campestris* collected in Ecuador have now been placed in long term storage or will be once the isolates have been fully characterized.

Strengthen bean breeding program in Guatemala: The program in Guatemala largely at the Chimaltenango Research Station focuses on black bean improvement for the highlands. A major crossing effort is seeking to introduce resistance to anthracnose, rust, angular leaf spot, and ascochyta into bush beans. Over 500 individual crosses were made to generate a group of 26 distinct simple crosses to combine sources of resistance to rust, anthracnose, ALS and drought. Success rate varied from 18-100% with a majority exceeding 80% success which is high for a program just being established. These F_1 have been used as parents to produce 50 three-way crosses with the three main black bean varieties. Within the segregating populations being advanced, 480 families have been selected for combination of seed and plant traits and initial reaction to disease present in the nurseries.

A group of 276 black bean breeding lines from MSU were evaluated at Chimaltenango and rated for reaction to ALS and rust pressure. Yields ranged from 10 to 1452 kg/ha with an average of 552 kg/ha. A select group of 50 lines will continue to be tested at various locations in-country to identify potential lines for advance and use as parents in the breeding program. A group of 19 populations from CIAT were evaluated for reaction to Ascochyta and 10 were selected for high levels of resistance combined with good architectural and favorable adaptation. In addition 10 F_7 generation materials were selected for high levels of resistance to rust and yield that exceeded the local check.

Combining earlier maturity with high yield potential has also been a major focus. The early-season variety Texel matures in 82 days compared to the high-yielding full-season varieties Hanapu and Altense that mature in 105 and 106 days, respectively. Efforts using mutation breeding have been deployed to develop lines that combine the yield potential of Hanapu (1060 kg/ha) with the early maturity of Texel (686 kg/ha). In the irradiated lines from Hanapu, two lines were selected that were 14 days earlier in maturity (91 d) than the parent and were equivalent in yield yet were only nine days later than Texel. In the irradiated lines from Altense no earlier maturing lines exceeded the yield of the parent, but 10 lines exceeded yield of Texel and were only 1-7 days longer in maturity.

A collection of 600 accessions of climbing beans were evaluated for 17 phenological and morphological traits. They were also classified for correct taxonomic species of *Phaseolus*. Harvest maturity ranged from 160 to 203 days and seed size varied from 19-46 g/100 seeds, underscoring the long-season maturity of climbing beans. Yields in the protected plots (with IPM) ranged from 1150-1565 kg/ha in the best 50 accessions, whereas yields ranged from 150-1150kg/ha in the same 50 lines in the unprotected plots where no IPM practices were used. Yield reduction ranged from 20 to 87% supporting the impact of disease pressure on these long-season accessions. The major diseases were ALS, Ascochyta, anthracnose, rust and *Phytophtora* which was particularly severe on certain accessions, particularly the non-*vulgaris* species. The iron content of the seed was measured in the collection of 600 climbers and the level averaged 73 mg/kg which is quite high. Over 40 accessions had values in excess of 80 mg/kg. A principal component factor analysis accounted for over 70% of the variability in the first five PC, days to flowering and maturity loaded in PCI, leaf size loaded in PC2, pod size and seed number loaded in PC3, earliness, pods traits and number loaded in PC4, and early flowering and seed size loaded in PC5. Two climbers, Guate 1026 and Guate 1201 were identified as possessing the best potential as parental material and have been crossed to G 2333, a well adapted red climbing bean with the highest level of resistance to anthracnose. The F_1 are now being backcrossed to the Guatemalan parents to help retain critical adaptation traits within these climbing bean populations.

Participatory bean breeding in Ecuador: Extensive testing of advanced lines is being continued in CIALs in the Northern Ecuadorian communities of Concepcion, Santa Lucía, San Clemente and El Tambo. New materials available for participatory plant breeding work include 14 advanced red mottled lines being evaluated for performance and rust resistance. Five lines exhibited resistance (3 on scale of 1-9) and yields exceeded 3T/ha compared to checks with rust rating from 4 to 6 and yield averaged 2.7 T/ha. Lines with higher levels of rust resistance were detected but yield was lower.

Root Heath and Architecture in Ecuador: Twenty genotypes were evaluated for reaction to root rotting pathogens *Fusarium solani* and *Rhizoctonia solani* present in the soils at Tumbaco, Ecuador. Those genotypes that exhibited the highest level of resistance were: A55, L88-63, DOR466, Porrillo Sintético and Negro San Luis when compared to local commercial cultivars. All the resistance sources are small-seeded Mesoamerican lines and will require a lengthy cyclic breeding system to introgress the resistance into large-seeded white, yellow and red-mottled types grown in Ecuador.

Nine genotypes differing in plant architecture were evaluated in grower fields in the Choto and Mira Valleys of Northern Ecuador. The ideal root ideotype for these conditions consist of a deep taproot with highly branched lateral roots. Four genotypes, exhibiting this root ideotype, Negro San Luis, SEQ 1016, and TP6 y PxJ-2 were included in the evaluation. An additional group of seven genotypes were selected: BAT 477, SEA2, SEA3, SEA9, SEA11, SEA12, and SEA14 as they possessed larger seed and should require less backcrossing to introgress into large-seeded Andean bean types grown in Ecuador.

Drought tolerance in Ecuador: A trial was conducted at Tumbaco to assess drought resistance in 26 inbred backcross lines (IBL) developed using a cranberry bean line C97207 as a recurrent parent. Five genotypes

C03102, C03121, C03131, C03151 and C03155 were selected based on combined performance (geometric mean between treatments). The first three genotypes exhibited higher yields than the recurrent parent and the last two genotypes exhibited an improved seed quality (Table 1). The IBL method for developing drought-resistant lines suitable for Ecuadorian conditions and markets is promising, given the difficulty of generating commercial seed types through single crosses with small-seeded genotypes. The drought resistant lines selected from the IBL population need to be tested in different environments in the Ecuadorian Highlands to confirm drought resistance. The selected IBLs with high levels of drought resistance were crossed with local cultivars to improve the drought resistance of large red mottled types as part of the overall breeding strategy to improve drought tolerance of common beans in Ecuador. A total of 14 distinct crosses were made which generated over 140 F_1 seeds for advance and selection.

Introgress new resistance sources into Ecuadorian bean germplasm: Twelve bean genotypes considered to be important sources of genes for resistance for rust, ALS and CBB were evaluated in five bean production locations, Santa Lucía, La Concepción, San Clemente, Tumbaco, and El Tambo (Table 2). High disease pressure was observed at all locations based on reaction on the susceptible checks: `Bola Pallatanga,´ for all the diseases `Cocacho,´ for ALS and CBB; and `Red Small Garden´ for rust. Genotype VAX 2 showed the best levels of resistance to all the diseases in all the locations. CAL 143 and G916 were resistant to rust and ALS and intermediate resistant to CBB. JE.MA. was highly resistant to rust. VAX 6, VAX 4, MAR 2, and G2333 were resistant to ALS and CBB in all the locations but showed intermediate to susceptible reaction to rust. POA 10, BAT 477, and `Mexico 54´ were resistant to ALS and showed intermediate reaction to rust and CBB. AND 277 showed a good source of resistance to ALS, but was susceptible to rust and CBB. Since VAX 2 was the best source of resistance for all diseases, it will be used as part of the crossing program to develop genotypes with multiple disease resistance. Several backcrosses must be considered as well since the seed quality differs widely from the Andean seed type. Other resistant genotypes with Andean seed type such as JE.MA., CAL 143, G 916, and AND 277 might be intercrossed to generate multiple resistant lines with commercial characteristics (Table 2). In addition, sources of resistance to anthracnose, angular leaf spot (ALS) and common bacterial blight (CBB) were also evaluated for reaction to rust at Tumbaco. Among the anthracnose differentials: only Cornell 49242, TU and AB 136 exhibited rust resistance; ALS-differentials: México 54, BAT 477, MAR 1, MAR 3 and Cocacho were highly resistant: CBB-differentials: VAX 1, VAX 2 and VAX 3 were resistant; local improved varieties: INIAP- 418 JE.MA., INIAP- 420 Canario del Chota, INIAP- 422 Blanco Belén and INIAP- 423 Canario were resistant, whereas INIAP- 414 Yunguilla, INIAP 419 Chaupeño, INIAP- 424 Concepción and INIAP-425 Fanesquero had an intermediate reaction.

Marker-Assisted Selection in Ecuador: Routine Marker-Assisted Selection (MAS) is being performed for anthracnose at the Santa Catalina station and efforts to do the same for other genes that condition resistance to other pathogens is underway. This effort is increasing in importance as the breeders combine diverse resistance sources that cannot be easily detected by routine screening.

Table 1. Geometric means, yield under non-stress, yield under stress conditions, seed quality, and 100 seeds weight of the IBL population evaluated in Tumbaco, Ecuador, 2005.

		Water Regimes			
Genotypes	**Geometric Mean**	**Stress**	**Non-stress**	**Seed**	**100 Seed**
IBLs		**Kg/ha**			**(g)**
CO3131	2235	1746	2860	5	48
CO3122	2142	1637	2803	5	53
CO3102	2078	1722	2508	4	52
CO3110	2055	1698	2488	6	55
CO3121	2028	1606	2560	3	56
CO3163	1985	1672	2358	4	54
CO3127	1797	1544	2091	6	47
CO3155	1792	1530	2098	3	52
CO3151	1746	1297	2349	3	45
CO3149	1558	11306	1859	6	41
CO3157	1523	1225	1894	4	53
CO3161	1466	1295	1659	5	45
Parents					
NSL	3358	2649	4259	NA[4]	41
C97407	1861	1414	2448	5	49
Checks					
Mil Uno	2395	1866	3073	NA	62
L88-63[3]	2017	1435	2835	NA	19
MEAN	**1893**	**1521**	**2364**		**48**
LSD		**346**	**574**		**4**
(0.05)		**13.9**	**14.9**		**4.6**
CV (%)					

[1] Selected genotypes, [2] Scale from 1 to 9, where 1 is the best quality and 9 is the worst.
[3] Drought resistant line (Frahm, 2004): [4] Comparisons performed only among cranberry seed types.

Table 2. Reaction to rust, angular leaf spot (ALS), and common bacterial blight (CBB) in 15 bean genotypes in four CIALs in Northern Valleys of Ecuador.

Genotype	RUST					ALS			CBB		
	Concepcion	Santa Lucia	San Clemente	El Tambo	Tumbaco	Santa Lucia	Concepcion	El Tambo	Santa Lucia	Concepcion	Tambo
JE.MA.	1*	1	1	1	1	4	4	5	4	4	4
CAL 143	2	2	2	3	3	2	2	2	5	4	4
G916	2	2	2	2	2	3	1	2	5	4	4
VAX 2	1	2	1	2	2	2	2	2	2	3	2
VAX 6	6	3	2	5	6	2	2	1	3	3	1
VAX 4	5	3	1	4	6	3	3	2	2	3	2
MAR-2	5	3	3	2	2	2	3	2	3	3	2
G2333	5	5	1	3	3	3	3	2	3	3	3
POA 10	3	3	4	5	4	3	3	3	6	4	2
BAT 477	6	4	1	5	2	3	3	2	4	3	5
AND 277	4	3	7	7	6	3	2	2	7	5	5
Mexico 54	3	4	2	3	2	3	2	3	5	4	4
Controls											
Red Small Garden	7	8	8	9	7	----	----	----	----	----	----
Bola Pallatanga	7	7	7	7	7	6	7	7	4	5	3
Cocacho	1	3	2	2	2	7	7	8	7	7	8

* 1-9 scale evaluation: - 1 = resistance, 9 = death plant caused by the disease.

LAC6-A2

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Identification and Deployment of Resistance Genes for Anthracnose, Rust and Drought in Beans for the Highlands Using Modern Molecular Genetics Tools

Principal Investigators and Institutions:
James Kelly, Michigan State University, U.S.; Eduardo Peralta, INIAP, Ecuador; Julio Villatoro, ICTA, Guatemala

Collaborators and Institutions:
George Abawi, Cornell University, U.S.;Angel Murillo, INIAP, Ecuador; Esteban Falconi, INIAP, Ecuador; Roberto Morales, ICTA, Guatemala

Justification and Objectives

The transfer of molecular genetic technologies to national programs is important for institutional development and the effectiveness of the national bean breeding programs. To facilitate the pyramiding of resistance genes into improved varieties of beans for Ecuador and Guatemala, the deployment of linked molecular markers for rust and anthracnose resistance and QTL for root rot and drought resistance are considered necessary.

The characterization of the race structure of the major fungal pathogens, chiefly anthracnose and rust, in Ecuador and Guatemala and the development of gene deployment strategies to extend genetic resistance to both pathogens is needed. Both anthracnose and rust are well known for their pathogenic diversity that can render a cultivar resistant in one location and susceptible in another. Based on extensive research on the variability present in *C. lindemuthianum* in certain Latin American countries (Balardin et al., 1997; Balardin and Kelly, 1998), anthracnose races present in Ecuador are most likely of Andean origin, however this needs to be ascertained through surveys. Regarding rust, and understanding of virulence patterns of the rust pathogen are needed to formulate control strategies through breeding and gene pyramiding.

Andean bean germplasm is known for its susceptibility to root rot. An inbred backcrossing (IBC) program at MSU has developed large-seeded Andean kidney and cranberry bean genotypes with resistance genes to root rot derived from highly resistant, small-seeded black bean germplasm from México. Given the quantitative nature of inheritance of resistance to root rot, the resistance trait was analyzed as a Quantitative Trait Locus (QTL). Regions of the bean genome on linkage groups B2 and B5 that contribute to root rot resistance were identified (Roman-Avilés and Kelly, 2005). Based on these findings, enhanced levels of resistance could be achieved by combining through crosses different QTL controlling resistance to root rot into single genotypes. This effort requires marker-assisted selection to identify the QTL for resistance.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Collect isolates of anthracnose, rust and root rot pathogens in Ecuador; anthracnose in Guatemala.
- Characterize pathogenic variability of anthracnose, rust and root rot isolates collected in Ecuador and Guatemala.
- Develop drought tolerant recombinant inbred line (RIL) populations for Ecuador, Central America and East Africa.

Research Results, Achievements and Outputs

Root rots: The Tumbaco, Ecuador, has become an excellent site for nurseries to evaluate bean germplasm to both *F. solani f. sp. phaseoli* and *R. solani*. Significant differences in the reaction of bean germplasm to *Fusarium* and *Rhizoctonia* were observed in 2006, confirming earlier results. A group of 20 genotypes were evaluated for root rot resistance using a 1-9 scale. (l=resistant). Five black-seeded genotypes: A55, L88-63, DOR 446, Porrillo Sintético and NSL had values less than 4 compared to a value of 6.5 for the susceptible check "Imbabello" across all replicates. The highest resistance levels reside in small-seeded black beans. A prolonged cyclic breeding effort will be required to transfer root rot resistance into the large-seeded Andean genotypes.

A diagnostic survey conducted by Dr. Abawi (November 2006) assessed the incidence of prevailing bean pathogens during the production cycle in the northern areas of Ecuador. A total of 25 sites were evaluated. Root disease symptoms caused by *R. solani*, *F. solani f.*

sp. phaseoli, *Sclerotium rolfsii*, *F. oxysporum f. sp. phaseoli*, and root-knot nematode (*Meloidogyne sp.*) were observed at a frequency of 96, 84, 40, 16, and 24%, respectively (Table 1). The survey revealed that growers are knowledgeable of foliar diseases of bean, but not of root diseases even where symptoms are prevalent. This gives evidence of the need for an illustrated fact sheet(s) of the major root diseases of beans in Ecuador that can be distributed to growers and extension educators.

This survey also reveals the need to confirm the identified sources of resistance to root pathogens in field nurseries in controlled tests under greenhouse conditions. The reaction of promising parental lines should be evaluated against representative isolate(s) of single root pathogens. In addition, there is a need for pathogenic and genetic characterizing of isolates of the collected root pathogens. This will be a priority activity for the CRSP bean breeding team in 2007.

Rust: Extensive variability was detected in 11 isolates of rust collected in the Northern production area of Ecuador (Table 2). Eight races- 0:20, 0:24, 2:24, 0:28, 2:28, 0:29, 0:30, and 0:61 were identified. The isolates were highly virulent on genotypes with Andean origin. Race 0:61 was the most virulent in this group infecting five of the six Andean differentials. Race 0:30 was the only race able to infect cultivar Redlands Pioneer that carries the Ur-13 gene from the Andean gene pool. Andean genotypes PC-50, Montcalm and Golden Gate Wax were susceptible to almost all isolates. The susceptibility displayed by the majority of Andean genotypes in the differential set suggested that the breeding strategy must focus on the incorporation of Mesoamerican resistance genes into local cultivars. Races 2:24 and 2:28 were also able to infect the cultivar Aurora (Ur-3 gene) from the Mesoamerican gene pool. The 12-differential cultivars for rust were evaluated at Tumbaco. Five of the six Mesoamerican cultivars had values from 1-3 and only Aurora exhibited values of 4 or greater. Among the Andean cultivars, Early Gallatin, Redlands Pioneer and Golden Gate Wax showed resistance with values 2-3, whereas Montcalm, PC 50 and PI 260418 were susceptible with values from 4-6. In addition, 17 resistance sources BelDakMi RMR 15, 16, 17, 18, 19, 20, 22, 23, and BelMiNeb RMR 3, 8, 9, 10, 12 ,13 including local varieties, JE.MA., Cocacho and Canario Imbabura, all proved to be highly resistant (1-3) compared to the local check that had a rating from 6 to 8.

Anthracnose: A collection of different isolates of anthracnose was made in the highland localities of Chimaltenango, Jutiapa and Tecpan, Guatemala. Twenty isolates were collected and will be evaluated on the 12-differential series to identify the races of anthracnose present in these regions. The results of this study will provide information to breeders on the best resistance sources to use to control anthracnose in these production areas.

A fifth allele at the Co-1 locus was characterized in the Andean cultivar Widusa. To-date, all Andean resistance sources identified reside at the Co-1 locus unlike the nine other loci identified in the Mesoamerican gene pool. This limitation greatly restricts the choice of Andean genes that bean breeders can use in resistance breeding particularly in those regions of the world where Andean genes would be useful. Breeders cannot pyramid Andean genes for resistance, but are forced to select among the five different alleles at the Co-1 locus to choose the most effective allele against the races present in one's production area. The most effective allele is Co-12 present in the large white-seeded cultivar, Kaboon. This allele has not been widely used in breeding as the donor parent is agronomically inferior. The Co-12 allele has been successfully moved into a high-yielding black bean background, combining it with the most effective Mesoamerican gene Co-42. This combination affords resistance to all known races of anthracnose worldwide. These black bean breeding lines are now available for testing in Guatemala.

Since the breeding program in Ecuador is working to combine resistance to three major pathogens in future varieties, an inoculation sequence is being developed to screen the same plants for each pathogen. Many segregating populations could potentially carry resistance to all three pathogens. The best inoculation sequence involves anthracnose inoculation at the primary leaf stage, rust on the first trifoliate and ALS inoculation on the third trifoliate. A deliberate time delay between inoculations reduces the risk of cross-protection.

Drought resistance: Drought resistance is a complex characteristic that comprises the interaction of many different traits that relate to performance under stress. Fourteen genotypes were selected from among 45 genotypes planted in an observation nursery and evaluated for reaction to drought, rust and overall adaptation at Tumbaco. These genotypes are being used as parents to introgress drought resistance into local cultivars and the first backcross generations have been made. In addition, six populations are being advanced to produce inbred backcross populations for study of inheritance of drought resistance. These populations are currently being inbred and advanced by a single seed descent to a suitable level of homozygosity for testing in replicated trials under stress and non-stress conditions.

Table 1. Results of diagnostic survey of bean root rot pathogens conducted November 15-16, 2006 in northern bean production regions of Ecuador.

	F. Solani	***Rhizoctonia***	***Sclerotinia***	***F.***	**Root Knot**	**Insects**
1	-	+++	-	-	-	NR
2	++	++	-	-	-	NR
3	+	++	-	-	-	NR
4	+	+	-	++	-	NR
5	+	+	-	-	++	NR
6	+	+	+++	-	-	NR
7	+	+	++	-	-	NR
8	+	+	-	+++	-	NR
9	+	++	-	-	-	NR
10	++	-	-	-	-	+++
11	+	+	-	-	-	++
12	++	+	-	-	++	-
13	+	++	+	-	-	++
14	++	+	++	-	++	++
15	+	+	+++	-	+	-
16	+	+	-	-	-	+++
17	+	+	++	-	+	++
18	+	+	-	+++	-	-
19	-	+++	+++	-	-	+
20	+	++	+++	-	-	+
21	-	+	+++	-	-	-
22	+	++	+++	-	-	-
23	+	+	-	-	+	-
24	+	+	-	++	-	++
25	+	+	-	-	-	-
Tumbac o	+	+++	-	-	+	-
%	84	96	40	16	24	?

Table 2. Races of Uromyces appendiculatus identified with the standard bean differential set for rust from 11 isolates collected in Northern Ecuador.

	Mesoamerican Gene Pool							Andean Gene Pool						
Isolate code	GN11	Aurora	Mex 309	Mex 235	CNC	PI 181996	Binary number	Early G	Redlands Pioneer	Montcalm	PC-50	GGW	PI 260418	Binary number
1	-[1]	-	-	-	-	-	0	+	-	+	+	+	+	61
2	-	-	-	-	-	-	0	+	-	+	+	+	-	29
3	-	-	-	-	-	-	0	-	-	+	+	+	-	28
4	-	-	-	-	-	-	0	-	-	-	+	+	-	24
5	-	-	-	-	-	-	0	+	-	+	+	+	-	29
8	-	-	-	-	-	-	0	-	-	+	+	+	-	28
9	-	-	-	-	-	-	0	-	-	+	+	+	-	28
13	-	-	-	-	-	-	0	-	-	+	-	+	-	20
16	-	+	-	-	-	-	2	-	-	+	+	+	-	28
20	-	+	-	-	-	-	2	-	-	+	+	+	-	24
21	-	-	-	-	-	-	0	-	+	+	+	+	-	30

CC1-A3

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Bean- and Cowpea-Based Foods for Micro- and Small-Scale Enterprise Development: Integrating Perspectives from Food Technology, Nutrition and Agricultural Economics

Principal Investigators and Institutions:
Anne Ferguson, Michigan State University, U.S.; Joan Fulton, Purdue University, U.S.; Germaine Ibro, INRAN/DECOR, Niger; Mbene Faye, ISRA, Senegal

Collaborators and Institutions:
S. Ramatou, INRAN, Food Science, Niger; E. Sakyi-Dawson, University of Ghana-Legon; Jess Lowenberg-DeBoer, Purdue University, U.S.

Justification and Objectives

In West Africa, cowpea-based street and snack foods are almost exclusively prepared and sold by women. The most common product is the cowpea fritter (called "kosaï" in Hausa, and "akara" in languages used in coastal areas). Regional products include steamed cowpea paste (called "moin-moin" in Nigeria and "coky" in Cameroon), boiled cowpeas with oil and herbs (Mali), rice and beans, and boiled cowpeas as a side dish. The number of women involved can be quite large. A preliminary count in Bauchi, Nigeria, revealed about 500 kosaï vendors in that small city. Case studies in Cameroon and Nigeria suggest that these cowpea-based foods can be quite profitable, given the low opportunity cost of labor. Little information is available, however, on the technical and economic problems faced by these women. The overall objective of this study is to identify the major problems faced by women entrepreneurs producing and selling cowpea-based food products in West Africa and to implement programs to assist these women in overcoming these challenges.

The report highlights progress made in research activities in FY 06 to achieve the following objectives:

- Expand the census and survey entrepreneurs to other regions of West Africa utilizing the same methodology used in Niamey, Niger, to provide an estimate of the number of entrepreneurs producing and selling cowpea-based food products in Senegal and Nigeria by market segment, to determine characteristics of the entrepreneurs, and to make comparisons of women entrepreneurs across geographic regions.
- Analyze the data collected in Objective 1 to identify gender differences in their operations and problems encountered by geographic region and other factors, determine the most important business and technical problems faced by the entrepreneurs, propose responses to the problems, and to seek solutions to problems related to gender inequity.

Research Results, Achievements and Outputs

Census and survey of women entrepreneurs: Two case studies of women entrepreneurs in West Africa selling street food from cowpeas were completed. The first case study involved a woman in Bauchi, Nigeria who makes "danwakee." This is a steamed product made from ground cowpeas. For the cowpea flour, the woman ground up the whole cowpea (without removing even the hulls before grinding). The costs of inputs for one day of business (in Naira) were:

Cowpea (45 kg)	1,500
Grinding of Cowpea	200 - 300
Wheat Flour (2.5 kg)	80
Potash (2.5 kg)	70
Leaves of Bamboa Tree (2.5 kg)	80
Firewood	200 – 400
Labor	750
Total Costs (Naira)	2,980 per day

This woman entrepreneur reported generating revenue between 6000 - 8000 Naira per day for a profit margin of 3020 to 5020 Naira per day (24 US$ - 40 US$ per day). These costs and revenues represent daily revenues and variable costs. The woman also had capital costs associated with the business. She had purchased the land for the small building that she had for her business. She reported that she had paid 100,000 Naira for the land. She then had to construct the building and was unable to tell us the cost of construction.

The second case study involved a group of women in the village of Togone, Niger. Activity PIs and collaborators

(Fulton, Ibro and Seydou) interviewed the women about various aspects of their operation including production of "berua" as well as the selling and marketing of berua. Berua is a couscous made from cowpeas and a traditional food for people in the Dougondoutchi region of Niger. The production of berua is complicated with many steps including: dehulling, cleaning, drying, and grinding the cowpeas followed by sieving the ground cowpeas to get consistent size, grinding the cowpeas to make a fine flour, hand mixing the ground cowpeas with a moist sticky mixture and the fine product to make the couscous product, drying, steaming and drying again.

There are 75 women in this group. These women both prepare and market berua individually and as a group. They sell this product at the main intersection in Dougondoutchi. The village of Togone is seven kilometers from Dougondoutchi. The women walk to and from Dougondoutchi to sell their product.

Data analysis for identifying gender differences: Data collected as part of this project were analyzed and presented as a selected paper at the American Agricultural Economics Association annual meeting in August 2006 (Ibro et. al., 2006). Kosai production utilizes a significant quantity of cowpeas each day. Vendors in Zinder purchase an average of 3 kg of cowpea each day, while vendors in Niamey and Maradi purchase an average of 2 kg and 1.3 kg of cowpeas each day. The enumeration revealed that there were 1305 kosai vendors in Niamey, 199 vendors in Maradi and 195 vendors in Zinder. Kosai vending is an important entrepreneurial activity for women with little or no education. Between 50 and 60 percent of the vendors reported having no formal education. In Niamey, just over one-quarter of the vendors reported some primary education while in Maradi, only 4% had some primary education and in Zinder, 8% has some primary education. In all three cities, less than 5% of the vendors had some secondary education. The vendors in Maradi and Zinder were more likely to have Koranic education than those in Niamey. The participation by girls in any schooling, French or Koranic, has been historically very low in Niger in general and in the more rural areas in particular. The literacy rate for females in Niger is 9.7% (CIA). It is interesting to note that while the vendors in the Niamey sample have a higher level of formal French schooling, total schooling including Koranic schools is higher in Maradi and Zinder.

Ninety-two percent of the vendors in Niamey are using income from kosaï for some savings, while 67% of the vendors in Maradi and 77% in Zinder reported using the money earned for savings. In Maradi over 80% of the vendors used the money to help the family pay for health care, clothes and food. In Zinder, virtually all of the vendors use the money to buy clothes and 80% of the vendors use the money to help the family. Sixty-one percent and 60% of the vendors in Zinder use the money on food and health care respectively. The vendors in Maradi and Zinder use the money for more immediate expenditures while the vendors in Niamey are more likely to use the money for savings and longer term expenditures, such as buying goats and school. These results may reflect a higher standard of living in Niamey.

Respondents were asked what factors were constraining for their business. While just over one-quarter of the vendors in Niamey noted that capital equipment was a constraint for their business, over 80% of the vendors in Maradi and Zinder felt that capital equipment was a constraint. The operations activities of buying cowpeas, getting the cowpeas to the grinder for grinding, and preparing the batter were noted as important by around 80% of the vendors in Niamey. Virtually all of the vendors in Niamey identified storage of kosaï as a constraint. Capital seems to be a greater constraint in Maradi and Zinder than in Niamey. This is probably due to the slightly higher level of resources in Niamey.

Regression analysis was conducted to identify the factors that contribute to success for these women entrepreneurs. In the regression analysis reported here, size was the variable used to signify success with size measured by the amount of cowpeas (measured in kg) that the vendor uses per day. Cowpeas are the main ingredient for kosaï production and there is a direct relationship between the amount of cowpeas used and the level of kosaï production.

The independent variables utilized in the analysis include Years, which represents the number of years of experience the vendor has as a kosaï vendor and Capital Constraint which is a dummy variable equal to one if the vendor indicated that capital equipment was an important business constraint. Cowpea Constraint and Prep. Batter Constraint are dummy variables equal to one if the vendor indicated that the operations aspects of purchasing the cowpeas everyday and preparing the batter were important business constraints. Primary, Secondary and Koranic are dummy variables equal to one if the vendor had education at that level. Finally the variables for Maradi and Zinder are dummy variables equal to one if the vendor was from that city. The co-efficients for Years are positive and statistically significant for all of the models, indicating that vendors with more experience are more successful. The co-efficients for Capital Constraint are negative and statistically significant for the first two models. Vendors who identify capital equipment as an important constraint to doing business are less likely to be successful. The co-efficients for Cowpea Constraint are negative and statistically significant for all models, suggesting that vendors who find purchasing cowpeas everyday is an important business constraint are less likely to be successful, again as expected. It is interesting to note that the co-efficients for Prep. Batter Constraint are positive and statistically significant for the first two models. The positive sign was not as expected since this suggests that women who consider the preparation of batter to be an important constraint are, in fact, more likely to be successful.

The production and selling of kosaï by women street vendors in West and Central Africa is an important economic activity. This value-added processing of cowpeas uses a significant amount of cowpeas. The nutritious snack is regularly consumed by everyone – from small children to the elderly and by people from all walks of life and social classes. The income that the women earn from selling kosaï is spent on savings, food, clothes and other family expenses. This activity is important for economic development and poverty alleviation.

Collaboration with food scientists to develop dry cowpea product: In July 2006, R. Phillips, E. Sakyi-Dawson and J. Fulton met in Niamey, Niger to work with G. Ibro and S. Ramatou to propose responses to the problems associated with the production of kosai that the women had identified and seek solutions to these problems. The focus of this visit was on developing a dry cowpea product (a form of flour) of the correct texture to make good quality kosai. It is necessary to first dehull the cowpeas before they can be ground into flour. Since the cowpeas must be wet to dehull them and then dried before the grinding step, it was necessary to conduct tests on the hydration and dehydration rate of the cowpeas.

The other technology that was explored was the most appropriate method of grinding the dried, dehulled cowpeas to create a dry product of the proper texture to produce good quality kosai. Samples of cowpeas were taken to local entrepreneurs with plate mills for grinding. In addition, the hammer mill at the INRAN laboratory was used. The results of the analysis concluded that the hammer mill was the appropriate technology for grinding the cowpeas. It uses screens for the ground particles that fall through resulting in the correct particle size of the dry product. Samples from the small batches of kosai that were made were provided to INRAN employees. All reported that the kosai was excellent. However, a more general consumer acceptance of this product still remains to be tested.

CC2-A3

Bean/Cowpea Collaborative Research Support Program
Latin America and the Caribbean Basin Regional Project

Impact Assessment of Bean/Cowpea CRSP's Investment in Degree Training

Principal Investigators and Institutions:
Richard Bernsten, Michigan State University, U.S.

Collaborators and Institutions:
Jess Lowenberg-DeBoer, Purdue University, U.S., Mywish Maredia, Michigan State University, U.S.

Justification and Objectives

The Bean/Cowpea CRSP exemplifies one of the models for university engagement in long-term training. A salient feature of the CRSP model for long-term training is that the degree training is integrated into CRSP-supported collaborative research projects both at the U.S. and collaborating host country universities. Principal Investigators identify the trainees based on host country training needs and the university admissions criteria. The graduate training occurs under the direct supervision of CRSP researchers, ensuring that the training activity directly contributes to CRSP research goals and objectives, as well as to institutional capacity building in partner host countries. Involvement in the CRSP research program also fosters the student-mentor relationship between the trainee and the university professor, which leads to a continued collaborative research relationship between the U.S. and the host country institution beyond the formal training program. The integration of training with an on-going research program in many cases leads to cost-sharing by the university in the form of reduced tuition costs, reduction in overhead costs and/or partial support from other sources to support the thesis research costs of completing a graduate degree.

The application of this "CRSP model" of long-term training in the Bean/Cowpea CRSP over the years has resulted in building of substantial human capital and institutional capacity. For example, since 1980, the Bean/Cowpea CRSP has fully, partially or indirectly supported 478 trainees for undergraduate or graduate degrees in the U.S. and in developing country universities (forty-seven of these trainees received support from the Bean/Cowpea CRSP for the completion of two or more degrees). The host country institutions directly impacted by the CRSP training and capacity building programs include, Bunda College in Malawi, Sokoine University of Agriculture in Tanzania, INIA (IIAM) in Mozambique, the Escuela Agricola Panamericana in Honduras, INIFAP in Mexico, INIAP in Ecuador, CEDAF in Dominican Republic, University of Ghana-Legon, ISRA in Senegal, IRAD in Cameroon, SARI in Ghana and ATBU in Nigeria.

The report highlights research progress made in research activities in FY 06 to achieve the following objectives:

- Assessing the impact of CRSP long-term training activities.

Research Results, Achievements and Outputs

Data Collection: A list of trainees and PIs (and contact information) was compiled by reviewing the MO's databases and searching the Internet for addresses. Two survey questionnaires were developed--one for the former Bean/Cowpea CRSP trainee alumni (from collaborating countries and the U.S.) and another for the PIs/scientists who supervised the trainees during their CRSP-supported GDT (graduate degree training). In addition, two case studies were carried out to highlight the impacts of the CRSP's investment in LAC (at the regional level) and in SUA (at the institutional level). Further, an internet search of all trainees was done to collect information that would both complement and supplement evidence of impacts gathered or were missed through other approaches. A modified Kirkpatrick's framework (impact of training on KSA; knowledge, skills, and attitudes) was used to assess training impacts. The results from this study were based on the analysis of surveys returned by 76 former trainees for whom contact information was found and who returned the survey. The respondents representing 60% of the frame population (41% of the target population); and 25 former and current U.S. PIs, supplemented by face-to-face interviews with HC PIs from LAC and ESA. Seventy-nine percent of returnees returned to the same institution at which they were employed prior to their GDT. Most of the returnees earned a Ph.D. degree (86%), specialized in plant sciences, (69%) and either worked for the government (36%) or at universities (31%). Most of the returnees (72%) were now working in a bean/cowpea related field, compared to 50% for non-returnees.

Survey of former CRSP Trainees: Trainees felt that their CRSP graduate degree training (GDT) was necessary for their professional development (100%), was highly relevant to their current work/job responsibility (92%); and that their CRSP research was necessary for their professional development (97%) and highly relevant to their current work/job responsibilities (83%). Trainees considered the ability to "design/conduct/analyze scientific research" (87%) as the most important KSA (knowledge, skills, and attitudes) acquired from their GDT. Most trainees shared their acquired KSAs through publication (66%), seminar/conference (70%), and research supervision of students (66%). Most of female respondents (62%) currently work at a university, vs. 38% of male respondents. Most of the respondents with Ph.D. degrees now have positions at a university (52%), vs. 25% of M.S. graduates; 31% of M.S. graduates are now employed in the private sector. Most respondents in the plant sciences were still active in bean/cowpea research (60%), vs. 41% for the social sciences, and 17% for the food sciences. Most HC trainees were still active in bean/cowpea research (69%), vs. 23% for U.S. trainees.

Most trainees (78% HC, 40% U.S.) earned less than US$15,000/year prior to their GDT. At their present or most recent employment, a majority of the respondents (57% HC, 97% U.S.) reported earning more than US$15,000/year. The acquisition of a graduate degree greatly increased trainees' salaries. Before GDT, a HC respondent with a B.S. degree earned about US$9,000/year. At their present or most recent employment, HC respondents with M.S. degrees earned about US$21,000/year, while those with Ph.D. degrees earned US$35,000/year. On the other hand, a U.S. national with a B.S. degree earned about US$19,000/year prior to GDT. At their present or most recent employment, U.S. trainees with M.S. degrees earned US$65,000/year, while those with Ph.D. degrees earned US$81,000/year. These numbers represented an increase of about 180% from B.S. to M.S. and about a 300% increase from B.S. to Ph.D. There was large wage differentiation between a degree (B.S./M.S./Ph.D.) received from a U.S. university and from a local university, especially in the LAC and WA regions. Few U.S. trainees (19%) had outside consultancies, while more than 55% of trainees from ESA and WA were involved in outside projects to augment income from their principal job.

Most of the trainees (71%) reported changes in their personal lives that evolved around improved financial status, greater self-confidence, an opportunity to learn a second language, and gaining new friends outside their home country. Most trainees (78%) cited changes in their professional lives that evolved around improved capacity or enhanced KSAs to perform well in their desired jobs. A majority of trainees (57%) considered their role in the release of varieties, awards or recognition received from their bean/cowpea research, papers published, and the important positions or jobs they held as important bean/cowpea related achievements. Most of HC respondents (86%) returned to their home country or to another developing country after receiving their highest degree. Further, 79 percent of returnees returned to the same institution at which they were employed prior to their GDT. Most of the returnees earned a Ph.D. degree (86%), specialized in plant sciences, (69%) and either worked for the government (36%) or at universities (31%). Most of the returnees (72%) were now working in a bean/cowpea related field, compared to 50% for non-returnees. Many of the returnees (36%) were able to get outside consulting opportunities to supplement their income from their primary job. Most of HC trainees (60%) continued to collaborate with their Bean/Cowpea CRSP supervisor after their GDT, while 85% of U.S. trainees did not collaborate with their Bean/Cowpea CRSP supervisor after their GDT.

Survey of former and current U.S. PIs: Many PIs (56%) praised the Bean/Cowpea CRSP's strong and continued commitment to long-term training. Most PIs (68%) acknowledged the need for greater funding support to degree training, particularly at the Ph.D. level. The primary reasons cited for fully supporting a trainee was because he/she was from a collaborating host country (31%) and that the trainee could not pursue a graduate program without full funding (27%). The main reason for partially supporting a trainee involve the availability of leveraged money, either from the department (39%) in which the trainee was enrolled, or from external sources (25%), such as foreign government scholarships or another research grant. Significant problems that PIs encountered while sponsoring students under the program involve the delays in receiving funds from the Bean/Cowpea CRSP (20%) and the need for an increase in budget for training (16%). Most PI respondents (64%) reported the significant jobs held by their former trainees in their respective profession as important bean/cowpea related achievements. Several PIs cited the contributions of their trainees in their research area (15%) and noted the publications and awards that resulted from the trainees' bean/cowpea related research (6%).

SUA Case Study: Ten out of the 11 CRSP-supported trainees from Tanzania returned home after completing their GDT in the U.S. and the majority is still working at SUA. Furthermore, the returned trainees have become principle collaborators on Bean/Cowpea CRSP projects at SUA. The CRSP has played a major role in helping

SUA develop its research and teaching program, particularly in the areas of crop science and bean genetic improvement. The launch of the "bean project," matched with its commitment to training host country nationals, has made SUA one of the key institutions within the Tanzanian national bean program--Uyole ARI, Selian ARI, and SUA. The role of the CRSP in supporting bean research in Tanzania has diminished over time due to its focus on bean production in low altitude areas. Currently, the Centro Internacional de Agricultura Tropical (CIAT) plays a dominant role in applied bean research in East Africa. However, for training per se, CIAT acknowledged that the CRSP is a major player in training bean scientists. The strong and continued commitment to long-term training is the strength of the CRSP. The research impacts of the CRSP's investment in Tanzania were more difficult to substantiate. In the 25 years of CRSP involvement at SUA, it has released only four bean varieties, two of which were released this past year. Furthermore, farmer adoption of these varieties is, to a great extent, unknown and has been greatly limited by constraints to seed production and multiplication. An institutional visit to SUA affirmed that former trainees are now contributing to developmental impacts through their teaching and advising of students, many of which are now in strategic positions in NARS. Further, former Bean/Cowpea CRSP trainees have been successful in getting externally-funded bean-related projects to complement and enhance their existing CRSP projects.

EAP (Zamorano) Case Study: In contrast to SUA, the focus of the Bean/Cowpea CRSP at Zamorano has not been on staff development training. Being a small institution, it is not possible for EAP to send staff members for training and hold open the position until he/she returns. While the Bean/Cowpea CRSP has not had a direct impact on staff development, it has had a significant impact on creating a strong regional research program (under the leadership of a former Bean/Cowpea CRSP trainee from another country), which has increased bean productivity in Central America. The CRSP is the major source of funding for the region's network of multi-locational varietal trials. Working in collaboration with national bean programs in Central America, EAP has developed numerous varieties that have been widely adopted throughout the region. In addition, the excellent reputation of the bean research program has served to both recruit students from the region and encourage EAP students to major in plant science. With resources made available by the CRSP, EAP has provided numerous students with the opportunity to gain experience conducting research and gain expertise in using lab equipment purchased with CRSP funding. Upon returning home, many of these graduates have taken key positions in national research programs and continue to collaborate with EAP on regional bean research. Key informants reported that the bean research program has greatly enhanced the reputation of EAP and thereby contributed to the institution's success in obtaining external funding for bean research and seed multiplication. The site visit affirmed that by enhancing EAP's capacity to train students and support varietal development throughout the region, the CRSP has had a major impact on strengthening regional research capacity, increasing bean production, and increasing small farmers' incomes in Central America.

Recommendations: The study affirmed that the CRSP is playing an important role in capacity building for teaching and research on beans and cowpeas, benefitting both the U.S. and host countries.

Recommendations for the Bean/Cowpea CRSP MO: Continue its commitment to GDT and give high priority to supporting HC trainees; require trainees to submit a short report at the end of each training year, as part of a routine assessment of the training program; require trainees to complete an exit survey and request future contact information; organize an e-mail group list as an effective way to facilitate communications between PIs and trainees and to encourage future collaboration; assert its role as intermediary or ombudsman for possible conflicts between U.S. PIs and trainees; continue its support to trainees after the GDT, perhaps by maintaining a link in the Bean/Cowpea CRSP website that identifies employment/post-doctoral fellowship opportunities for bean/cowpea scientists; and update data and contact information of trainees on a regular basis.

Recommendations for U.S. PIs: Recognize the constraints (e.g., poor infrastructure, unstable source of electricity, limited Internet access) faced by HC partners in collaborative projects and maintain contact with former trainees.

Recommendations for HC PIs: Continue to be aggressive in obtaining leveraged money to supplement and promote local bean/cowpea research and develop stronger linkages with NARS (i.e., universities in the ESA region).

Recommendations for USAID and other donors: Continue and increase financial support to training, particularly for HC nationals; recognize that a majority of HC trainees return to their home countries after the GDT and the returned trainees play important roles in building capacity at HC institutions; recognize that the CRSP's graduate degree training has been very successful in developing scientific capacity on bean/cowpea research in the U.S. and HC; and help to facilitate in the recruitment of HC nationals to come to the U.S. for their training.

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Developing the Human Factor: Degree and Non-Degree Training Activities Supported by the Bean/Cowpea CRSP

Degree Training

In FY 06, the fourth year of the current grant, the Bean/Cowpea CRSP continued its strong commitment to human resources development and institutional capacity building by implementing an innovative and cost-effective "CRSP training" program. The Bean/Cowpea CRSP allocated at least 25% of its annual budget to degree training activities across all three regional projects. A total of 61 students were included in the FY 06 workplan under different Components. As of the end of FY 06, September 30, 2006, all but five of these trainees had been supported for degree training as planned. Thus, a total of 56 trainees were "active" or had completed degree programs through the Bean/Cowpea CRSP during FY 06 (Table 1).

Table 1: Status of Degree Trainees as of the End of FY 06.

1. Degrees completed:	17
2. Active:	39
Total (Active and Completed)	*56*
3. Delayed/Pending:	0
4. Discontinued:	5

The innovativeness of the Bean/Cowpea CRSP's training program lies in the integration of training with long-term research, managed by scientists (predominantly Principal Investigators) based at academic institutions (universities in the U.S. and in host countries) (Table 2). Since long-term training is an integral part of CRSP research projects in the developing countries, PIs frequently leverage funding from other private and public sources to support in part or full the education and research activities of the CRSP trainees. Twenty-seven of the Bean Cowpea CRSP trainees, representing nearly 50% of the degree trainees, were partially or indirectly supported utilizing leveraged resources in FY 06 (Table 3). This unique feature of the CRSP model (e.g., engaging trainees in CRSP research projects, training students at advanced Host Country institutions, cost-sharing training expenses including thesis research activities, etc.) make the overall Bean/Cowpea CRSP training program highly cost-effective.

Table 2: Location and Type of Degree Training Supported.

Location and Degree:	No. Trainees
• U.S. university	12
– Ph.D. degree	12
– M.S. degree	0
– B.S. degree	
• H.C. university	5
– Ph.D. degree	17
– M.S. degree	10
– B.S. degree	

Table 3: Level of Support Provided to Degree Trainees.

Levels of CRSP support	No. Trainees	%
• Full	29	52
• Partial	22	39
• Indirect	5	9

Other noteworthy observations about the degree training activities conducted by the Bean/Cowpea CRSP in FY 06 are as follows (Table 4):

- As indicated by the origin of trainees, a majority (82%) of trainees in FY 06 are from CRSP host countries (46 out of 56), which is the global goal of the Bean/Cowpea CRSP.
- The Bean Cowpea CRSP office has sought to promote gender balance in its training efforts as evidenced by the fact that the number of female students trained in FY 06 equals the number of male trainees.
- In terms of disciplinary focus, strong contingents of trainees are pursuing degrees in food science and human nutrition (29) and in the social sciences/extension (12). This distribution is

appropriate considering the "value-chain" focus of the current program. Disciplinary training in such areas as plant breeding and agronomy, however, do not dominate the training agenda as in the past.

- In the new grant, the Bean/Cowpea CRSP has sought to utilize "advanced" host country institutions for degree training as a measure to achieve economies and to take advantage of degree training programs which might best prepare students for the academic and agro-industry contexts to which the students will be returning to and working upon graduation. This is evident in the fact that all the Bachelors degree level and half of Masters degree level training occurred at host country institutions. Overall, more than 50% of the Bean/Cowpea CRSP degree training occurred in host countries.
- The number of degree programs completed in FY 06 was just over 30% of all the students supported. As the Bean/Cowpea CRSP approaches the final year of its grant, we anticipate the number of students completing their degree programs to increase in FY 07.

Table 4: Distribution of Degree Trainees by Regional Project and Region/Country of Origin.

Numbers Trained by Regional Project:	
• WA Regional Project	14
• ESA Regional Project	19
• LAC Regional Project	22
• Cross-Cutting	1
Region of Origin of CRSP Trainees:	
• West Africa	11
• East/Central/Southern Africa	19
• Latin America/Caribbean	18
• U.S.	7
• Asia	1
Numbers Trained From:	
• CRSP HCs	46
• U.S.	7
• Non-HCs	3

As indicated in Table 5, academic programs supported by the Bean/Cowpea CRSP cut across many disciplines with the majority in the food science and human nutrition (29 out of 56) followed by plant and agronomic sciences (15), and social sciences/extension (12). The Bean/Cowpea CRSP still maintains a strong commitment to the training of scientists in the plant and agronomic sciences. These include such disciplines as genetics and plant breeding, agronomy, pathology, nematology, and entomology.

Table 5: Distribution of Degree Trainees by Degree Level and Discipline.

Numbers trained in:	
• Plant and agronomic sciences	15
• Food science and nutrition	29
• Social science/extension	12

Non-Degree Training

Non-degree training and short-term training are considered important for attaining CRSP institutional capacity building goals. This includes training through organized workshops, group training, and short-term individualized training at CRSP participating institutions. Like degree training, all non-degree training is integrated with research activities and is incorporated into the annual research workplans of each regional project. In FY 06, several non-degree, short-term training activities were supported by the Bean/Cowpea CRSP (Table 6). These activities range from a few days training programs (e.g., workshops) to a few weeks or months of individualized training in lab techniques or training in a field setting. Unquestionably, short-term training activities are essential for the CRSP to develop the necessary human resources for national agriculture research institutions and universities to address the emerging needs and opportunities of the bean/cowpea sectors in developing countries.

Table 6: Summary of Short-term Training Activities Supported by the Bean/Cowpea CRSP, FY 06.

Description	Location	When occurred?	Beneficiaries	Number of Beneficiaries		
				Male	Female	Total
Training of trainers' workshop on the dissemination of value-added cowpea products	Suhum, Eastern Region, Ghana	August 2006	Agricultural and nutrition extension workers and community health workers in rural areas	8	15	23
Training workshop on screening methods for food quality	Maputo, Mozambique	March 9-10 2006	Researchers from IIAM, Bunda College, SUA, UEM, WSU, OSU and MSU	8	4	12
Participation by graduate students in the study involving rehabilitation of malnourished children. Training in research design, data collection and data analysis	SUA, Tanzania	2006-2007	Ms. H. Martin and Ms. K. Kokuletage	0	2	2
Training in seed system development	Lilongwe, Kasungu, Nkhotakota and Zidyana	August-December 2006	Smallholder bean farmers	239	62	301
Short-term research training in root evaluation methods and drought adaptation	PSU, USA	Spring/ Summer 2006	L. M. Flores from INTA, Nicaragua	0	1	1