2003 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

This publication was made possible through support provided by the Office of Economic Growth, Agriculture and Trade, U.S. Agency for International Development, under the terms of Grant No. DAN-G-SS-86-00008-00. The opinions expressed herein are those of the Bean/Cowpea CRSP and do not necessarily reflect the views of the U.S. Agency for International Development.

Published August 2004

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

Table of Contents

PREFACE

The Bean/Cowpea CRSP 2002-2007 Grant

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 *2003 Research and Training Highlights* Report presents noteworthy achievements by Bean/Cowpea Collaborative Research Support Program (CRSP) scientists during FY 2003, the first year of a new five-year grant from EGAT/ USAID-Washington. These achievements in research and training resulted from partnerships between scientists at eleven U.S. land-grant universities and 24 Host Country National Agriculture Research Systems and agricultural universities involved in three multi-disciplinary regional projects to address priority constraints to enhancing bean and cowpea utilization and production in developing countries in West Africa, East and Southern Africa, and Latin America and the Caribbean Basin.

The objective of this report is to "highlight" the technical progress made by each of the 19 different research teams. We also 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. 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 newly 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.

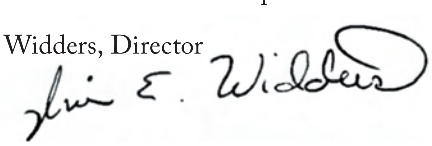
As is evidenced in this report, Bean/Cowpea CRSP scientists seek to make accessible, train in the use, and ***apply cutting-edge science*** to developing countries through the collaborative research activities. Such cutting edge science includes methodologies and instrumentation utilized in modern molecular genetics to map the genome, to isolate, sequence and clone genes, to introgress important genes into beans and cowpeas, and to 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 brought about by HIV/AIDS, weak institutions of higher learning, civil strife, struggling economies, etc. 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 research progress and achievements identified in this 2003 Highlights Report give evidence of the dedication and commitment of Bean/Cowpea CRSP scientists to this vision. 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.

Irvin 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), regional bean and cowpea research networks (e.g., PROFRIJOL, PRONAF), 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.
5. Increase the **sustainability** of bean and cowpea production systems in divergent agro-ecological zones.
6. Enhance the **productivity and quality** of beans and cowpeas through genetic improvement, utilizing both tools of molecular biotechnology and traditional breeding.
7. 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 Africa

U.S. AND HOST COUNTRY INSTITUTIONS PARTICIPATING IN THE WEST AFRICA REGIONAL PROJECT BEAN/COWPEA CRSP

Purdue University
Texas A & M University (TX A&M)
University of California-Riverside (UC-R)
University of Georgia (UGA)
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
Savannah Agricultural Research Institute (SARI), Ghana
University of Ghana-Legon (UG-L), Ghana
University of Zimbabwe (UZ), Zimbabwe

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 2003.

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; Mbene Faye, ISRA, Sénégal
Germain Ibro, INRAN, Niger; Augustine Langyintuo, SARI, Ghana; Saket Kushwaha, ATBU, Nigeria

Collaborators and Institutions:

Prosper Tine, WVI, Senegal

Justification and Objectives

The preliminary diagnosis of cowpea marketing in West Africa has identified the following general picture: a) Poor flow of price and quality information between some countries; b) Characteristics of improved varieties of cowpeas are not necessarily those prized by consumers; c) High transportation and transaction costs; d) Market power exercised by some merchant communities; e) Little value added by cowpea processing. 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.

This report highlights progress made in research activities in FY 03 to achieve the following objectives:

- Develop cowpea grain marketing opportunities by estimating the economic potential for coastal shipping of cowpeas, developing preliminary estimates of the market value of cowpea cooking time and sugar content, and describing the marketing information system in Sénégal, Niger, Nigeria and Ghana.
- Estimate potential demand for cowpea-based processed products in West Africa.

Research Approach, Results and Outputs

The Economic Potential of Coastal Shipping of Cowpeas: Cowpea exporters were identified and interviewed in Touba and Louga in Senegal. About 90% of the interviewees use trucks to export their cowpeas. A few of them have utilized coastal shipping by mixing small quantities of cowpeas with other food products in the same container. Some of the exporters declared that they are shipping to European countries such as France, England, and Italy but further investigation will be conducted in order to confirm this information. One of the constraints identified by the merchants is the risk related to insect damage when shipping their product. Other details about the cost, the destination, and the exporters' willingness to ship their cowpeas by boat is currently being collected.

Market Value of Cooking Time and Sugar Content: Data for cooking time and sucrose content were added to the data collected in four of the markets (Castors, Nioro, Mpal, and Tilene) in Senegal, starting in January 2002, to estimate the market value of cooking time and sugar content. The average sucrose content was 4%, with a minimum of 1% and a maximum of 7%. The sweetest cowpeas are found at Mpal followed by Tilene and Castors. The lowest sugar content was observed at Nioro. In Senegal, the average cooking time is relatively constant 30 minutes but varying from 11 to 62 minutes (Faye, 2003).

Econometric analysis using the Seemingly Unrelated Regression technique (SUR), was conducted with the data to determine the market value associated with cooking time and sugar content. Grain size is important for consumers in the Castors and Nioro markets. Consumers in the Mpal market preferred red skin color while consumers in the Castors and Nioro markets preferred black speckled skin. The co-efficient for smooth skin in the Nioro market is positive and statistically significant at the 10% level, suggesting some preference for smooth skin. Sucrose level was positive and statistically significant. The results suggest that consumers in Senegal prefer a sweet cowpea. The sucrose test is statistically significant in all four markets tested. In the Nioro and Mpal markets, consumers are willing to pay a 20 FCFA/kg premium for a 1% increase in sucrose, while in the Tilene market they are willing to pay a 40 FCFA/kg premium. In this preliminary analysis, cooking time was found to not have a statistical impact on price in Senegal.

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Cooking time was added to the data collected in the Niamey cowpea price and quality study. Descriptive statistics indicate that the price and quality characteristics at the two Niamey markets are similar. The grain size and average cooking time are almost the same for both markets, but both characteristics were more variable for cowpeas purchased in the Petit Marché.

SUR regression analysis of the two markets in Niger showed some potential for the cooking time variable in hedonic price analysis. In both markets, the dominant variable was testa color. Eye color was statistically significant in the Wadata data. As hypothesized, the estimated cooking time variable was negative. Cooking time was almost statistically significant for the Petit Marché data (P value = 0.06). The cooking time co-efficient is interpreted as the market discount for each minute increase in median cooking time. The estimated co-efficients indicate that all other things equal, market price in Niger would decline 1 to 2 FCFA/kg for each minute of extra cooking time. It is interesting to note that the co-efficients for cooking time were not statistically significant in the Senegalese markets but were statistically significant or at least looking promising in the Nigerian markets. It remains to be determined if consumers are reacting to cooking time or if cooking time happens to be strongly correlated with some visually assessable variable.

Description of Marketing Information System: Further analysis of price and quality data of cowpea marketing in Senegal was conducted. Several interesting results were observed. Consumers in Senegal are willing to pay a premium for larger grain size in all markets. There is little evidence that consumers in Senegal are willing to pay a premium for fewer bruchid holes as evidenced by the fact that the co-efficient was only statistically significant in the Tilene market. One possible explanation is the already low level of infestation by insects in the market samples. The co-efficients for smooth skin cowpeas are statistically significant and negative for the Nioro, Mpal and Tilene markets. Consumers discount prices for smooth skin cowpeas by 22, 25 and 30 FCFA/kg in the Nioro, Mpal and Tilene markets, respectively.

Market participants in Senegal were interviewed to determine their sources of information. Their main sources are the telephone network, newspapers, and the Internet.

Market participants in Niger were interviewed to determine their sources of supply, the type of commercialization they were involved in, the place that they sold from, and their sources of information for cowpea prices. The vendors of cowpeas in Niamey have several sources of supply. During the period of harvest and for two to three months after harvest, the retailers source their cowpeas from local villages in the production region near Niamey. Later in the year, the retailers source their cowpeas from middlemen and wholesalers. During this time, the price of cowpeas in the production zone increases. The wholesalers buy cowpeas from the interior of the country. There are four categories of cowpea vendors, including wholesalers, SOCOPAP, middlemen, and retailers. The main sources of information used by the retailers and middlemen is word of mouth. The telephone, fax and electronic communication were found to be key for information exchange.

The market participants in Nigeria, including producers, middlemen, wholesalers and retailers were interviewed to determine their sources of information as well as factors affecting the way they conducted business. Musa Shehu provides an extensive description of each of the components of cowpea marketing, from farmers through to the consumers in Nigeria (Ph.D. dissertation from Abubakar Tafawa Balewa University). There is a timely flow of information along the value-chain accompanied by timely changing of prices to correspond with the new information. Shehu reports that many of the individuals involved at the wholesale and distribution stages of the value chain have recently started to use cellular phones. The use of cellular phones has shortened the time for information flow from northern Nigeria to the markets in southern Nigeria and appears to have further increased market efficiency. Shehu used regression analysis to examine the question of whether the Kano market dominates the other cowpea markets in Nigeria. Shehu's results do not support the assertion that the prices in the other Nigerian markets are controlled by the Kano market prices.

Langyintuo (Ph.D. dissertation at Purdue University) examined the potential impacts of changes in trade policies, including the adoption of the West Africa Monetary Zone (WAMZ) on cowpea trade in West and Central Africa. Langyintuo developed an empirical spatial and temporal price equilibrium model for cowpeas for the Nigerian Cowpea Grainshed including: Benin, Burkina Faso, Cameroon, Chad, Côte D'Ivoire, Gabon, Ghana, Mali, Niger, Nigeria, and Togo. Using the model, he examined the impact of specific changes that are expected to result from the adoption of WAMZ, including a decrease in real interest rates on capital and a decrease in the level of trade barriers.

A 7% real interest rate on capital within ECOWAS (Economic Community of West African States) increased cowpea inventories in all ECOWAS countries because of relatively cheaper storage costs, except in Nigeria where storage was hardly affected. Removing non-tariff barriers to trade within ECOWAS facilitates cowpea shipment leading to an increased trade volume by 3% over the base year. Reduction in trade barriers led to lower cowpea prices in net importing countries, higher prices in net exporting countries, and an overall increase in net social welfare.

Langyintuo also examined the impact of decreases in transportation costs and increases in the level of demand and supply of cowpeas. Reduction of transportation costs in ECOWAS countries by 10% led to a decrease in price in importing countries and a resulting increase in demand and decrease in domestic supply in these countries. Net exporting countries experience an increase in price and supply and a decrease in domestic demand. An effort to improve the transportation network within the trading bloc would have beneficial effects on the whole region. However, the producers in net importing countries would experience a loss of welfare and would need to be compensated.

Improved yields that lead to improved supply of cowpeas resulted in trade flow changes that left producers in countries with improved yields better off and producers in countries without improved yields worse off. A Bt cowpea could substantially increase regional welfare. A 10% reduction in storage loss from adopting improved storage technologies resulted in an increase in net social welfare, with cowpea producers experiencing a loss of welfare because improved storage increased supply without more production.

An increase in the demand for cowpeas resulted in an increase in welfare for producers and a decrease in welfare for consumers. There was an overall increase in the volume of trade and an increase in net social welfare.

Assessment of Potential Demand for Cowpea-Based Processed Products in West Africa: Processors of cowpeas have been interviewed in Dakar, Thies and Kebemer in Senegal where most of them are located. Because of the lack of regular demand among the ten production units visited, only two (la Viviere and the Kandala Women Group) still continue to produce cowpea-based products. Collection and analysis of data on consumer preferences for cowpea-based products is continuing in FY 04.

Market participants involved in Kosai production and marketing were interviewed (Kushwaha and Shehu, 2003). Kosai, a deep fried cake or fritter made from cowpeas, is an important processed cowpea product. It is useful to note that, while the analysis reported here is for Kosai in Nigeria, the deep fried cake product from cowpeas is sold throughout West Africa under different names. Six different market segments exist for Kosai, including: households, school children, travelers, casual laborers, patrons of beer shops and others. It is not uncommon for someone from a household to go out to the local Kosai vendor in the morning to purchase Kosai for the household as a breakfast item. School children will purchase Kosai as an after school snack. Travelers will purchase Kosai since they are easy to carry and can be eaten "on the go." Casual laborers will purchase Kosai because they are a quick lunch or snack. It is not uncommon for Kosai vendors to be located near beer shops as the patrons of the beer shops will purchase Kosai to eat while enjoying the beer. Kosai merchants are effectively utilizing market segmentation as part of their business strategy. This is evident by the vendors' selection of the location and time of their business, by the type of oil they use, by the size of their cooking pot, by their use of spices, and by the attention that they pay to cleanliness of the operation. While a constant price (of one Naira per Kosai) exists throughout all of northern Nigeria, it is evident that the Kosai markets are efficient with non price factors being important in the balance of supply and demand. For example, the size of the Kosai varies throughout the year along with fluctuations in the price of cowpeas. All Kosai vendors are women. Most Kosai operations involve at least two people. One person is in charge of the stand where the Kosai are cooked and sold, while the other person prepares the batter and brings it to the vending stand.

Literature Cited

Faye, M. 2003. Cowpea Preferences in Senegal, Including Premiums Paid for Sweetness and Cooking Time. Bean/Cowpea CRSP Africa Economics and Marketing Group Consumer Preference Estimation Workshop. March, Accra, Ghana.

Kushwaha and Shehu. 2003. Challenges in Measuring Consumer Preferences for Kosai in Nigeria." Bean/Cowpea CRSP Africa Economics and Marketing Group Consumer

Preference Estimation Workshop. March, Accra, Ghana.

Langyintuo, A., J. Lowenberg DeBoer and C. Arndt. 2003. Potential Impacts of the Proposed West African Monetary Zone on Cowpea Trade in West and Central Africa, Selected Paper, American Agricultural Economics Association Annual Meeting, Montreal, Canada, July 30 (full paper is available on Ag Econ Search at http//agecon.lib.umn.edu/).

Langyintuo, A., J. Lowenberg DeBoer and C. Arndt. Potential Impacts of the Proposed West African Monetary Zone on Cowpea Trade, submitted to Agricultural Economics.

Langyintuo, A. and J. Lowenberg DeBoer. Grain Price Adjustment Asymmetry: The Case of Cowpea in Ghana, submitted to the Journal of Development Economics.

Langyintuo, A. and J. Lowenberg DeBoer. Assessing the Potential Impacts of Biotechnologies on Cowpea Trade in West and Central Africa; draft paper to be submitted to Journal of Development Economics.

Shehu, M. 2003. Cowpea Marketing in Nigeria. Ph.D. Dissertation. Abubakar Tafawa Balewa University, Bauchi, Nigeria.

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 and Susan Kay McWatters, University of Georgia; Esther Sakyi Dawson, University of Ghana-Legon, Ghana

Collaborators and Institutions

Stanley Fletcher and Manjeet S. Chinnan, University of Georgia; Sam Asuming Brempong and O. Sakyi Dawson, University of Ghana-Legon; 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.

This report highlights progress made in research activities in FY 03 to achieve the following objectives:

- Determine consumer preferences and market opportunities for value-added processed cowpea products.
- Develop processed foods with high nutritive and health values, including storable snacks and fast foods.

Research Approach, Results and Outputs

Consumer Preferences and Market Opportunities: Initial surveys were conducted in two communities in Southern Ghana to assess the degree of adoption of previously introduced technologies (fermented cowpea-fortified dough) using TORA (Theory of Reasoned Action) methodology. Ninety percent of the respondents were female while 10% were males. This is mainly because food preparation is seen as a woman's job. Whereas, 45% of respondents indicated they had no problems regarding the use of the cowpea-fortified maize dough, 55% indicated some perceived problems, including diarrhea if foods were not well cooked (45%), and allergy to maize (10%). Five percent of respondents also listed a faster rate of spoilage (compared to traditional corn dough), watery texture, low shelf life, unpleasant smell, and causes vomiting by children. The respondents indicated they would consult women leaders, peers, and community health nurses about the preparation of cowpea-fortified maize dough. The majority of the respondents (62%) indicated they had attended demonstrations on the preparation of cowpea-fortified maize dough. This was organized by the Hunger Project Ghana, in collaboration with the CRSP and the University of Ghana. Most frequent contact with extension providers was with Government health officials and Hunger Project/CRSP representatives. Fifty three percent (53%) of the respondents indicated they had never prepared the cowpea-fortified maize dough; 32% had prepared it within the last three years and 15% had prepared it but they did not remember when they prepared it. The main issues indicated by respondents that are likely to influence their decision to buy or process the cowpea-fortified maize dough include nutrition, and sensory quality. Most respondents believed the major reason for using cowpea-fortified corn dough were improved health and nutrition, while the major reasons for not using it were related to cost and sensory characteristics.

A survey to document the types of cowpea products available and information on ways in which cowpeas are utilized was conducted in Southern and Central parts of Benin where cowpea production is highest. The study identified about 15 cowpea-based traditional products, which are processed and consumed in various forms in Benin. There are groups of products that are similar to each other and vary slightly in the processing steps from one locality to another.

In the U.S. a new approach to surveying food processors and consumers was implemented. The UGA team and Inland Empire Foods, Riverside, California, co-hosted an exhibit/booth at the annual meeting of the Institute of Food Technologists (IFT) in Chicago, July 2003. This meeting featured ~1,000 exhibitors and ~20,000 attendees; and afforded an excellent opportunity to collect product concept and acceptability information for novel, cowpea-based foods. Inland Empire Foods, a leading supplier of

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

legume ingredients, prepared akara balls from Cal Cream cowpeas, a white-eyed variety developed by Drs. Tony Hall and Jeff Ehlers, University of California Riverside, using the formula and preparation procedure developed by the UGA team. Visitors to the booth represented food processors, ingredient suppliers, academia, and regulatory agencies; they were invited to evaluate akara and an extruded pork rind like snack made from a mixture of cowpeas and rice flours. For akara, 72.5% indicated that they liked the product, 11% did not, and 16% were indifferent. Of those who liked akara, flavor was the most appealing attribute (65% of respondents) followed by texture (46%), appearance (26%) and aroma (20%). For the cowpea/rice snack food, 75% of the respondents indicated that they liked the product, 9% did not, and 16% were indifferent. Of those who liked the product, texture was the most appealing attribute (65% of respondents) followed by flavor (49%), appearance (14%) and aroma (10%). Determining the acceptability of cowpea-based products by food manufacturers and ingredient suppliers will suggest approaches to improving the products while introducing them to key players who would be involved in their implementation.

Development of New Food Products with High Nutritive and Health Values: Several new products were tested by the research team. These include:

Cowpea peanut milk: Milk from legumes and nuts have been shown to be a potential substitute for cow's milk. In previous studies, a production process for milk from cowpea and peanut was developed. The purpose of this study was to optimize the production process of cowpea peanut milk and investigate its thermal stability. Peanuts and cowpeas were obtained from the local market in Accra. After cleaning, the grains were soaked in tap water for six hours, drained and placed in a sterilized moist jute bag to germinate for a period of 24, 48 and 72 hours. The samples of the germinated seeds and non-germinated seeds were blanched in boiling water and the seeds were dried in an oven at 45-50°C for four hours. After drying and dehulling, the mixture of one part cowpeas and three parts groundnuts was soaked in either tap water or in 2% NaHCO3 for 3 and 18 hours, respectively. After soaking, the mixture was decanted and then blended with water (ratio of one part seeds to six parts water). The resulting suspension was kept at room temperature for 3-4 hours and filtered. The filtrate (milk) was then pasteurized at 85-90°C for 10 minutes. The Brookfield Viscometer was used to measure the viscosity of the different samples after holding at 90°C for 20 minutes and cooling to 50°C. The results obtained so far gives an indication that the nutritional content and functionality of the cowpea peanut milk can be improved with a combination of germination and soaking in 2% NaHCO3.

Canning cowpea (Nigeria and IT87D195Y) varieties: The objective of this study was to determine the optimal pre-processing conditions required for good quality canning of different varieties of cowpeas. A Central Composite Rotatable Design was used in the experiment with independent variables being: Blanching time, Soaking time and Sodium hexametaphosphate concentration. The dependent variables studied included the following: hardness of canned cowpeas, drain weight of canned product, pH of drained liquid, moisture content of the canned cowpeas, percent splitting, leached solids, ash content and phytate content. The result revealed that soaking time, blanching time and [(NaPO3)6] significantly affected most of the indices studied. The optimal processing parameters to achieve canned cowpeas of good quality were not very different for the two varieties of cowpeas. Based on what quality criteria are most important for a particular canning operation, modifications would have to be made in the salt concentration, soaking times and blanching times. Salt concentrations ranging from 0.2% to 0.8%, soaking times of 12-19 hours and blanching times of five minutes are adequate to achieving a good quality canned product.

Carbohydrates in cowpeas and their effect on cooking characteristics: The contribution of the carbohydrate and protein fractions of different cowpeas towards their cooking and other quality characteristics was evaluated. Cowpea varieties used were Asontem, CR 06 07, Bengpla and Asetennapa, which are varieties released by the Food Crops Development Project (FCDP), Kumasi for planting by farmers. The starch content of different varieties on a dry weight basis ranged from 31% (CR 06 07) to approximately 40% (Asetenapa). After cooking for the same length of time, CR 06 07 was the firmest and required the highest force for cutting and Asetenapa was the softest. Based on the results of solubility, swelling power and swelling volume, it is postulated that Bengpla and Asetenapa starches may produce pastes that have better stability and viscosity than Asontem and CR 06 07.

During the cooking period the firmness of the seeds was monitored. The rate of decrease varied for the different varieties. The data indicates that after 60 minutes hardly any further softening occurs. This indicates that it is important to establish the cooking times for different varieties of cowpeas. In canning, one cannot use the same processing parameters for all cowpea varieties. Varietal differences in seed components play a significant role in the cooking quality of cowpea seeds.

Cowpea milling and flour utilization: Results indicated that an optimal particle size distribution with a geometric mean diameter of 200 microns after whipping can be produced using a hammer mill and plate mill. The resulting meals have desirable water holding and swelling capacity. A cowpea-based fried product, akara, was prepared to demonstrate the feasibility of using cowpea meal as an ingredient for food preparation. Cowpea meal made from a hammer mill equipped with 2.54 mm screen and from a plate mill with one turn clearance had good paste consistency and handling properties before frying, and produced an end product (akara) with excellent sensory quality. Companies in the U.S. are interested in marketing this cowpea-based product and are currently doing marketing studies.

Heat moisture treatments of cowpea flour and their effect of the inactivation of Phytase: Phytase proved to be fairly heat stable such that exposure to the highest temperature (95°C) and time (32 minutes) combination resulted in the destruction of less than 50% of the enzyme activity at the lowest moisture content. This thermal stability has been reported in other studies. The inactivation kinetics of phytase did not follow typical first order reaction being more adequately described by a modified first order reaction. This is known as the fractional conversion model, which accounts for non-zero activity after prolonged heating. Overall, phytase activity was significantly affected by heating temperature and initial moisture content of the flour; increasing temperature and initial moisture content resulted in increased inactivation of the enzyme. This behavior was observed at all the three moisture contents studied. The fractional conversion model was used to estimate the kinetic inactivation parameters, namely, the inactivation rate constant, k, of the heat labile fraction and the remaining percentage of active enzyme, A.

Extruded cowpea-based snacks: The process variables (cowpea levels, feed moisture and barrel temperature) showed significant effects on the system variables (die pressure, product temperature and specific mechanical energy input). Increasing the cowpea level increased the die pressure. High moisture extrusion reduced the die pressure, and mechanical energy input. The cooling water exit temperature, which indicates the rate at which heat energy is removed from the system was highest at low moisture and low temperature extrusion conditions, that coincided with high mechanical energy input. Compression tests showed that crispy and friable textured products could be obtained at high temperature (150°C) and high cowpea content level (50%). Hard textured extrudates were obtained at high cowpea levels, low temperature and high moisture extrusion conditions. Acoustic analyses of the sounds produced during compression of the extrudates showed that feed moisture, extrusion temperature and cowpea level affected the amplitude of the sounds produced. The regression model from the acoustics data had r squared of 0.98, and had a non significant lack of fit. The power spectrum density (i.e., the area under the amplitude frequency plots) showed high cowpea products extruded at high temperatures afforded the crispest products. Extrudates obtained under those conditions also had the lightest bulk density and high water soluble solids. Extrusion of cowpeas and rice blends at high moisture produced dense and hard products. However, at low moisture and high temperature extrusion, high levels of cowpea blends afforded light, puffed and crispy products that could be developed into pork rind type snacks.

Literature Cited

AOAC Official Methods of Analysis, 1990.

Lopez, A. 1987. A Complete Course in Canning, 12 ed. The Canning Trade Inc. Baltimore MD, U.S.

Lu, C. L., K. H. Hsu and L. A. Wilson. 1984. Quality Attributes and Retention of Selected B Vitamins of Canned Faba Beans as Affected by Soaking Treatments. Journal of Food Science 49:1053-1056.

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; Mohamadou Gandah, INRAN, Niger; A. B. Salifu, SARI, Ghana

Collaborators and Institutions

M. Amadou, Germaine Ibro and F. Seyni, INRAN, Niger; T. Adam, University Abdou Moumouni, Niger; D. Marafa, University Abdou Moumouni, Niger; Maria Balota, Wayne Greene and Charles Rush, Texas A&M; Bonnie Pendleton, West Texas A&M.

Justification and Objectives

In West Africa, cereals such as pearl millet and sorghum are traditionally intercropped with cowpeas (Subbarao et al., 2000). Sole cowpea is seldom planted, and cereal/legume rotations are rare. Although cropping systems differ from region to region, generally both cereal and cowpeas are sown at very low densities (< 5000 hills/ha) with no fertilizer or other chemical inputs. The productivity of this traditional system is very low. Because current cropping systems are not keeping pace with food demand, causing soil degradation, and becoming less productive, they are not sustainable. They must therefore be intensified in manners that meet local food demands, protect or improve the soil resource base, and generate income.

The Panhandle region of Texas is also faced with increasingly unsustainable cropping systems in terms of economics, soil degradation, and especially water supply. Because cowpeas are a legume adapted to dryland conditions and may hold market opportunities in the local cattle market, which suffers annually from fodder shortage, it has potential to render cropping systems more sustainable in the Texas Panhandle.

This report highlights progress made in research activities in FY 03 to achieve the following objectives:

- Develop and implement sustainable, intensified cowpea-based cropping systems for semi-arid West Africa and Texas.
- Optimize agronomic practices for production, integrated strategies for pest management, sustainability, and income generation.

Research Approach, Results and Outputs

Multi factorial agronomic experiments involving cowpeas and cereals were initiated at two sites in Niger and one site in Texas. In the northern Nigerian site of Sadore, the cereal crop was pearl millet; in the southern site of Gaya, it was sorghum. A Latin square design was used at both sites in Niger that included as treatments--cropping system, management intensity, and cowpea genotype. Because the rains ended unusually late this year, yield data were not yet available as of the end of FY 03 from Niger.

In Texas, a dryland cropping system experiment was initiated in which cowpea crop was rotated after wheat under no till conditions. Three cowpea varieties were chosen based on results of a preliminary experiment funded by the Specialty Crop Research and Product Development Program of the Texas Department of Agriculture. The three varieties, CB46, UCRCC26, and UCR1340, were chosen on the basis of maturity group, water use, dry matter and pod production, disease score, and fodder quality.

The cropping system study used four treatments as part of a three-year rotation with sorghum and wheat in a RCB with three replications. The four treatments are fallow, early cowpeas, dual purpose cowpeas, and late maturing fodder cowpeas. Each system component (wheat, fallow/cowpea, and sorghum) will be present every year. In addition to yield, soil water content and cowpea fodder digestibility will be measured, and disease incidence assessed. The experiment will be continued for at least two rotations (six years).

In order to obtain no till conditions, the rotation experiment was installed following the first rains sufficient for germination in a field that just had wheat harvested.

Therefore, the soil profile was very dry. This, coupled with another extreme drought in the Texas High Plains during the summer, resulted in yield failure for sorghum and cowpea grain. Mean dry matter yield was 3065 kg/ha for sorghum. Dry matter yield for cowpeas was 676 kg/ha for CB46, 1222 kg/ha for UCR1340, and 1696 kg/ha for UCRCC26. Although CB46 flowered and formed pods, moisture was insufficient for significant grain production.

Chemical analyses have been completed on cowpea forage samples and data analyses are ongoing. At 50% flowering, crude protein for all three varieties was similar at 20%. At harvest, however, crude protein was 29% for UCR1340, 18% for UCRCC26, and 15% for CB46 reflecting different stages of maturity.

Soil water distribution at harvest associated with the different treatments reflects the extremely dry conditions under which crops were grown. Nonetheless, water distribution manifests differences among rotation phases for water extraction and among cowpea varieties. Only under fallow conditions was there any plant available water within the upper 1 m. Sorghum extracted the greatest amount of water from the profile. Among the cowpea varieties, extraction appeared to be greatest for UCRCC26 and least for UCR1340.

Even though these preliminary results are from a dry year and a rotation system that is only just beginning, the amount of good quality fodder produced by UCR1340 with minimal water extraction is encouraging. In the preliminary irrigation experiment of 2002, this cultivar produced as much biomass under dryland conditions as under full irrigation conditions. It remains to be seen whether apparent water conservation by this cultivar, combined with other positive rotation effects attributed to legumes, will be reflected in next year's wheat yields.

Literature Cited

Subbarao, G. V., C. R. Renard, W. A. Payne and A. B. Bationo. 2000. Long Term Effects of Tillage, P Fertilization and Crop Rotation on Pearl Millet/Cowpea Productivity in West Africa. *Expl. Agriculture* 36:243- 264.

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

Principal Investigators and Institutions

Phillip Roberts, University of California- Riverside; Ousmane Boukar, IRAD, Cameroon; Ndiaga Cissé, ISRA, Senegal; Issa Drabo, INERA, Burkina Faso

Collaborators and Institutions

J. D. Ehlers, University of California-Riverside; J. Ouedraogo and C. Dabire, INERA, Burkina Faso; B. B. Singh, IITA, Kano Station, Nigeria; L. Murdock, Purdue University; M. Ishiyaku, Institute for Agricultural Research, Zaria, Nigeria; M. Timko, University of Virginia

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.

This report highlights progress made in research activities in FY 03 to achieve the following objectives:

- Identify genes and characterize cowpea germplasm for insect and disease resistance.
- 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.
- Characterize genetic populations and develop molecular tools necessary for implementation of marker-assisted selection (MAS). Develop molecular markers and mapping populations segregating for photosensitivity, high sucrose, aphid, nematode and virus resistance, seed size, time of flowering and plant habit.

Research Approach, Results and Outputs

Useful pest resistance traits were identified for improved cowpea cultivars for West Africa and the U.S. and are being developed using traditional breeding and molecular genetic approaches. Screening for resistance to cowpea aphid (*Aphid craccivora*), flower thrips (*Megalurothrips sjostedti*), pod sucking bugs and the parasitic weed *Striga gesneroides* (*Striga*) was conducted and sources of resistance to these pests identified. Two UC-R breeding lines selected for resistance to pod sucking bug, *Lygus hesperus*, in California showed antibiosis type resistance to the African pod sucking bug, *Clavigralla tomentosicollis*, in laboratory bioassays in Burkina Faso. A local accession, 'Kiembara,' however, had more impact on the survival rate of C. *tomentosiclosi*s and may represent an even stronger source of resistance.

At UC-R, two IITA breeding lines (IT98K-1479 and IT98K-1491) were identified with strong resistance to lygus bug in field trials over two seasons. Trials in Senegal confirmed earlier results that ISRA-58-57, breeding lines derived from crosses with 58-57, and several Ghanian lines supported low numbers of flower thrips. Up to now, only race 1 of *Striga* was known to exist in Burkina Faso. The 2002 results suggest at least one additional race may be present in Burkina Faso.

A CRSP cowpea germplasm database was established that contains resistance and agronomic trait information for 65 important genotypes, IITA breeding lines that carry one or more characteristic(s) and other germplasm. Significant additions to the database were made during FY 03. Data for resistance to two species of root knot nematode were collected and entered for all genotypes; data for resistance to aphids, *Striga*, pod sucking bugs and flower thrips was compiled and entered for some of the genotypes.

The collaborative efforts of the cowpea breeding research team led to the release of the following three cowpea varieties in 2003 in West Africa:

- **Apagbaalawas** developed by the Savannah Agricultural

Research Institute (SARI) and released in May 2003 in Ghana as high grain yielding, resistant to *Striga* and heat tolerant during reproductive development.

- **Marfo-Tuyaalso** developed by SARI, was released in May 2003 for cultivation in the Guinea and Sudan savannah zones of Ghana because of its high grain yield in soils of low fertility, tolerance to heat during reproductive development and resistance to *Striga*.

- **Yacine** was developed by the Institut Senegalais de Recherches Agricoles (ISRA) and was released in Senegal in 2003. Yacine has resistance to cowpea aphid, major strains of cowpea aphid-borne mosaic potyvirus and bacterial blight, and has early maturity. Yacine is adapted for dry grain production under rainfed conditions in the Sahelian Zone of northern Senegal. In addition, many new cowpea populations were developed using different methods of crossing for traits preferred by consumers (Table 1). Significant progress was made in developing new large-seeded versions of elite CRSP cultivars suited to West Africa using backcross breeding. New crosses were made to develop improved germplasm with resistance to several pests and diseases and having resistance to multiple races of *Striga*. Trials at multiple sites in each country identified promising breeding lines for varietal release. On-farm tests of a promising line, ISRA-819, were conducted in Senegal. ISRA-819 is erect, early maturing, with large brown seed and resistant to cowpea aphid, bacterial blight, and Cowpea Aphid Borne Mosaic virus. Five Recombinant Inbred Line (RIL) populations were advanced by two generations. Analysis of sucrose content of one RIL population at Purdue indicated major gene control of sweetness. Molecular markers were developed for one RIL population that will help identify markers for phenotypic traits.

Table 1. List of populations developed during FY 02-03 using different methods of development

Cross#	Pedigree	Cross#	Pedigree
Populations developed to combine sweetness from two genetic sources with adaptation to California:		*Populations developed to improve the seed size of CRSP varieties using the cross, self, select and re-cross to recurrent method:*	
02226	KVx61-1-1/24-125B-1//CB27-6-3	02120	01-15-52/Sul-518
02227	24-125B-3/KVx61-1-1//CB27-6-3	02123	01-15-48/Ein-El-Ghazal
		02124	01-15-48/Melakh
		02126	01-15-127-2/Mouride
		02141	SuVita2/01-15-127-2
		02145	Cameroon 7-29/01-15-127-2
		02146	01-15-48/Cam.12-58
		02147	01-15-127-2/B22-Vallenga
		02148	01-15-127-2/Ein-El-Ghazal
Populations developed to combine large seed size with the best features of CRSP varieties using three- and four-way crosses:		*Populations developed to improve seed size of CRSP varieties using the direct backcross, self and select large seed and backcross approach:*	

02201	01-15-52/ItxP148//Mouride	02198	01-15-52/Melakh//Melakh
02202	01-15-52/KVx61-1//Mouride	02200	01-15-52/Mouride//Mouride
02203	01-15-52/KVx61-1//Melakh	02204	01-15-52/KVx61-1//KVx61-1-1
02205	ITxP148//01-15-52/KVx61-1	02213	01-15-52/Sul-518//Sul-518
02210	01-15-52/Mouride//01-15-52/KVx61-1		
02211	01-15-52/Mouride//ITxP148/01-15-52		
02212	01-15-52/Sul-518//01-15-52/KVx61-1-1		
02219	01-15-127-2/B22-Val//Sul-518		
02220	01-15-127-2/B22-Val//01-15-52/Mouride		
Populations having one parent with multiple Striga-race resistance and another with sweet or large seed in order to combine these features:		*Populations developed to help re-establish the Cameroon breeding program:*	
02206	01-15-52/KVx61-1//IT98K-553-1	02134	Cam.12-58/Sul-518
02207	01-15-52/KVx61-1//IT98K-697	02135	Cam.12-58/Mouride
02208	01-15-52/KVx61-1//IT84S-2135	02136	Cam.12-58/B22-Vallenga
02209	01-15-52/KVx61-1//IT95K-1497	02142	Cam. 7-29/B22-Vallenga
02222	IT97K-499-39//01-15-52/Melakh	02143	Cam.7-29/CB27-6-3
02223	IT97K-499-39//01-15-52/KVx61-1-1	02144	Cam. 7-29/Melakh
02224	IT97K-499-39//01-15-52/Mouride	02214	Cameroon 12-58/CB27//SuVita2/CB27-6-3
		02215	Cameroon 12-58/CB27//IT98K-128-2
		02216	SuVita2/CB27-6-3//Cameroon 12-58/CB46
		02218	Cameroon 12-58/CB46//IT98K-558-1

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-Riverside; Ndiaga Cissé, ISRA, Senegal; Issa Drabo, INERA, Burkina Faso

Collaborators and Institutions

O. Boukar, IRAD, Cameroon

Justification and Objectives

A determination of the incidence and species present of root knot (*Meloidogyne spp.*) and other nematode species including *Scutellonema cavenessi* on cowpeas and in cowpea-based production systems is needed in Senegal, Burkina Faso, Cameroon and Ghana. 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 poor mineral nutrition of the cowpea crop and thus their low yields. Nematode infection reduces the function of root systems in the uptake of water, nutrients and minerals. 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 the development of resistant cultivars from the breeding programs, and their subsequent implementation into nematode management schemes in commercial cowpea production.

Unpublished surveys conducted late in 2001 by ISRA scientists, detected high levels of the plant parasitic nematode, *Scutellonema cavenessi*, in soil in several fields in the main cowpea production zone of Senegal. They also observed that multiplication of this nematode was substantial on eight widely used cultivars and breeding lines but very low on two old cultivars. Further survey work in 2002 found *S. cavenessi* in every field sampled, and root knot nematodes in 60% of sampled fields. These findings indicate further studies should be conducted 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 breeding efforts for nematode resistance in different countries and agro-ecological zones. Development of cultivars with nematode resistance that are broadly effective will be most useful and will contribute to productivity and stability of cowpea production.

This report highlights progress made in research activities in FY 03 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 the University of California-Riverside's (UC-R) advanced breeding lines to the most important nematode species on cowpeas.

Research Approach, Results and Outputs

Major surveys were undertaken in the cowpea growing regions of Burkina Faso and Senegal to determine the distribution and incidence of plant parasitic nematodes in cowpea fields. Seventy-five field sites were sampled in the late season in both countries. Root and soil samples were analyzed and nematodes identified to genus level, and in some cases to species level. The results of these initial surveys revealed important nematode associations with cowpeas in both countries. In Senegal, six genera of nematodes with potential for damage to cowpeas were found in the primary northern production region (the peanut basin). These included: *Meloidogyne, Pratylenchus*, *Helicotylenchus,*

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Scutellonema, Tylenchorhynchus, and Hoplolaimus. Of greatest significance was the occurrence at 100 percent of the sampled sites of *Scutellonema cavenessi*. While this nematode had been identified previously as a serious problem on peanuts in the main cowpea growing region of Senegal, its association with cowpeas was not clear. A high abundance of the nematode was also indicated from the population densities in soil recorded for many of the samples. These results suggest that *S. cavenessi* is likely to be a major limiting factor to cowpea growth and yield in most cowpea fields in the peanut basin of Senegal. The second important finding was the presence of root knot nematodes (*Meloidogyne*) in 62% of the sampled cowpea fields. We are using morphological, bioassay and biochemical analyses to identify the root knot nematodes to species level. Root knot galling symptoms on roots have not been reported much in cowpeas previously, other than in locations where cowpeas followed irrigated vegetables. However, the survey results indicated that root knot may be much more important as a cowpea pathogen in Senegal than previously recognized. The excellent root knot resistant cowpea genotypes developed at Riverside will be screened against the Senegal root knot populations to determine whether gene resources are already available for incorporating into suitable local cowpea varieties.

In Burkina Faso, the distribution and abundance of plant parasitic nematode species in cowpea fields was determined by a survey in three agro ecological zones. The sampled sites included farmers' fields, seed multiplication centers and research stations. At least 12 genera of phytoparasitic nematodes were found on cowpeas in this Burkina Faso survey. These included: *Meloidogyne, Pratylenchus, Helicotylenchus, Scutellonema, Tylenchorhynchus, Telotylenchus, Hoplolaimus, Rotylenchulus reniformis, Paratylenchus, Criconemella, Xiphinema and Paratrichodorus*). Of these, the most abundant of the potentially more damaging forms were *Helicotylenchus, Scutellonema, Tylenchorhynchus, Telotylenchus, Pratylenchus, and Meloidogyne*. Species of these genera can cause severe yield losses in cowpeas, and it is important to note that they were all found in relatively high frequency and abundance. The population densities were indicative of damaging levels of infestation in many cases. *Rotylenchulus reniformis* is an important nematode species that is abundant but less frequent than those in the above group. Species of the genus *Meloidogyne* were not found in the Sahelian zone (rainfall <600 mm/year) or the North Central Sudan Savannah zone (rainfall of about 800 mm/year), but the lesion nematode *Pratylenchus* was the primary endoparasite in the North Central Sudan Savannah zone. In the meridional Sudan Savannah zone (rainfall between 900 mm and 1200 mm/year), high numbers of root knot nematodes (*Meloidogyne*) were found in some locations, and root knot appears to be the major endoparasitic nematode in this zone.

Criconemella sp. was frequent on cowpeas but less abundant than the above mentioned groups, and it may be a less active parasite in cowpea production conditions in Burkina Faso. Of the remaining genera, *Hoplolaimus, Paratylenchus, Paratrichodorus, and Xiphinema* did not appear to cause any direct damage to cowpeas, and may be secondary parasites in rotation plants and weed hosts found in farmers' fields. From the survey, cowpeas were cultivated in association with cereals in 55.9% of cases; 42.2% of farmers had a sole crop of cowpeas; most cowpeas were local varieties (71.4%), while improved cultivars represented only 28.6% of cases; cowpeas were generally cultivated in sandy soil (55.2%); and cowpeas were grown after cereal or cereal/cowpea association (59.7%). As with the Senegal samples, we have started to use morphological, bioassay and biochemical analyses to identify the nematodes to species level. Based on these initial survey results, protection of cowpeas against nematodes in Burkina Faso may be more important for the humid and semi humid zones rather than the Sahelian zone.

Towards the second objective, several experiments were planted in Senegal and Burkina Faso to evaluate the importance of nematodes on cowpea performance. As a complement to the host country experiments, at Riverside a collection of local African lines and varieties were screened for resistance to common root knot nematode species, *M. incognita* and *M. javanica*. Most lines were found to be susceptible. In addition, as a complement to the Senegal screening efforts, attempts are underway to raise cultures of *S. cavenessi* at Riverside under quarantine isolation, with a goal of screening for resistance under controlled conditions.

Bean/Cowpea Collaborative Research Support Program
West Africa Regional Project

Molecular Genetic Improvement of Cowpeas for Growers and Consumers

Principal Investigators and Institutions:

Larry Murdock and Ray Bressan, Purdue University; A. B. Salifu, SARI, Ghana; Idah Sithole-Niang, University of Zimbabwe, Zimbabwe

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 pod borer (*Maruca vitrata*), thrips, pod-sucking bugs, 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.

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

- Develop and optimize a reproducible and efficient genetic transformation system for cowpeas.
- Identify optimized genes for control of *Maruca* and cowpea weevil.
- 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 for Cowpeas: Cotyledon segments and embryonic axes from immature embryos of cowpeas (*Vigna unguiculata* [L.] Walp.) were used for the transformation experiments. Based on our genotype screen for morphogenic response the genotype ITH98-13-1was used for further studies.

All media (pH 5.8) contained MS macro- and micronutrients (Murashige and Skoog, 1962), BA, and NAA (Naphthaleneacetic acid). In addition, media were supplemented with modified B5 vitamins (Gamborg et al., 1968) (100 mg/L inositol, 12 mg/L thiamine HCl, 0.5 mg/L pyridoxine, 1.0 mg/L nicotinic acid), 30 g/L sucrose, and 7.0 g/L agar.

Embryos were excised from seeds collected from green pods, and the embryonic axes and cotyledons were separated. Explants were plated on CP1 agar solidified medium. After Agrobacterium co-cultivation, explants were cultured for three weeks in the dark at 26°C and plated onto the CP2 (callus maintenance) or CP3 (shoot elongation) medium in light (16 h photoperiod, 20-25 "mol"m-2's-1 "cool white" fluorescent illumination) to promote shoot development. Developing shoots were re-cultured on fresh CP3 medium at two weekly intervals. Shoot regeneration was conducted under continuous selection pressure (kanamycin or bialaphos). Shoots that survived on selection medium were transferred to CP4 rooting medium.

A binary vector in *Agrobacterium* based on the pML112 plasmid was used for transformation with kanamycin selection. The pML112 plasmid contained the nptII coding region (kanamycin resistance) under control of

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

the mas promoter, the uidA gene driven by the CaMV 35S promoter, and contained a 5' end intron to prevent expression contamination by *Agrobacterium* during co-cultivation and subsequent culturing. We also used a binary vector based on the DP532 plasmid for transformation with bialaphos selection. The DP532 plasmid contained uidA reporter gene and bar selectable marker, both driven by CaMV promoter.

Agrobacterium tumefaciens strain LBA4404 containing the binary plasmid with either kanamycin or bialaphos selectable marker genes driven by the CaMV35S promoter were used for transformations. *Agrobacterium tumefaciens* infection of explants was performed by co-cultivation, following mechanical injury of explants by either micromanipulation with a needle or by vortexing with carborundum. After five minutes incubation, explants were removed from the *Agrobacterium* solution and placed on solidified CP1 medium at 30°C in the dark to complete infection. After 72 h infection, explants were repeatedly washed with liquid CP1 medium, blotted, plated onto solidified CP1 medium supplemented with carbenicillin and either kanamycin (50 mg/L) or bialaphos (1 mg/L), and cultured in the dark. After three weeks, explants were plated onto the CP3 medium and transferred to the light. Plant regeneration was performed as described above, under continuous selection pressure after shoot or shoot meristem regeneration on selection medium using 5-bromo-4-chloro-3-indolyl-D-glucuronidase (X-Gluc, Biosynth AG, Biochemica, and Synthetica, Switzerland). Samples for histological analysis of uidA gene expression were prepared as per Kononowicz et al. (1992).

Cotyledon explants and embryonic axes of immature embryos isolated from green pods were chosen as the primary explant for transformation based on previous experience. The culture conditions (mostly BA concentration and the presence or absence of auxin) that resulted in maximal adventitious shoot initiation were determined with these explants (Barwale et al., 1986a, b; Gulati and Jaiwal, 1992). Consistent with our past studies, 2-3 week old cultures of these explants in the dark on high BA medium (CP1 medium) followed by culture in light on low BA medium (CP2 or CP3) resulted in the formation of adventitious shoots via callus intermediary tissue. Developing shoots do not result from the growth of axillary buds on an already existing shoot, but are formed adjacent to one another in a de novo fashion. Organogenic culture can be maintained for several months by subculturing on CP2 medium and adventitious shoot production occurs as long as explants remain on this medium. Over a period of 8-10 weeks, up to 15 shoots can be regenerated from a single primary explant, making the system suitable for transformation. Shoots obtained from cotyledon segment and embryonic axis cultures can be easily elongated on CP3 or MS0 medium, and subsequently rooted on CP4 medium.

When cultured on high BA medium in the dark, primary explants produce white, compact, undifferentiated callus masses. After culture on Cp2 or CP3 medium in light, the morphology and structure of the vigorously growing callus changed significantly; due to chloroplast development increasing in size, green sectors started to appear on the periphery of callus pieces. Further, microscopical analysis of the histological sections showed the presence of numerous meristematic centers, consisting of relatively small cells with prominent nuclei and dense cytoplasm. The absence of meristematic centers are earlier stages of callus growth indicates that they are formed de novo, 3-4 weeks after culture initiation. Anticlinal and periclinal cell divisions followed by cell growth and differentiation proceeds in a highly organized manner, and result in the appearance of small protuberances, which later form structures resembling shoot apical meristems and leaf primordial. The polarity of the longitudinal axes of developing organs can be observed. After further development, multiple shoots are produced. Axillary buds developing in the leaf axis can be detected in the expanding shoots. The first burst of the organogenesis results in the production of up to 15 shoots from each primary explant.

Since it is anticipated that T^0 plants from morphogenic cultures will have a tendency to be more homogeneously transformed than those regenerated from shoot apex and axillary bud meristems, our transformation attempts have been focused on primary explants that contain morphogenically competent cells and morphogenic callus.

Using genotype ITH98-13-1 we have evaluated the use of kanamycin and bialaphos as a selection agent for cowpeas. High concentrations (100-200 mg/L) of kanamycin are required to obtain a high degree (80-90%) of lethality of cowpea explants. On the other hand, 50 mg/L kanamycin was able to cause significant bleaching (chlorosis) (Wilmink and Dons, 1993) in developing nontransformed shoots. This phenomenon has been utilized in our experiments for "visual" selection of kanamycin-resistant shoots.

Treatment of explants with kanamycin within a few days after DNA delivery resulted in very low survival of shoots, without clear evidence of an enrichment of the population in terms of transgenic tissues. This is probably because only minute portions of the initial meristems are transformed, and these cells are not able to survive immediate exposure to a high level of the selection agent. Previous experiments indicated that some enhancement of selection is obtained by imposing kanamycin or Bialaphos after some degree of shoot development has occurred. However, it was found that this selection strategy results in numerous nontransformed "escapes." Therefore, kanamycin and Bialaphos selection pressure was increased and applied during all induction and regeneration processes. From approximately 1,100 explants we were able to induce shoot formation at a relatively high frequency (average 4.8 shoots per explant). Also a reasonable number of putative transformants were identified after three subcultures on selection medium (75 mg/L kanamycin and bialaphos, 2 mg/L), based on the "bleaching" and necrosis effects (approximately 1/20 shoots). However after examination of more than 100 of these shoots for uidA expression (GUS positives), all were found to be chimeric transformants.

The frequency of transformants and amount of GUS positive tissues in transformants was considerably more than observed in past studies. Therefore, there is a reasonable possibility that whole or substantial parts of meristems may have been transformed in such experiments. The plants generated by these selection procedures can be grown to maturity and the seeds produced would reflect the degree of transformation of meristems resulting in reproductive structures. Any transformed meristem cells that produce gametophyte cells (pollen sperm or egg) would result in non-chimeric seeds (embryos). At the present time, we are examining these possible transformants. However, we still feel that the inherent problem in cowpea transformation is based on inefficient morphogenic cells at the time of DNA transfer.

Identification of Optimized Genes for Control of Maruca and Cowpea Weevil: Several laboratories have been working to develop a viable regeneration/transformation system for cowpeas. Certain laboratories include a Bt gene in the transformation vector. It has become evident that it is better for the plant to express two different Bt genes rather than just one. Such plants can resist a wider range of insects, will require less supplementary insecticide, and even more importantly, the resistance will be more durable, that is, will be less likely to break down as a result of the emergence of a resistant biotype in the target insect population.

In FY 03, the capacity to carry out bioassays with *Maruca vitrata* at Purdue was re-established. The research team has obtained some early results with three Bt proteins: (a) cry1Ab, trypsin activated, chromatographically purified, salt-free powder; (b) cry1Ac, trypsin activated, chromatographically purified powder; (c) cry2Aa, inclusion body preparation.

Each of the Bts were incorporated into commercially-available European corn-borer artificial diet (BIO-SERVE, Frenchtown, NJ) to which one percent cowpea (California Blackeye No. 5) flour had been added. Each Bt type was tested at six dosages plus a control containing no Bt. Each treatment consisted of five replicates each containing five newly hatched first-instar larvae. Thus, the response to each dose of each Bt was based on the responses of 25 larvae to that dose.

Based on the preliminary results, several observations can be made with confidence: Larval mortality in control treatments (no Bt) at day 12 was about 20 percent, an acceptable level.

- cry1Ac - There were no surviving larvae at the cry1Ac dose of 1 ug/g and higher at day 12; and a few survivors at a dose of 0.05 ug/g. Larvae feeding on a diet containing 0.2 ug/g survived well, but were mostly in the third instar rather than in the fifth as seen with the controls, and thus, were clearly retarded in their development. The LC50 (the lethal concentration for 50 percent of the population) for cry1Ac can only be estimated roughly for these data but would appear to be between 0.02 and 0.05 ug/g.
- cry1Ab - LC50 appears to fall between 0.02 ug/g diet and 0.1 ug/g.
- cry2Aa2 - The estimated LC50 appears to fall in the dose range of 0.1 and 0.5 ug/g of the diet.

Reducing Flatulence Causing Oligosaccharides Using Genetic Engineering: Total RNA isolated from cowpea pods, 25 days after flowering was used in a reverse transcription polymerase chain reaction (RT-PCR) to amplify a 450-bp fragment. The fragment was cloned into the pGEM-T easy vector and sequenced by automation. Genomic DNA was isolated from eight cowpea lines, digested and resolved by agarose gel electrophoresis. The DNA was transferred to a nitrocellulose membrane then detected using a digoxigenin-labelled 450-bp fragment to determine the copy number.

Literature Cited

Barwale, U. B., H. R. Kerns and J. M. Widholm. (1986a) Plant Regeneration from Callus Cultures of Several Soybean Genotypes via Embryogenesis and Organogenesis. Planta 167:473-481.

Barwale, U. B., M. M. Meyer, Jr. and J. M. Widholm. (1986b) Screening of Glycine Max and Glycine Soja Genotypes for Multiple Shoot Formation at the Cotyledonary Node. Theoretical and Applied Genetics 72:423-428.

Gamborg, O. L., R. A. Miller and K. Ojima. 1968. Nutrient Requirements of Suspension Cultures of Soybean Root Cells. Experimental Cell Research 500:151-158.

Gulati, A. and P. K. Jaiwal. 1992. In Vitro Induction of Multiple Shoots and Plant Regeneration from Shoot Tips of Mung Bean (Vigna radiate [L.] Wilczek). Plant Cell, Tissue and Organ Culture 29:199-205.

Kononowicz, A. K., D. E. Nelson, N. K. Singh, P. M. Hasegawa and R. A. Bressan. 1992. Regulation of the Osmotin Gene Promoter. Plant Cell 4:513-524.

Wilmink, A. and J. J. M. Dons. 1993. Selective Agents and Markers Genes for Use in Transformation of Monocotyledonous Plants. Plant Molecular Biology Reports 11:165-185.

Generating New Knowledge and Technologies in East and Southern Africa

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

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/Prosser
Bunda College of Agriculture, Malawi
Eduardo Mondlane University (EMU), Mozambique
Instituto Nacional de Investigacao Agronomica (INIA), Mozambique
Sokoine University of Agriculture (SUA), Tanzania
University of Pretoria (UP), South 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 03.

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; Patrick Kambewa, Bunda College, Malawi; Anna Temu, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions

André Jooste, University of the Free State, South Africa; Carol Miles, Washington State University; Julius Mangisoni, Bunda College

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 (ESA) have focused on production issues. Little work has been done 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 on developing traits and practices that can lead to bean and cowpea products that are marketable in the region.

The report highlights progress made in research activities 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.
- Pilot test a methodology for the study of bean price and quality relationships in Malawi and Mozambique.
- Study the supermarket procurement opportunities for small-scale bean farmers in Tanzania.

Research Approach, Results and Outputs

Description of Market Structure for Beans and Cowpeas: The physical location of bean production is well known (see Wortman et al. 1999), but the market structure is poorly understood, especially the cross border trade of beans. In FY 03, a literature review was completed for bean markets in Eastern and Southern Africa (Tenkorang 2002). To provide some additional information on market structure in Malawi, Mozambique and Tanzania, key informant interviews were conducted with market participants. In addition, CRSP collaborator, André Jooste, provided a perspective on bean markets in South Africa.

- The literature review suggests that the quantity of beans moving between countries is much smaller compared with cross border trade of cowpeas in West Africa. The largest quantity of bean trade reported in the internationally available literature is the roughly 40,000 MT imported annually by South Africa, from mainly non-African sources. The largest bean trade within the region is the roughly 9,000 MT moving annually in the mid-1990s from Uganda to Kenya. In contrast, roughly 300,000 MT of cowpeas are traded from Niger to Nigeria annually.
- The trade study in Tanzania shows that the southern highlands (Rukwa, Mbeya and Iringa regions) of Tanzania supply beans to Malawi and the Republic of Congo and some to Zambia, but mostly in informal trade. Also, the north, east and central Tanzania receive Kablanketi beans from the southern highlands and Morogoro regions. Red and red sparkled beans come from the northwest (Kagera, Tabora, Shinyanga), and northern Tanzania (Arusha, Kilimanjaro). Yellow beans come from the western Tanzania (Kigoma) region (along Lake Tanganyika). Most of the northern Tanzania beans will go to either Dar-es-Salaam or Kenya but rarely to the central region or Morogoro. Seasons differ and prices are high in Morogoro and Dar-es-Salaam during the harvesting time in the northwest.
- In 2001, roughly 2,000 MT of beans were traded from Tanzania to Kenya at Namanga. The most common bean

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

varieties traded across this border are Kablanketi type (common) beans, Rozikoko bean variety and Kariathei bean variety. The last two varieties have gained in popularity because of their taste and easiness in cooking.

- Problems affecting trade on Tanzanian borders is the long procedure to obtain a trade permit, as it requires one to go to Dar-es-Salaam to obtain the permit. One is required to acquire the products from another region while they are interested in selling crops from their own region. Obtaining the radiation certificate is also a long and tedious procedure.
- The importation of maize in Tanzania is free while other grains such as beans, rice, millet are taxed 25% import duty and VAT exempted.
- Beans are widely traded in and between Malawi and Mozambique. Within Malawi, beans from Dedza tend to go to Lilongwe and Blantyre, while those from the southern part of the Dedza area (e.g., Tsangano Turnoff) and from Mulanje strictly go to the southern Malawi city of Blantyre. Within Mozambique beans from Gorué tend to go to Maputo, while those from Alto Molocue go to Nampula. There is an indication that Maputo (and Beira) also draws beans from Gorongosa, Tete (Angonia) and Niassa.
- Both Malawi and Mozambique import and export some beans, with the largest flow currently being exports of beans from Milange and Angonia districts of Mozambique to Malawi. There is some indication that these flows are substantial. For example, in an interview with one of 20 or 30 bean wholesale traders in Milange it was revealed that he sends about 500 MT over the border each year. If this trader is considered average, this means that 10,000 to 15,000 MT of beans cross the border at Milange alone. Small quantities of high quality dry pack and canned beans come to both countries from South Africa. Some bulk beans, apparently from South Africa or Swaziland, are sold in Maputo at informal markets.
- Consumers in Central Malawi seem to prefer khaki or "sugar beans" (tan with brown, black or red speckles). Those in Southern Malawi tend to prefer red beans. Most of the beans flowing over the border into Malawi at Milange seem to be red beans produced as a cash crop by Mozambican growers because the preferred beans in most of Mozambique seem to be the khaki or sugar bean. There is evidence of a premium for red beans on the Milange market because of the demand from Southern Malawi. There is little evidence khaki or sugar beans from Milange or adjacent areas of Mozambique reach Lilongwe. Some khakis or sugar beans from Angonia reach Lilongwe via Ntcheu and Dedza area markets.
- It should be noted that other than dry pack in Malawi, there appears to be very little bean or cowpea processing in Malawi or Mozambique, either at the industrial or artisanal levels. In Tanzania, Malawi and Mozambique cowpeas are widely grown in lowland areas, but not as widely traded as beans. They are more of a subsistence crop. The CRSP team was not able to identify specific cowpea trade patterns, but it did note that the number of merchants handling cowpeas and the quantity of cowpeas handled is substantially less than that of beans.
- South Africa is both a bean producer and a major importer of beans. In the 1998-2003 period, commercial production has varied from around 25,000 MT to almost 100,000 MT depending on weather and the economic incentives for bean production. The average is 61,000 ha planted and about 70,000 MT harvested. In addition, non commercial production by communal farmers has ranged from around 5000 MT to 25,000 MT annually. The most commonly produced bean types are red speckled, large white kidney and small white beans. In the period since 1998, red speckled bean production has ranged from 20,000 MT to 70,000 MT.
- South African imports are usually around 40,000 MT annually, mainly from China, but also from the U.S., Canada and Argentina. Exports were as high as almost 30,000 MT in the early 1990s, but have dwindled in recent years to less than 5000 MT.
- Cowpeas in South Africa are mainly produced for forage. Some 10,000 to 15,000 ha are sown for forage annually. About 1000 ha is planted for seed production by commercial farmers. Substantial quantities of cowpeas are produced by communal farmers, but quantitative estimates are not available. There is no record of cowpea exports from South Africa. Some of the dry pack cowpeas marketed in South Africa and neighboring countries is imported in bulk, packed and re-exported. Dry pack cowpeas observed by the CRSP team on sale in a Maputo supermarket in June 2003, marked as packed in South Africa, were traced with the help of the

South African Dry Bean Producers Organization (DPO) to imports from Argentina.

The idea of developing bean exports to South Africa is attracting wide interest in Malawi. The CRSP team discussed this idea with several groups in Malawi, including the National Smallholder Farmers Association of Malawi (NASFAM), USAID, World Vision and private traders. A preliminary analysis by Filipe (2003) suggests that there may be some competitiveness problems with Malawian beans in the South African market. Preliminary analysis indicates that for the period of 1996 to 2003, the cost of Malawian beans delivered to Durban averaged about 60% higher than comparable beans from non-African sources. The potential for bean exports to South Africa is also attracting attention in Mozambique. In general, bean prices are lower in Mozambique than Malawi, so Mozambican beans are likely to be more price competitive than the Malawian product. One of the key questions in Mozambique is how much bean supply could expand if an export market to South Africa was developed. A preliminary analysis for the province of Manica (in southern Mozambique on the Zimbabwe border) suggests that land tenure and capital would be the initial constraints to expanding bean supply.

Study of Bean Price and Quality Relationships: Bean consumer preference information was reviewed by Dr. Temu for Tanzania and by Dr. Kambewa for Malawi. No documented bean preference information was found for Mozambique. Kambewa noted that bean consumer preference studies had previously focused on farm families, not urban buyers. Among other information, Temu provided data from a survey in urban areas, which indicated that bean type preferences are related to the type of food prepared. Red-seeded beans are preferred for recipes that mix whole/ dehulled maize grain or banana-based meals with beans, while the gold colored Kablanketi types are favored for stiff porridge (ugali) and rice-based meals, when beans are used as relish.

Due to the differences between cowpea markets in West Africa (which are more informal/traditional) and bean markets in Eastern and Southern Africa (which are more formal with a year-round supply of beans from different sources) the price and quality study methods developed in West Africa will need to be adapted for beans in ESA. For beans, it will be important to note the market category, harvest time, production location, shine or dullness (instead of testa texture) and damage in terms of number of grains per 100 that are discolored.

Supermarket Procurement Opportunities for Small-scale Bean Producers: It should also be noted that the growth of supermarkets pose a challenge for the type of price and quality studies that the CRSP has implemented. While going forward with the implementation of the price and quality studies in traditional markets, the CRSP Africa marketing and economics team will continue to seek methods for assessing quality response in formal market settings. Temu and Lowenberg-DeBoer developed a protocol for bean price and quality data collection in Morogoro, as well as a data collection form. As a pilot study, it was decided to initiate data collection in Central and Sabasaha Markets in Morogoro. Bean price and quality data collection was started in both markets in April 2003.

The Tanzanian protocol and data collection form was adapted for use in Malawi (see Kambewa and Lowenberg-DeBoer, 2003, for details). Data collection has been initiated in Blantyre, Lilongwe/Kawale, Lizulu/ Chimbiya, Zomba and Muloza.

Information on supermarkets was gathered primarily in Tanzania. The growth in Tanzania has followed a pattern similar to that observed in other developing countries. In Tanzania, the Pick "N" Pay chain from South Africa opened five "Scores" supermarkets in Dar-es-Salaam in the 2001-2002 period. Imaleseko, a Tanzanian chain, opened four stores in Dar-es-Salaam and one in Arusha during the same period. This is in addition to the original Imaleseko store in Mwanza. Shoprite opened its first store in Tanzania in Dar-e-Salaam in December 2001. A second Tanzanian store was opened in Arusha in February 2002. In late 2002, Shoprite bought all of the Scores supermarkets. Shoprite has plans to open stores in Mwanza, Morogoro, Mbeya, Dodoma and Moshi. Shoprite is a South African chain that has opened stores in most southern and eastern African countries in the last decade.

The interviews showed that for beans Shoprite and Imaleseko follow very different procurement strategies. Shoprite has a very structured procurement system standardized for all products that they handle. Currently, Shoprite reports purchasing beans from three companies in Tanzania--Fidahussein, Illula and Coastal Grain Trading Company. In contrast, Imaleseko buys bulk beans in Dar-es-Salaam traditional markets. The beans are then cleaned and dry packed in plastic bags with the Imalesko label. They pack 1, 2, 5 and 10 kg bags.

Both Shoprite and Imalesko carry a range of canned beans from Tanzanian processors, as well as those from Kenya, Zimbabwe, South Africa, Malaysia, Italy, UK and the U.S. Imported canned beans appear to dominate sales. The quantities of beans canned in Tanzania appear to be relatively small. For example, the CEO of Red Gold, a processor based in Arusha, said that they use about 2 to 3 tons of white beans every year for canning.

While Shoprite managers say that beans are an important product for them, the observed shelf space allotted and the inventory on hand suggests that dry beans are not a top priority item. During the July 2003 visit to Imaleseko stores, the team found six types of beans on the shelves: Rosecoco, Soya fupi (a kablanketi short type of grain), Soya ndefu (a kablanketi long type of grain), Yellow Kigoma, Red Marble, and White. Also the popularity of the larger 2 and 5 kg packets, and the relatively high bean volume suggests that Imaleseko may be reaching a lower income group that eats more beans than the core Shoprite clientele.

Traders in the Dar-es-Salaam's open market said that beans piled in the open air were less prone to bruchid infestation than those in dry pack bags. In a visit to the Lilongwe, Malawi Shoprite in March 2002, Temu and Lowenberg-DeBoer observed beans being sold in bulk. Customers could bag beans themselves. This has potential advantages for small-scale suppliers of reducing bruchid damage and eliminating the packaging requirement.

Literature Cited

Filipe, M. 2003. Cost of Beans Delivered to South Africa from Malawian and Non African Sources, Bean/Cowpea CRSP, Purdue University.

Kambewa, P. and J. Lowenberg-DeBoer. 2003. Annual Research Activity Progress Report Market Assessment of Bean and Cowpea Grain and Processed Value Added-Products. Bean/Cowpea CRSP, Chancellor College/Purdue University.

Tenkorang, F. 2002. Beans Markets in Eastern and Southern Africa Bean/Cowpea CRSP, Purdue University.

Wortman, C., R. Kirkby, C. Eledu and D. Allen. 1999. Altas of Common Bean Production in Africa, CIAT.

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

Enhancement of the Use of Quality Criteria for Crop Improvement Programs of Beans and Cowpeas in the ESA Region

Principal Investigators and Institutions

Ralph Waniska, Texas A&M University; Louis Pelembe, Eduardo Mondlane University, Mozambique; Amanda Minnaar, University of Pretoria, South Africa

Collaborators and Institutions

Leda Hugo, Eduardo Mondlane University, Mozambique; Agnes Mwangwela, Ph.D. student from Bunda Collage at University of Pretoria; Dr. Manuel Amane, Instituto Nacional de Investigacao Agronomica (INIA), Mozambique; Creighton J.C. Miller, Texas A&M University; Jeff Ehlers, University of California-Riverside

Justification and Objectives

Cowpeas are an important crop mostly consumed by rural family farmers, while some are marketed or traded as a 'cash-crop' in Southern and Eastern Africa. Most legumes, including beans and cowpeas, are consumed as cooked seeds because of limited resources. Integrity of the cooked legumes and taste of the cooked leaves appear to be important for consumer preference

Food quality traits in legumes vary due to genotype, environment and agronomics. Including consumer preferences at an early stage in the breeding process requires knowledge of food quality attributes preferred and methods to rapidly determine these attributes. Additionally, macronutrient compositions (protein, moisture, carbohydrate and fat content) of legumes are needed to formulate nutritionally improved foods. Thus, there is a need for developing procedures to determine the nutrient composition of beans and cowpeas.

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

- Document food utilization of cowpeas in Mozambique.
- Conduct studies on the composition and functionality of cowpea lines grown in southern Africa.

Research Approach, Results and Outputs

Documentation Studies: As a first step towards understanding the food utilization of cowpeas in Mozambique, the CRSP team identified food products prepared from grains and leaves of cowpeas, determined the processing procedures of the identified products, and determined the preferred grain properties for the preparation of those specific products in traditional African, Indian and Asian communities. At the moment, product identification and collection of the processing procedures in the traditional African and Indian communities have been completed. The identified products and brief description of the same is presented in Table 1.

Varieties of cowpeas most used in Mozambique: Eighteen varieties or types of cowpeas were collected, from Manhiça (representing the South region of Mozambique) and Morrumbala (in representation of the North region of Mozambique), and characterized. Preliminary data reveals the following:

- There is a large variety of cowpeas grown in Mozambique (Heemskerk 1993). Some are specific to each agro-ecological region, which is mainly divided into drier in the south region and wetter in the north region of the country. The factors used to distinguish types or varieties of cowpeas are the plant growing habit (the plants being distinguished between erect, prostrated and climbing types); the size of the grain, the color and the taste (whether strong or bland cowpea flavor).

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Table 1. The main food products prepared from cowpeas in Mozambique

Product name	Type of product	Eaten as
African products		
Tihove	A mixture of cooked samp (maize endosperm pieces), cowpea grain, peanut flour and salt	Main dish
Chiguinha	A thick paste made from a mixture of cooked cowpea grains, cassava pieces, peanut flour, coconut milk and optionally, "cacana" leaves can be added	Main dish
Cowpea curry	Cooled cowpea grains, with fried onions, tomatoes, salt. Meat, fish or shrimps can be added. Coconut milk or peanut flour can also be added.	Curry eaten with maize, rice, sorghum or cassava cooked as a paste or rice-like product
Nhangana	Cowpea fresh or dried leaves, young pods broken in quarters, dried or fresh shrimp or any other sea food cooked with onions, tomatoes, salt, coconut milk and/or peanut flour	Same as above
Ecute	A soft paste made from decorticated cowpea grains, flavored with fried onions, tomatoes, coconut milk can also be added	Same as above
Indian products		
Dahl	The same as ecute, but with more spices	Curry eaten with rice and wheat tortillas (chapatis)
Badgias	Fried pieces of a paste made with cowpea flour, water, salt, onion and garlic	Snacks
Kigiri	Rice and decorticated cowpea grains, cooked with butter and/or coconut milk and salt	Main dish
Apas	Tortillas made from a mixture of wheat flour and cassava flour	Eaten with different types of curry
Cowpea curry	The same as African cowpea curry but more spicy	Eaten with rice, cassava or wheat tortillas (chapatis)

- Farms in rural areas (the main consumer of cowpeas) prefer varieties with double use, meaning that grains and leaves can be eaten. Varieties with large grains, red to dark brown in color are in slightly less demand.
- Large grains, mostly the traditional types, were found to be tastier than the small grains.
- In Manhiça (south), we found farmers who grow cowpeas basically for the leaves. In these cases, little attention is paid to the production of dried grain. The pods, if produced, are broken and cooked with the leaves.

Composition and Functionality of Cowpea Lines Grown in Southern Africa: Composition and functionality of nine cowpea lines from Malawi and South Africa were also conducted. Protein and moisture contents, water uptake during cooking, splitting of cooked cowpeas and cooked texture were determined to select the two most divergent lines. This is important because cowpeas with different cooking qualities should respond differently during the hydrothermal treatment. It was decided to continue the next phase using the Betchuana White cultivar from South Africa and a Malawian line 462 primarily based on their different cooking characteristics, i.e., water uptake during cooking, splitting and texture of cooked cowpeas.

Betshuana white cowpeas absorbed more water during cooking than line 462 resulting in a significantly softer cooked texture. More splitting of Betchuana White cowpeas was observed after heating 45 minutes whereas virtually no splitting occurred during cooking of the Malawian line. This may be explained only in part by the different levels of water uptake observed during the cooking of the seeds. Although cooking times using the Mattson cooker has not been done as yet, it is evident that Betchuana White cowpeas require a shorter cooking time.

Literature Cited

Heemskerk, W. 1993. Espécies e variedade de feijão existentes em Moçambique. Serie divulgação. Instituto Nacional de Investigação Agronómica (INIA), Maputo, Mocambique.

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

Development of Technologies to Facilitate the Introduction of Low Cost, Value-Added Bean- and Cowpea- Based Food Products

Principal Investigators and Institutions

Ralph Waniska, Texas A&M University; Louis Pelembe, Eduardo Mondlane University, Mozambique; Amanda Minnaar, University of Pretoria, South Africa

Collaborators and Institutions

Minah Phadi, M.S. student from Botswana at the University of Pretoria, South Africa

Justification and Objectives

Cowpeas are protein and carbohydrate rich legumes, consumed in developing countries. However, in Sub- Saharan Africa the use of cowpeas is limited due to extended cooking times, requiring wood and time (DeMooy and Demooy, 1990; Brouwer, et al., 1996). A possible way of reducing the cooking time of cowpeas is through the use of micronization, an infrared, short time and high temperature dry heat treatment (wavelengths of 1.8 –3.4 µm). Micronization reduces the cooking time of some legumes (i.e., lentils and pinto beans) while maintaining their protein digestibility and nutritional quality. Micronization may cause partial starch gelatinization and fracturing of cotyledon cell walls resulting in improved hydration of seeds during cooking (Arntfield, et al., 2001).

In general, the availability of raw and partially cooked grits, flours, brans and whole grain of legumes (beans or cowpeas) at affordable prices will increase the demand, utilization and the variety of legume containing foods for urban consumers. Foods that require less preparation time and have diverse textures and flavors will have significant positive impacts on the women's role in society and quality of life.

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

- Develop and introduce low cost, value-added food processing technologies for beans and cowpeas.
- Utilize processed legumes in low cost, value-added food products.

Research Approach, Results and Outputs

Low Cost, Value-added Food Processing Technologies: Micronization conditions of process time, temperature profile and ending temperature, moisture content and time of tempering and energy requirements for drying products were optimized for selected cowpea lines. Quality parameters of the micronized and dried products were then determined. This included physicochemical properties of color, texture and pasting properties of micronized and boiled products, cooking time, and selected quality parameters critical for consumer preference.

The results indicate that micronization pre-treatment reduced the cooking time of cowpeas by approximately 30% by increasing the hydration rate during the initial period of cooking. Micronized cowpeas were found to be significantly softer than raw cowpeas after 15 to 25 minutes of cooking. This correlates with the water uptake results where micronized seeds absorbed significantly more water than the raw seeds when cooked between 10 to 20 minutes. Improved hydration rate for micronized seeds may be due to the formation of fissures or cracks in the cotyledon (Fasina, et al., 1999).

After 20 minutes of cooking, the middle lamella of raw seeds was still intact compared to the micronized seeds where a marked separation was observed. The latter probably contributed to the softer texture of micronized seeds. According to the sensory focus group, raw and micronized cowpeas had an acceptable texture and flavor only after 70 and 50 minutes of cooking respectively, indicating a significant reduction in cooking time. This was not evident from the objective instrumental texture measurements because the texture analyzer only measures softness/hardness of cowpeas and not necessarily the degree of cookability.

Low-Cost Value-Added Food Products: The hypothesis was confirmed that hydrothermal processing of cowpeas yielded dry, shelf stable grain that cooked into acceptable whole cowpeas in less time. Even though a "product" with improved functionality has been prepared, the economics, consumer preference and optimization of processing costs need further investigation.

As a next step, the project team plans to evaluate treatments that require less soaking and heating to optimize the beneficial effects of processing at the lowest cost of time and energy to attain a low moisture, shelf stable product with improved cooking time and texture. During the next research period, the team will also investigate consumer acceptance of cowpea products that require less processing time and energy.

Literature Cited

Arntfield, S.D., M. G. Scanlon, L. J. Malcolmson, B. M. Watts, S. Cenkowski, D. Ryland and V. Savoie. 2001. Reduction in Lentil Cooking Time Using Micronization Comparison of Two micronization Temperatures. Journal Food Science 66(3)500 505.

Brouwer, I.D., T. M. A. Wijnhoven, J. Burema and J. C. Hoorweg. 1996. Household Fuel Use and Food ConsumptionRelationship and Seasonal Effects in Central Malawi. Ecology of Food and Nutrition 35, pp. 1–13.

DeMooy, B. E. and C. J. DeMooy. 1990. International Journal of Food Science and Technology 25, pp. 209–212.

Fasina, O., R. T. Tyler, M. D. Pickard and G. H. Zheng. 1999. Infrared Heating of Hulless and Pearled Barley. Journal of Food Processing and Preservation 23, 135–151.

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; Henry Laswai, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions

Theobald Mosha, Ph.D. student from SUA at MSU; Elizabeth Rondini, Ph.D. student at MSU

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. Thus, there is a desperate need to formulate low-cost foods based on locally produced food that will be capable of providing adequate protein, energy and other nutrients to support nutritional rehabilitation and normal growth. Increasing bean utilization and making more nutritious diets available at affordable cost will be 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 to achieve the following objectives:

- Determine the quality of bean maize/sorghum/ rice products and their potential to reverse malnutrition.
- Investigate the per capita contribution of beans to the household food and nutrition security of vulnerable groups especially children under five years of age in selected urban households.
- Begin a 12-month study to determine if feeding beans/cowpeas will inhibit chemically-induced mammary cancer.

Research Approach, Results and Outputs

Assessment of Bean-based Products to Reverse Malnutrition: Corn, beans and rice are common staples consumed in Tanzania. Small sun-dried fish (sardines or sprats) are readily available and an inexpensive source of high quality protein and calcium. Processed foods were prepared by drum drying. The biological value of the staples were evaluated singularly (rice meal (RM), bean meal (BM), and corn meal (CM)) or combinations of beans and a cereal (rice bean meal (RBM) and corn bean meal (CBM)) or as composites that included a small amount of fish (rice bean sardine composite meal (RBSM) and corn bean sardine composite meal (CBSM)). Weanling rats served as animal models for small children. The composite meals were formulated to meet the WHO guidelines for cereal-based supplementary foods; with an amino acid score of > 68%, protein energy value of > 14%, net dietary protein calorie (NDpCal%) value of 8 10%, and energy density of >360 kcal/100 g. The beans and cereals were combined to maximize the amino acid score of the mixture. Quality attributes of the foods (amino acid profile, protein digestibility and utilization, growth, and potential for rehabilitation of malnourished children) were determined. All nutrient requirements for rats (except protein content and quality) were met so that the only factor limiting growth was protein.

Results show that it is not possible to meet all WHO guidelines for small children with combinations of cereals and beans. Foods prepared from an individual staple have even more deficiencies in amino acids (lower amino acid score). However, the composite meals met or exceeded all of the WHO guidelines. Growth is a direct indicator of overall protein quality and the results are shown in Figures 1 and 2. Corn meal, corn-bean meal, rice-meal, rice-bean meal, and bean meal did not support acceptable growth. However, when a small amount of fish is added, overall protein quality is equal to milk protein. Neither corn nor rice provided an adequate amount of protein or an adequate amount of the essential amino acids. Beans can provide an adequate amount of protein but not an adequate amount of the essential amino acids. The same is true for bean-rice and bean-corn combinations. The differences in growth shown in Figures 1 and 2 directly reflect the ability of the staples or the combinations of beans and cereals to provide an adequate amount of the essential amino acids. Only the composite meals provided all of the essential amino acids. Rats fed with corn meal, corn bean meal, or bean meal lost weight or grew poorly (malnourished rats). These rats were fed either the composite meals or milk protein to evaluate the potential of the composite meals for rehabilitation of malnourished children. The results show that the composite

Figure 1. Growth potential for corn, bean, corn-bean, and bean-corn-fish products

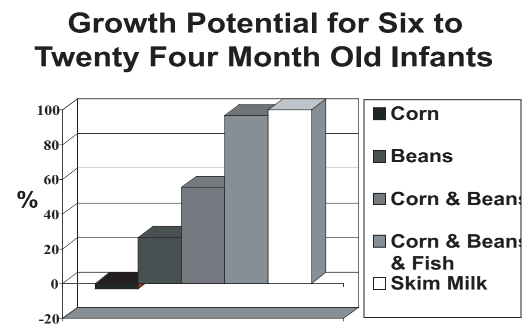
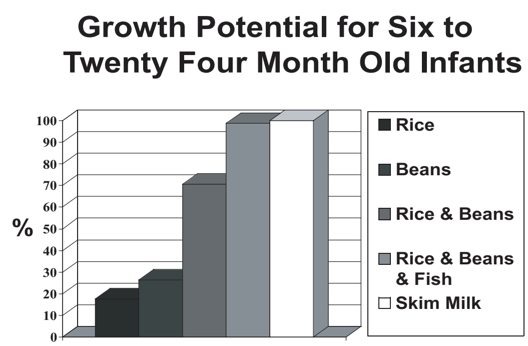


Figure 2. Growth potential for rice, bean, rice-bean, and bean-rice-fish products



meals were as suitable as milk protein for rehabilitation of malnourished rats. The composite meals need to be fortified with an inexpensive mineral vitamin premix to form a complete supplement for children 6 to 60 months of age. The food ingredients used to prepare the composite meals are inexpensive, locally produced (stimulus for agricultural production), and easily prepared. The composite meals are pre-cooked, dehydrated powders that simply need to be added to hot, potable water.

Contribution of Beans to Household Food and Nutrition Security: Six hundred and fifty six households in the urban areas of the Morogoro and Kilosa districts (Tanzania) were selected randomly. The average intake of calories and protein from beans, proportion of calories and protein contributed by beans and the amount of income spent on purchasing beans relative to other foods and its share on the overall expenditure on food was determined. Nutritional status of children under the age of five was assessed in the surveyed households.

A good number of the respondents were civil servants and the households in areas surveyed included primarily households that do not grow beans. Thus, most of the beans consumed in these households were purchased from the market. Also, very few households grew or consumed cowpeas. When cowpeas were consumed, it was in the form of green leaves.

Role of Beans in Reducing Mamarian Cancer: A rodent model of human breast cancer compared mammary cancer development in rats fed black beans, navy beans, and light red kidney beans. Most of the protein was provided by the beans. A control diet utilized casein as the protein source. All diets provided similar amounts of nutrients per Kilocalorie and were nutritionally adequate. The fat content of the diets provided approximately 35% of the energy (similar to humans). Mammary cancer was induced by a single injection of 3 methyl nitroso urea. The injection was made when the female rat is 51-53 days of age. At this age, the mammary tissue is very sensitive to mutations because of the high mitotic rates that occur in the mammary alveolar tissue. Beginning eight weeks after the injection, the rats were palpated weekly to identify the appearance of tumors. When a tumor reached 2.5 cm in diameter, the rat was sacrificed. Tumors were weighed, processed for pathological examination, and classified by a pathologist. Tumor parameters were calculated (mean tumor latency and survival rates).

Preliminary data indicate that feeding black beans or navy beans slowed the appearance and growth of mammary cancer. Black beans were more effective than navy beans. Light red kidney beans did not protect against breast cancer.

Literature Cited

Armstrong, B. and R. Doll. 1975. Environmental Factors and Cancer Incidence in Different Countries, with Special Reference to Dietary Practices. International Journal of Cancer 15: 617-31.

Correa, P. 1981. Epidemiological Correlations Between Diet and Cancer Frequency. Cancer Research. 41:3685- 90.

Doll, R. and R. Peto. 1981. The Causes of CancerQuantitative Estimates of Avoidable Risks of Cancer in the United States Today. Journal of National Cancer Institute 66:1191-1308.

Hangen, L. and M. R. Bennink. Consumption of *Phaseolus vulgaris* (Black Beans or Navy Beans) Reduces Colon Cancer in Rats. Faseb Journal 15(4):A61.

King, F. S. and A. Burgess. 1993. Nutrition for Developing Countries. 2nd Edn. London, Great Britain. ELBS with Oxford University Press.

Mosha, A.C. and U. Svanberg. 1990. The Acceptance and Food Intake of Bulk Reduced Weaning Foods:The Liganga Village Study. Food Nutr. Bulletin 12:69-74.

National Academy of Sciences. 1982. Diet, Nutrition and Cancer. Washington D.C.: National Academy Press.

National Academy of Sciences, National Research Council (U.S.). 1989. Committee on Diet and Health, Health Implications for Reducing Chronic Disease Risk. Washington, D.C.: National Academy Press.

Tomkins, A., D. Alnwick and P. Haggerty. 1987. Fermented Foods for Improving Child Feeding in Eastern and Southern Africa. In: D. Alnwick, S. Moses and O. G. Schmidt (Eds). Proceedings of a Workshop on Improving Young Child Feeding in Eastern and Southern Africa – Household Level Technology. Nairobi, Kenya, Kenya Publishing House.

Williams, C. D. A Nutritional Disease of Childhood Associated with a Maize Diet. Arch Dis Child 1933; 8:423-33.

World Cancer Research Fund/American Institute for Cancer Research. 1997. Food, Nutrition and the Prevention of Cancer: A global Perspective, Menasha, WI: Banta Book Group.

World Health Organization. 1990. Diet, Nutrition and the Prevention of Chronic Diseases. Technical Report series no. 797, Geneva: WHO.

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

Improved Water Management for Intensified Bean Production in Malawi in the Dry Season, Taking into Account Labor and Capital Constraints of Women and Resource-Poor Farmers

Principal Investigators and Institutions

Anne Ferguson and Sieglinde Snapp, Michigan State University; Henry Mloza Banda, Bunda College of Agriculture, Malawi

Collaborators and Institutions

Essau Mwendo–Phiri, World Vision International; Julius Mangison, Davis Ng'ong'ola and Darwin Singa, Bunda College of Agriculture, Malawi

Justification and Objectives

Many countries in Southern Africa face serious food shortages and hunger due to a combination of political and environmental causes. One strategy smallholders employ to address food shortages is the extension of the agricultural season by developing means for dry season crop cultivation. In Malawi and other countries in the region, this is often achieved through utilization of areas of residual moisture (streambanks and drainage lines) and water management of wetland areas (called *dambos* in Malawi). Production of bean seed and other high value crops in the *dambo* areas during the dry/cool season has received little research attention. There is a need for water management technologies, agronomic practices, and bean varieties that will reduce the labor requirements and thus, improve the well being of women and low resource farmers who practice irrigated dry season cultivation in these areas.

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

- Document the indigenous cropping system and water use practices to assist in upgrading technologies for water abstraction, delivery, and application as a model for the improvement of irrigated bean cultivation in Malawi.
- Intensify bean production in the dry season by introducing improved methods of water management and disease-free seed in order to reduce work and expand income opportunities for women and resource-poor farmers.

Research Approach, Results and Outputs

Reconnaissance/transect walks of four major dambo areas in Southern and Central Malawi were carried out in July 2002 to gather information from key informants on the extent of bean cultivation in each area, farming practices, production, and marketing constraints in the dry season, and to select a site for more intensive research. We chose Chingale dambo in Zomba district as the site for further study. Chingale dambo is located in a rain shadow where production during the rainy season is challenging but the area is ideal for irrigated, dry season production of crops such as beans, cowpeas, rice, and vegetables for both subsistence and commercial purposes. We selected this site for a number of reasons: 1) intensive bean seed production takes place in this area in the dry season, and project researchers felt that seed and grain production could be increased with the introduction of improved water management practices and new CRSP bean varieties, and 2) key informant interviews suggested that marketing constraints were a serious impediment to increasing smallholder incomes. These included the need to better synchronize production and marketing and to improve smallholder farmers' ability to negotiate with buyers, and 3) World Vision-Malawi (WVM) has a project in Chingale aimed at addressing food insecurity and the low incomes of many smallholder farmers. The program focuses in part on bean seed production and sale. The WVM Program Manager expressed strong interest in collaborating with the CRSP to help assure that bean seed production and marketing is sustainable when WVM withdraws and to improve the food security and incomes of farmers.

A baseline survey of farming practices was undertaken in July 2003. It involved a total of 84 farmers split into three categories. The first category of 28 respondents participated in the on-farm trials of 12 advanced breeding lines for the Bean/Cowpea CRSP breeding component; the water use and irrigation technology trials described below. The second category of 26 respondents were current beneficiaries of

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

World Vision-Malawi technologies and support. The third category of 30 respondents were not beneficiaries of WVM support. Respondents in the first category were purposely selected amongst bean farmers. Respondents in the second and third categories were randomly selected across the four zones of the ADP. Information was gathered to address division of labor by gender, bean production practices in the dry and rainy seasons, water use practices, and marketing constraints.

On-farm trials were initiated in 2003 by M.Sc. Student Davie Kadyampakeni (Bunda College) to investigate water options in the Chingale *dambo*. The objectives of the research are to: 1) determine the seasonal water requirement for the bean crop in contrast with the supply of water; 2) compare CRSP and local varietal bean performance under three irrigation water management methods (overhead and surface irrigation, residual moisture); and 3) evaluate the technical and economic feasibility of prevailing and potentially new irrigation technologies and management practices. Twenty seven (27) farmers who grow beans were randomly selected with the assistance of staff of WVM to participate in the study. Bean varieties developed by the CRSP, either already released or in the final stages of release, are being used in the study. The trials of various water abstraction methods involved pumping by treadle or diesel pump, drawing by a hand-bucket or watering can, and gravity diversion. Water application methods included furrow irrigation, sprinkling (using a pipe, watering can, or bucket) and residual moisture. The following parameters were measured: volume of water used by the bean crop, water use efficiency, evapo transpiration, conveyance, and application efficiencies of the irrigation system. The seasonal crop water requirement was estimated to compare with water supplied by the treadle or diesel pump, traditional bucket system, and canals. The average climatic data for ten bean crop seasons (1992-2002) for the location will be used. The Food and Agricultural Organization Radiation Method was used to estimate and measure evapo transpiration. The baseline survey discussed above provides data on irrigation costs, including pump costs, repair costs, lubrication costs, production costs (inputs), operational costs, labor costs, and installation costs. Data will be subjected to a cost/benefit analysis and a technical analysis using SPSS statistical package. Biological data collected will be analyzed using a computer package, GENSTAT. Staff from WVM and farmers were trained in bean agronomy and data collection. Field handbooks for disease and insect pest identification were produced for farmers and staff.

The aim of the study is to see which irrigation technologies and water management practices are economically and technically suitable and sustainable. It is expected that gross margins will show feasibility of adoption of a particular irrigation method by farmers in different economic categories. Particular attention is placed on determining if there are ways to lessen the labor of women farmers who rely predominantly on handbuckets. The findings of this study will identify appropriate irrigation technology and water management practices for the bean crop in Chingale and areas with similar agro ecological features.

A second research objective is to understand and address marketing constraints identified during the reconnaissance survey in Chingale dambo, particularly the need to: 1) better synchronize production and marketing, 2) develop sustainable marketing strategies for the WVM bean seed program, and 3) perform capacity building involving training smallholder farmers to negotiate more effectively with private traders both on-site and in Blantyre City where much of the produce is sold. The marketing systems instituted for seed production by WVM have enabled participating farmers to move from subsistence to commercial seed and crop production. However, farmers identified the following problems: uncertainty over sales owing to the protracted process of seed certification and the long wait to receive their payments after selling; and the lack of supplies/dealers in the area for the purchase of fertilizers and pesticides.

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; Jonathan Lynch, Pennsylvania State University; Robert Mabagala, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions

James Semoka and Susan Nchimbi Msolla, Sokoine University of Agriculture, Tanzania; J. Drevon, INRA, France; Ken Giller, Wageningen, Netherlands; Phil Miklas, USDA; Roland Chirwa, CIAT, Africa; Steve Beebe, CIAT, Colombia; M. Hungria, EMBRAPA, Brazil; Ricardo Maria, INIA, Mozambique

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. 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/yr. Concern with the future availability of phosphorus fertilizers, and with 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, which is the emphasis of this research component. That improvement in N_2 fixation and P use efficiency is possible, is evident in the progress made with soybean in Brazil, and in our own studies on cultivar improvement in nitrogen fixation at Minnesota (Elisondo et al., 1999; Christiansen and Graham, 2002).

Ken Giller (pers. comm.) also suggests that the majority of soils in Eastern Africa have pH limitations for bean growth. High Al and Mn concentrations are also a constraint, but of lesser priority. Wortman et al. (1998) suggested that 52% of East African soils and 42% of Southern African soils are of pH 5.2 or less. Acid soil areas are clearly important in Tanzania, Malawi, Rwanda and Burundi.

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

- Select bean cultivars and rhizobia with tolerance to low P and N levels in soil, and ability to nodulate and fix N_2 under these conditions.
- Select bean cultivars and Rhizobium with tolerance to acid soil factors, and ability to nodulate and fix N_2 at acid pH.

Research Approach, Results and Outputs

Selection for Tolerance to Low P and N: A total of 102 bean lines selected from a range of sources (CIAT, EMBRAPA, UMN, EAP, and SUA) for tolerance to (often unspecified) edaphic constraints were assembled at UMN, and their seed multiplied, then small quantities forwarded to Tanzania, where they have been further multiplied.

Bean tolerance to edaphic stresses is being tested using a coarse sand, intermittently irrigated and drained nutrient solution system (Vargas and Graham, 1988). The nutrient solution being used is modified from that of Summerfield et al. (1978) for growth chamber grown grain legumes, but contains only 10 ppm N. pH (4.25 to 5.5), Ca (200 400-M) and P (25 to 100-M) content are varied according to the edaphic stress to be imposed, and $AlK(SO_4)2.12H_2O$ (400mM) or $MnSO_4.H_2O$ (250mM) applied to induce toxicity of Al or Mn. All trials were inoculated at planting with *R. tropici* UMR1899, and are grown 4-5 weeks at 24/20^{o}C day night temperature.

An initial evaluation of the low P screening procedure was undertaken using sixteen cultivars for which we had abundant

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

seed. When results in these tests proved satisfactory, 48 bean cultivars were evaluated for growth and nodulation at 25 uM P. There were marked differences between cultivars, with nodule fresh weight and plant dry weight again correlated. BAT477 and AFR675 were outstanding with DICTA17 and Romano also exhibiting excellent growth and nodulation at low P. It is interesting that BAT477 and AFR675 performed well in both low P and pH testing. This could be due to production of chelates, or an indication of effects of pH on the availability of medium P. To determine whether the same cultivars would be prominent when supplied P in a less available form, the same 48 cultivars were then grown in Sunshine Mix No. 2 (No Nitrogen) with low levels of ground rock phosphate. With P availability from rock phosphate limited, growth and nodulation of all plants was affected, though E295 and Dade showed better development. Additional cultivars remain to be tested for all acid soil constraints.

Selection for Tolerance for Acid Soil Factors: The same screening procedure as detailed above, but with P at 50uM and pH in solution adjusted three times daily to pH 4.5 was used to evaluate bean cultivars for effective nodulation at low pH. Again, the procedure was tested with 16 cultivars for which we had abundant seed, then when results in this test proved satisfactory, with 48 bean cultivars from the "edaphic" collection. Some cultivars were little affected by this pH, and showed near normal growth and nodulation; others showed minimal nodulation and marked N chlorosis. For the cultivars tested, nodule fresh weight and plant dry weight were well correlated with BAT477, Garbanzo Zarco, G18479 and AFR675 outstanding. Seed of these lines is being multiplied for additional study.

Soil acidity is also becoming an important factor in the central region of Minnesota where heavy N fertilizer application to sandy and poorly buffered soils has resulted in significant soil acidification. Despite this problem, farmers resist changing to the more economically friendly and sustainable practice of inoculation with Rhizobium because they believe locally used varieties are inherently weak in nitrogen fixation. To determine if this was true, we compared the growth and yield of the locally important cultivars Montcalm, Drake, T39, Blackjack and Jaguar when supplied with N fertilizer or Rhizobium inoculant; and in a separate experiment contrasted the response to inoculation of the local variety, Montcalm, and the high N_2 fixing Honduran variety, Yeguare. For the five local varieties, yield with 100 kg/ha N fertilizer applied averaged 1767 kg/ha; when inoculated average yield for these varieties was only 1348 kg/ha. In contrast, yield for Yeguare when dependent on symbiotic N_2 fixation was 2167 kg/ha while that for the local cultivar, Montcalm, under the same conditions was only 1041 kg/ha. To introduce genes for high nitrogen fixation into locally adapted materials, crossing has been initiated between Montcalm and the two locally adapted high N_2 fixing lines EL19 and EL34 (Elisondo et al., 1999). Backcross populations from these crosses (which is a collaborative activity with Ken Grafton) should be available later this year.

Poor plant growth when dependent on N_2 fixation is a particular problem for farmers in this region wishing to convert to organic production. Studies started in 2003, examined the interaction between liming (conventional limestone or eggshells), inoculation using liquid inoculants to satisfy organic requirements, and manure application in farmers' fields. Data from these studies is still being analyzed.

Studies to develop appropriate screening procedures for the evaluation of cultivar differences in Al and Mn toxicity, using 16 cultivars for which there was an abundant seed supply, are close to completion. Clear symptoms of Mn toxicity are evident under the conditions imposed; however this procedure has not yet been applied to evaluation in the "stress" nursery.

At Sokoine, soils from areas where field experiments will be conducted have also been characterized for major (N, P, K, Ca, N) and micro (Zn, Cu, B, Co, Mo) elements and pH. Most soils in Morogoro and Mbozi district (Mbeya region) range in pH from 4.6-7.0 and are low in P (2-12 ppm P) and N (0.09-0.20 %N). Soils from Kilimanjaro and Arusha have medium P levels, while those from the Lushoto (Tanga) and Njombe (Iringa) districts also have low P levels. Mo is likely to be a constraint to nodulation and N_2 fixation in some areas.

Literature Cited

Amijee, F. and Giller, K.E. 1998. Environmental constraints to nodulation and nitrogenfixation of *Phaseolus vulgaris* L. in Tanzania. African Crop Science J. 6, 159169.

Anyango, B., Wilson, K.J., Beynon, J.L. and Giller, K.E. 1995. Diversity of rhizobia nodulating *Phaseolus vulgaris* L. in two Kenyan soils of contrasting pHs. Appl. Environ.

Microbiol. 61, 4016 - 4021.

Christiansen, I. and Graham, P.H. 2001. Variation in dinitrogen fixation among Andean bean (*Phaseolus vulgaris L.*) genotypes grown at low and high levels of phosphorus supply. Field Crops Res. 73, 133 - 142.

Elisondo Barron, J., Pasini, R.J., Davis, D.W., Stuthman, D.D. and Graham, P.H. 1999. Response to selection for seed yield and nitrogen (N2) fixation in common bean (*Phaseolus vulgaris L.*). Field Crops Res. 62, 119 -128.

Giller, K.E. and Cadisch, G. 1995. Future benefits from biological nitrogen fixation:an ecological approach to agriculture. Plant Soil 174, 255 - 277.

Graham, P.H. 1981. Some problems of nodulation and symbiotic nitrogen fixation in *Phaseolus vulgaris L.*) a review. Field Crops Res. 4, 93 - 112.

Hungria, M., Andrade, D.D., Colozzi, A., and Balota, E.L. 1997. Interactions among soil organism sand bean and maize grown in monoculture or intercropped. Pesq. Agropec, Brasil, 32, 807 - 818.

Karanja, N. et al. 2000. Agrobiotechnet Vol. 2, 10 pages (electronic paper)

Munns, D.N. 1970. Nodulation of Medicago sativa in solution culture. V. Calcium and pH requirements during infection. Plant Soil 32, 90 - 102.

Summerfield, R.J., Huxley, P.A. and Minchin, F.R. 1977. Plant husbandry and management techniques for growing grain legumes under simulated tropicl conditions in controlled environments. Exp.Agric. 13, 81 - 92.

Vargas, A.A.T. and Graham, P.H. 1988. *Phaseolus vulgaris* cultivar and Rhizobium strain variation in acid -pH tolerance and nodulation under acid conditions. Field Crops Res. 19, 91 - 101.

Wortmann, C.S. and Allen, D.J. 1994. CIAT workshop series 25, Kampala. 47 pp.

Wortmann, C.S., Lunze, L., Ochwoh, V.A. and Lynch, J. 1996. Bean improvement for low fertility soils in Africa. African Crop Science J. 3, 469 - 477.

Wortmann, C.S. et al. 1998. Atlas of common bean (*Phaseolus vulgaris L.*) production in Africa. CIAT publication 297, pp 133.

Wortmann, C.S., Silver-Rwaaikara, M. and Lynch, J. 1998. Efficiency of nitrogen acquisition and utilization in common bean in Uganda. 1. African Crop Science J. 6, 273 - 282.

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, Washington State University; Flavianus Magayane, Sokoine University of Agriculture, Tanzania; Charles Masangano, Bunda College of Agriculture, Malawi

Collaborators and Institutions:
Susan Nchimbi-Msolla and Anna Temu, Sokoine University of Agriculture, Tanzania; James Bokosi, Bunda College, Malawi; Patrick Kambewa, Chancellor College, Malawi

Justification and Objectives:

Over the last two decades, the Bean/Cowpea CRSP has developed improved bean varieties in East Africa. However, production and adoption of these varieties are limited. The government-led seed multiplication and dissemination systems in Tanzania and Malawi are generally dysfunctional and have ceased production of non-hybrid seed, including beans, due to low economic returns. To address this situation, NGOs and donor organizations began actively managing seed multiplication schemes, promoting smallholder seed associations, and encouraging private sector entrepreneurs to become more involved in the production and marketing of seed. There is, however, a major lack of infrastructure and training for foundation and certified seed production to support these projects. An additional issue impacting the performance of these projects is that farmers have not historically purchased bean seed and instead have relied on bean grain for their planting stock. Farmers save beans for replanting and buy bean grain for planting from local markets only when their farm supplies are inadequate. There is a general lack of awareness of the benefits of improved seed for a crop like beans.

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

- Multiply foundation, certified and quality declared seed (QDS) or farmer-approved seed (FAS) of CRSP varieties in Tanzania and Malawi to enhance maximum dissemination to rural communities.
- Investigate the efficacy of seed production guidelines and promotional materials in promoting good seed production practices and adoption of new varieties in Tanzania, Malawi and Washington.
- Investigate the costs-benefits of foundation, certified, and quality declared/farmer-approved seed multiplication to support the shift of this activity to entrepreneur seed producers, government agencies, or NGOs.

Research Approach, Results and Outputs

Multiplication of Foundation, Certified and Quality Declared Seeds: In Malawi, six hectares were planted for Kalima and Nasaka seed production. In addition, seeds of seven other released CRSP varieties were multiplied yielding at least 0.2 tons of each variety. The intent is to maintain seed viability and to produce enough seed so that Bunda College can supply seed for multiplication to meet the increasing demand. There was very high demand for seed this year from NGOs, which was beyond what the team could supply. Most of the CRSP seed went to smallholder farmers who intended to begin seed multiplication. Some of the seed multiplication farmers have done very well, especially one farmer who multiplies seed on a farm close to Bunda. Plans are to encourage expansion of production at this field site to engage more farmers and to enhance the supply of quality seeds.

A survey of bean growers in the state of Washington was completed and published (Miles and Sonde, 2003). The survey was designed in collaboration with Dr. Magayane, SUA, Tanzania. The survey captured nearly all the small-scale dry bean farmers in the state, but reached only a small segment of large-scale bean farmers due to the difficulty identifying those farmers. There is no dry bean association or organization in Washington and only a handful of bean farmers attend the annual state crop production conferences.

Forty-six farmers from 18 counties in Washington responded to the survey. Seventeen (37%) respondents were located in eastern Washington and 29 (63%) were in western Washington. Eleven of the respondents in eastern Washington were in the Columbia Basin; of these, nine were large-scale farmers who grew dry beans on 18-450 acres each, and 155 acres on average. In contrast, 37 farmers were small-scale farmers each with a total dry bean production area of 0.13 acre on average. None of the large-scale farmer respondents and half (57%) of the small-scale farmer respondents were women. Attendance at farmer conferences, workshops and field days indicate that women do not participate in large-scale farming events but do comprise at least half of the participant number at small-scale farming events. These results imply that women actively participate in small-scale farming including dry bean farming and do not participate in large-scale farming. These findings follow national trends where 90% of the farms owned and operated by women were small farms.

The 46 respondents grew a total of 69 different varieties of dry beans over the past 1-30 years. Large-scale respondents grew on average two varieties of dry beans each year, primarily pinto, red kidney and small red types. Small-scale respondents grew 1-20 varieties of dry beans each year, four varieties on average per respondent. Jacob's Cattle, Black Turtle, Cannellini, Calypso and Cranberry were some of the main varieties grown. Of the respondents, 46% saved seed from their bean crop, and none of the large-scale farmers saved seed from their crop. Of the respondents, 63% stored dry bean seed on the farm for up to six years. Common on-farm storage containers used were glass jars, sacks, plastic tubs or buckets and wooden boxes. Respondents reported they had no serious problems with seed production or seed saving but rated weeds as the number one problem in dry bean production (26%), followed by poor germination (22%), late maturity (20%), diseases (20%) and shriveled beans (13%). There was no correlation between saving seed and poor seed germination. Some respondents also reported that inadequate tools for small-scale dry bean threshing were a major constraint to increasing dry bean production. Disease symptoms that were most commonly observed by farmers were mold, seedling wilt, brown leaf spot, pod rot and anthracnose, while symptoms of Beet Curly Top Virus and Bean Yellow Mosaic Virus were sometimes observed. Most of the small-scale respondents were organic growers who did not use any chemical pest control measures. Because of the relative ease of production and storage of dry beans and their long marketing window, dry beans have the potential to become an important crop for many small farmers in the Pacific Northwest and elsewhere in the U.S.

In Tanzania, seeds were provided to CARE Magu in the Mwanza region for multiplication by ten groups of farmers. The 2003 growing season was very dry and only one group out of the 10 planted. CARE Magu was impressed by the variety planted and has asked to purchase additional seed for increasing the seed stock during the 2004 growing season.

Efficacy of Seed Production Guidelines and Promotional Materials: Brochures highlighting six released CRSP varieties were printed in English and Chichewa. Two thousand copies were disseminated to the ADDs in the major bean growing areas of the country and to the collaborating NGOs. Brochures were also distributed to other interested parties, including USAID Malawi and the National Smallholder Farmers Association of Malawi (NASFAM). As a result of the brochures, demand for seeds of all six released varieties have substantially increased.

Cost-Benefit Analysis: Cost-benefit analysis studies of bean seed production were initiated in Tanzania and Malawi. Seed was distributed to market vendors, and data collection has begun regarding market demand for CRSP varieties.

In Tanzania, consumer surveys were undertaken by Dr. Anna Temu in four urban centers. The premise of the study was to provide information and a better understanding of the characteristics of dry beans (*Phaseolus vulgaris* L.) that are most preferred by consumers. The results show that consumers ranked SUA varieties more highly compared to other varieties for the observable "after cooking" characteristics. Consumers agreed that they are relatively the same in color, shape and size after cooking. However preference after cooking remains for the light colored varieties (soya fupi, soya ndefu and SUA90).

Assessment of Seed Multiplication Systems: In Malawi, a literature review and a reconnaissance survey were conducted to identify the active seed multiplication and dissemination models in the country. Organizations that are involved with bean seed multiplication and dissemination were visited and key informant interviews were conducted. The organizations included in this study were: the National Bean Program, ActionAid Malawi, EU Food Security Program, Concern Universal, National Association of Smallholder Farmers in Malawi (NASFAM), Association of Smallholder Seed Multiplication Action Group (ASSMAG), and World Vision International. The desk officers for seed multiplication programs at each of these organizations were interviewed. Preliminary results indicate that Nasaka and Kalima, both varieties promoted by the Bean/Cowpea CRSP, are in high demand in the areas where they have been promoted through seed multiplication schemes. Nasaka has been multiplied by smallholder farmers in Salima ADD under the ActionAid food security program during the winter months using residual moisture, and as a result demand for Nasaka has been high in Salima ADD. Smallholder farmers in Dedza have multiplied Kalima seed under the Concern Universal Food Security and Sustainable Livelihoods Program, and as a result demand for Kalima has been high in the Dedza area.

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; Philip Miklas, U.S. Department of AgricultureProsser; James Bokosi, Bunda College of Agriculture, Malawi; Susan Nchimbi Msolla, Sokoine University of Agriculture, Tanzania

Collaborators and Institutions

Charles Masangano, W. A. B. Msuku, G. K. C. Nyirenda and Agnes Mwangwela, Bunda College, Malawi; Catherine Madata, Betty Gondwe and Margaret M. Mkuchu, TARI, Uyole, Tanzania; Robert Misangu, Robert Mabagala and Cornel Rweyemamu, Sokoine University, Tanzania; Carol Miles, Washington State University; Bob Gilbertson and Steve Temple, University of California-Davis

Justification and Objectives:

Bean (*Phaseolus vulgaris* L.) yields are about 400 to 500 kg/ha in farmers' fields in Africa, but yield potentials up to 1500 to 2500 kg/ha can be achieved when improved varieties and proper agronomic practices are used. Many problems contribute to low bean yields. Problems include local varieties that have low genetical yield potential, susceptibility to diseases, insects and poor adaptability to soil conditions and unreliable weather. The weather in low altitudes is hot with erratic and short rains. The cool wet weather in high altitude supports development of major bean diseases. Because of the differences in biotic and abiotic conditions, bean varieties developed in one country are not necessarily adaptable to conditions in other countries in the region. Therefore, it is imperative that technical support be provided to multiple bean breeding programs to develop varieties that satisfy local market demands and possess desired agronomic traits conferring high yield potential and pest resistances.

Improved lines in a few market classes have been developed by the National Programs and by Bean/Cowpea CRSP supported institutions in Malawi and Tanzania. Although these lines possess a few resistance genes, research is needed to identify more durable forms of resistance and to pyramid resistances into elite varieties. An integrated approach, combining the resources of both the U.S. and Host Country institutions to tackle biotic and abiotic constraints, while allowing individual programs to develop locally adapted materials is the most efficient way to make progress. The breeding programs collaborate with CIAT, ECABRN and SABRN within the Eastern and Southern African region.

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

- Evaluate germplasm, and preliminary and advanced lines for resistance to diseases and abiotic stresses.
- Incorporate and evaluate arcelin alleles to protect against bruchids and to release arcelin protected materials.
- Obtain germplasm and make crosses to elite materials to incorporate disease resistances.

Research Approach, Results and Outputs

Germplasm Evaluation: The advanced Kablanketi lines were evaluated in a replicated trial at SUA and in an on–farm trial in the Dihinda village. With the exception of one line, the yield performance of Kablanketi lines was higher than the local check 'Kenya' but not statistically different from SUA 90 and Rojo. EG 40 was lower yielding than the other experimental lines. EG 44 was the highest yielding followed by EG 21 and then EG 13. Overall yield performance was poor because of drought, which also affected the seed size of entries. Common bacterial blight (CBB) was the only disease observed in the trials, and disease scores were low, (ranging from 2-4 on a 1-9 scale). In on-farm trials, EG 10 was highest yielding followed by EG 21 and then 'Kenya.' Little disease was observed. EG 10 and EG 21 are proposed for release because of their good seed type and for having fast cooking times. Data on the on-farm evaluation reported in FY 01/02 demonstrated farmer acceptance of these two lines.

At UC-Davis, activities were conducted to help complete the evaluation and release of a series of improved bean lines representing a diversity of seed types that were bred during the previous East Africa regional project. In FY 03, the plan was

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

to complete the BCMNV confirmation tests on 11 nanyati (sugar bean) lines. These nanyati lines were developed via crosses with California and CIAT materials carrying the bc 3 gene for complete resistance to BCMNV. The NL-3 BCMNV isolate was used to inoculate ~100 young plants (primary leaf stage) of each line to confirm the nature of BCMNV resistance in these materials. Simultaneously, seed of these lines were sent to Malawi for planting and evaluation during the 2003-04 growing season. Data on BCMNV resistance will be used to eliminate those lines with susceptibility.

The Bunda developed line, BCMV B2, was entered into the Southern Africa Regional Bean Yield Trial (SARBYT) and evaluated at eight locations in Malawi, Zimbabwe, Mozambique, D.R. Congo, Swaziland, and South Africa. BCMV-B2, a small brown type II bean, gave an average mean yield of 1335 kg/ha across all sites which exceeded the grand mean (1144 kg/ha) across sites. The entry ranked fourth overall, and with the exception of Bembeke, Malawi and Harare, Zimbabwe, ranked in the upper quartile for yield at each location. Across locations, BCMV-B2 showed good resistance to ALS (except at Harare, Zimbabwe), and good to moderate resistance to CBB at all sites. The line also showed excellent resistance to BCMV and rust but was moderately susceptible to web blight. The reaction to ALS was excellent at Bembeke, Malawi, and a similar reaction was obtained for HB at Kisumu, DR Congo. It gave good resistance to antracnose as well.

In the Southern African Bean Evaluation Nursery (SARBEN), Bunda entered six entries (BCMV B10, PC 490 D8, DC 96 95, PC 512 B4, BCMV B18, and F6 Bc (19)). The nursery consisted of 100 entries and was grown at seven locations in the SADC region. Three sugar bean entries -- DC 96-95, PC 512-B4, and PC 490-D8 ranked 1, 2 and 20 over all locations. F6 Bc (19), BCMV-B10, and BCMV-B18 were ranked 31, 80 and 84 overall, but showed good performance at individual sites. Lower yields for these entries may have been due in part to missing data at some locations. Lines showed good resistance to BCMNV, Ant, and rust. All lines were resistant to ALS except BCMV-B10, DC 96-95, PC 512-B4, F6Bc (19), and BCMV-B18 at Bembeke, Malawi, and PC 490-D8 at Kisanga, DR Congo. Most lines showed good to moderate resistance to CBB (except BCMV-B10 at Bembeke, Malawi). DC 96-95, PC 512-B4, and F6Bc (19), showed resistance to halo blight at Delmas, South Africa. The lines showed good to moderate resistance to CBB and anthracnose. In summary, BCMV-B2 showed good adaptation in several SADC countries and may be useful as a released variety, or as a potential parental line in crosses. This line is being considered for release in Malawi. It has type II habit and small brown seed with best adaptation to Malawi. In the SARBEN trials, the Bunda entries faired quite well. Three out of the six Bunda entries were listed as potential lines for release in the breeding workplan FY 04 and FY 05. The lines include PC 490-D8, PC 512-B4, and F6 Bc (19). The good performance of these entries indicates greater potential for national and regional impact if they are released.

The National Bean Yield Trial (NBYT) of bush bean types was grown at five locations around Malawi (Bunda, Champhira, Dedza, Matapwata, and Ng'onga). Both Bunda as well as the National program at Chitedze contributed entries. Champhira and Dedza were high yielding sites, while the other sites had reduced yields due to various biotic and abiotic constraints. At Bunda, six entries out-yielded the control variety, Napilira. Lyamungu 90 gave the highest yield followed by RC15 and APN 130. CBB and BCMV were the major diseases at the site. At Champhira, eight entries out-yielded the control (Napilira). The highest yielding entry was Kambidzi followed by SDDT 54-C5, DOR 715 all from Chitedze. At Dedza only two entries, DOR 708 and APN 130, out-yielded the check. Both were from Chitedze. ALS and CBB were the major diseases. Napilira showed good resistance to all these diseases. Fourteen entries out-yielded the check variety (Napilira) at Matapwata, and all entries from Bunda exceeded Napilira. Only CBB was evident at this site. Ng'onga as a site had experienced drought conditions. Eleven entries out-yielded the check, with Kambidzi highest followed by DOR 715 and DOR 708. The site experienced no disease pressure. Lyamungo 90, a Kalima type released by the Tanzania National Program in Arusha, appears to have good potential in Malawi. Lines from CIAT and introduced by the Malawi National Program that have potential include DOR 708 and DOR 715. While red-seeded (a preferred color type), seed size is small (22 g/100 seeds). Among the Bunda lines, DC 96-64 and DC 96-95 are promising sugar bean types with acceptable yields and very good seed quality.

Sixteen entries were included in the NBYT II (climbing types), which were grown at the same five locations as the NBYT I. All sites had low yields on average, but at Dedza and Ng'gonga, yields were very low. At Bunda, five entries out-yielded the control (Bunda 93). The highest yielding entry was 5P/2 followed by 9E/3 and Kanzama. Most entries showed susceptibility to ALS, CBB and MCMV. However, Bunda had several soil fertility problems and some of the disease symptoms were compromised by deficiency symptoms-making disease evaluation more difficult and less reliable. The high CV for yield confirms the soil variability at this site. Seven entries out-yielded Bunda 93 at Champhira. The highest yielding entry was 5P/2 followed by 9E/3 and 5P/6. At Dedza, the highest yielding entry was 9E/3 followed by 5P/2 and 14K/2. Many of the entries showed susceptibility to ALS, CBB and HB, but good resistance to BCMV at this site. At Matapwata, the highest yield entry was 5P/2 followed by 9E/3 and 5P/6. CBB was the major problem, but most entries showed good resistance to both ALS and BCMV. Seven entries out-yielded the check variety at Ng'gonga. No disease pressure was experienced at this site due to drought. The highest yielding line was MCR2505 followed by Kanzama and 659.

Some entries in the National Bean Trials have shown relatively consistent performance under unfavorable environments-such as late planting and unfertile soils. Of greater interest are 5P/2, 9E/3 and 5P/6, which were consistent yielders at all sites except Ng'onga. These may prove useful when grown under low input environments. The major output is the identification of bean lines for on-farm trials and eventual release. The data that have been collected from the Dambo utilization component is being processed and will be used together with the regional data to recommend some lines for release. In addition, at least 50 kg of breeder's seed for each potential line will be produced under winter crop.

Incorporate and Evaluate Arcelin Alleles to Protect Against Bruchids: At Oregon State University, backcross (BC)2 F_1 plants were grown during the winter of 2002-03 and allowed to self pollinate. Individual $BC2F_2$ seeds were screened for arcelin and phaseolin content using polyacrylamide gel electrophoresis. Seed lacking arcelin, and/or with phaseolin present were discarded. Seeds homozygous for the phaseolin null allele and homozygous or heterozygous for arcelin 2 or 4 (depending on the population) were planted in the field during the growing season in 2003. Thirty-two and 21 plants respectively, of arcelin 2 and 4 were planted. Seed has been harvested and will be subjected to protein gel electrophoresis to verify the expected seed protein profile, and to determine which lines may be fixed for the appropriate arcelin allele. After verification, seeds will be sent to Tanzania for bruchid testing. The material continues to show a hybrid incompatibility reaction similar to that produced by the lcr (crippled leaf) trait. With two backcrosses, we should have recovered approximately 88% of the Rojo genome, and thereby eliminating the lcr syndrome. Apart from this observation, the backcross plants closely resemble the Rojo parent in plant habit and seed characteristics. We also plan to make one additional backcross in this material.

At SUA, the Arc2/Arc4 lines with Rojo background were subjected to feeding trials. Because of limited quantities of seed and the need to retain some for further propagation, 3-10 seeds per line were placed in a vial and 15 eggs of *Acanthoscelides* bruchids were added. The vials were kept in incubators at 28°C and relative humidity between 60-70% in the laboratory. After 60 days, bruchid damage was assessed by counting the number of F_1 bruchid adults emerged and the number of damaged seeds. There were significant differences among the lines in the number of damaged seeds and number of adults emerged. Line 2-2-19 appears to have high levels of resistance to *A. obtectus* because of little damage and reduced adult emergence. These results are preliminary; more experiments have been set to give conclusive results. The Arc4 materials did not appear to have any greater resistance than the check lines.

Crosses of the tepary source of bruchid resistance (G40199) with common bean were made in the greenhouse at Oregon State University (OSU) during the spring of 2003. Pod development up to about 20 days was observed, after which seeds and pods aborted. The most developed shriveled seed was kept from about 25 crosses.

Obtain Germplasm and Develop Disease Resistant Lines: Twenty-six germplasm were obtained from CIAT (via Dr. Chirwa), Selian and Uyole Agricultural Institutes. Accessions were evaluated in the field and selected ones were used in making crosses to improved adopted varieties, SUA 90, Rojo, and varieties from Uyole and Selian. ALS resistant accessions were crossed to elite varieties. F_1 seeds have been obtained, and have been planted so as to continue with the backcrossing breeding procedure.

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

The Use of Marker-Assisted Selection to Improve Selection Efficiency in Bean Breeding Programs

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

Collaborators and Institutions
Bob Gilbertson and Steve Temple, University of California-Davis; Catherine Madata, Agriculture Research Institute, Uyole, Tanzania; Deidre Fourie, ARC Grain Crops Institute, Potchefstroom, South Africa

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. We now have resistances to some diseases, most notably Bean Common Mosaic Virus (BCMV) and Bean Common Mosaic Necrosis Virus (BCMNV), rust, and in some cases, Halo Blight (HB), incorporated into improved breeding lines and released varieties. With the Tanzania and Malawi breeding programs possessing a germplasm base containing these resistances, our efforts need to focus on introducing more durable types of resistances to these diseases. We also need to tackle those diseases that have not been as amenable to genetic manipulation. High on the list for Africa are Angular Leaf Spot (ALS), Common Bacterial Blight (CBB), and root rots. These diseases have a common thread in that resistance is quantitative, making it difficult to achieve rapid progress. For other diseases such as anthracnose, the genetics of resistance have been elucidated, but the best sources of resistance have not been widely used. Resistances that have been previously incorporated into the breeding programs need to be retained, while new resistances to the other important pathogens are added. In the U.S., the bacterial blights are of major concern, and among the fungal diseases, white mold and root rots are a universal problem.

Selection of markers linked with known resistance genes and Quantitative Trait Locus (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, 2002). Populations, both inter gene pool and interspecific (primarily with *P. coccineus*), have been developed that could lead to the identification of new genes for resistance to root rot, CBB, ALS, rust, WM, and perhaps insect pests. For example, an accession of *P. coccineus* was identified that was resistant to all 54 isolates of ALS used in the study (Busogoro et al., 1999). Genes identified from such populations will be useful for improving the level of resistance to major pathogens and pests of beans in East Africa. Research is needed to study the inheritance of, and identify molecular markers linked with, the new sources of resistance. Marker-assisted selection for newly discovered resistance genes will facilitate development of cultivars with broader and more durable resistance to problematic pathogens limiting bean production in Eastern and Southern Africa and the U.S.

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

- Initiate crosses for marker-aided selection of CBB, BCMNV, rust and anthracnose into elite African materials.
- Cross lines with HB resistance to develop Recombinant Inbred (RI) populations for marker identification.
- Screen existing RI populations for root rot resistance.

Research Approach, Results and Outputs

Marker-Assisted Selection: Tanzanian cultivars, representative of the major market classes were chosen as recurrent parents: Kablanketi, Njano, Bwana Shamba, Rojo, Selian 97, and LY 90. These parents were assayed for presence/absence of resistance linked markers to determine their potential for marker-assisted selection (MAS) of particular resistance genes.

Results indicate that MAS for the bc 12 and Ur 4 genes cannot be applied to these recurrent parents because they possess the resistance linked markers. MAS for the I and other rust resistance genes will be applicable for at least five of the recurrent parents. The C11 marker for bc 3 is in trans linkage, thus will have limited utilization for MAS in a backcross program.

Looking toward future marker-assisted backcross breeding for ALS resistance, MAS for the Phg 2 gene for resistance to ALS will be restricted to Rojo and Selian 97. Conversely, the SAP6 marker for the CBB QTL on linkage group B10 will not be useful in Rojo or Selian 97. Marker data for the Phg 1 gene still needs to be generated, and the marker(s) linked with the QTL from MAR 1 have yet to be obtained from CIAT. A SCAR linked with ALS resistance from G10474 was obtained from CIAT, but seeds of G10474 has not been obtained yet.

An initial 45 F_1 crosses between the recurrent African parents and donor parents of BCMNV, rust, CBB, and ANT were harvested in Prosser, WA, February 2003.

The F_1 plants, backcrossed to the recurrent parents, generated 87 BC1 F_1 crosses. The BC1F_1 seeds will be planted and assayed for the respective resistance linked markers. Those possessing the appropriate markers will be backcrossed to the recurrent parents with BC2 F_1 seed harvested in February 2004.

Develop Recombinant Inbred Populations for Marker Identification: Resistant and susceptible parents were screened. Host differentials and select lines mostly representing parents of existing mapping populations were screened in South Africa against the differential set of nine Psp races. All lines were susceptible to Race 6, except for the known quantitative resistance sources PI 150414 and CAL143. Race 6 is prevalent in Africa and the predominant race found in North Dakota and Minnesota (Lamppa et al., 2002). HB-infected bean leaves collected in Vancouver, WA, (in summer 2003) by Carol Miles were determined by D. Fourie (ARC) to contain the two most pathogenic races, 6 and 8. This suggests that the WSU Vancouver field station should be considered as a future site for HB field screening of the RIL population Canadian Wonder/PI 150414.

Canadian Wonder crosses were made and F_1 and F_2 populations were grown. Halo Blight resistance sources (host differentials and quantitative resistance sources) were crossed with a universal susceptible cultivar Canadian Wonder (Bwana Shamba) to initiate development of RIL populations for the tagging and mapping of major resistance genes and QTL. Thirty one F_1 crosses were harvested and selfed to the F_2 generation.

In Prosser, WA (ARS), two populations--CWPI-20, CWTG-12, CWA43-21, and A52CW-10, were increased thus far to the F_3 and F_4 generations by the single seed descent (SSD) method to produce F_3:4 lines that trace back to an individual F_1 seed from each cross. Separately, ARC has similarly advanced CWRM- 2 and A53CW-1 populations.

Belneb RR 1/A55 was screened for HB. The parents of existing mapping population BelNeb RR 1/A55, had differential reactions to Races 1, 3, 4, 5, 7 and 9. Resistance to Races 3 and 4 derived from A55, and Races 1, 5, 7, and 9 from BelNeb RR 1. Three genes controlling resistance to HB were placed on the core map. Pse 3 gene conditions resistance to Races 3 and 4, and is located on B2 linkage group near the I gene. The Pse 4 gene conditions resistance to Race 5 and is tentatively located on B4 linkage group 14.7 cM from Pse 1 gene, which was observed to consist of a block of genes conditioning separate resistance to Races 1, 7, and 9. This is the first report of a gene cluster for halo blight resistance, and the first report for the map location of Pse 1 and Pse 4 genes.

Screening for Root Rot Resistance: Because the VAX population was still under development at North Dakota State University, it was not possible to obtain seeds in time for greenhouse increase and field evaluation in 2003. Three populations developed using the root rot resistant parent FR266 (large red kidney type) crossed to three bush blue lake bean varieties and breeding lines were evaluated. These were recombinant inbred populations developed through single seed descent for six generations. Populations consisted of 78,127, and 96 individuals, respectively from the 91G, 5402 and 5613 crosses. Lines were grown in the field at the Oregon State University (OSU) Vegetable Farm with one replication, but with repeated susceptible and resistant checks in each tier. Based on the checks, disease reaction was very uniform. Two samples per plot were evaluated and rated on a 1-5 scale (1=healthy roots, 5=dead roots). Each population showed essentially normal distributions for mean root rot score. The 5402 population showed little skewness, but the 91G population a long tail towards resistance. Transgressive variation was observed. The distribution suggests that many genes each with small effect control root rot resistance. Plans are underway to develop a molecular map for the 5402 population.

Literature Cited

Busogoro, J. P., M. H. Jijakli and P. Lepoivre. 1999. Identification of a Novel Source of Resistance to Angular Leaf Spot Disease of Common Bean within the Secondary Gene Pool. Plant Breeding 8: 417-423.

Lamppa, R. S., P. L. Gross and L. E. Del Rio. 2002. Races of Pseudomonas *syringae pv. phaseolicola* in North Dakota. Annual Report of the Bean Improvement Cooperative 45: 104-105.

Miklas, P. 2002. DNA Markers (SCARs) for Resistance Traits. http//www.usda.prosser.wsu.edu/ Scartable3.htm.

Building on Latin America and Caribbean Project's Accomplishments

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

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
Escuela Agricola Panamericana (EAP), Honduras
Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador
Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico
Instituto Nicaraguense de Tecnologia Agropecuaria (INTA), Nicaragua
Universidad de Costa Rica (UnCR)
University of West Indies (UWI), Jamaica

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 03 are summarized and highlighted in this Section.

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

Assessment of Constraints to Expanding Bean Supply in Central America

Principal Investigators and Institutions

Richard Bernsten, Michigan State University; Abelardo Viana Ruano, Guatemala

Collaborators and Institutions

Carlos Perez, CENTA, El Salvador; Juan Carlos Rosas, Raul Espinal and Louis Caballero, EAP (Zamorano), Honduras; Jim Beaver, University of Puerto Rico; Steve Beebe, CIAT, Colombia

Justification and Objectives:

Bean scientists require continued feedback on the characteristics of the bean sub-sector to establish research priorities. The LAC economics and marketing team of the Bean/Cowpea CRSP conducts research to generate data, information and knowledge regarding the on-farm performance of newly-released varieties, constraints to increasing productivity of the bean farming systems, and facts and trends in bean market opportunities and regional trade.

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

- Strengthening bean seed supply and distribution in Honduras.
- Assessing the constraints to higher bean yields in Honduras.
- Assessment of the impact of bean research in México.

Research Approach, Results and Outputs

Strengthening Bean Seed Supply and Distribution in Honduras: Data were collected in 2002 to document the bean seed system in Honduras, assess farmer demand for seed of improved varieties (IV), evaluate options for using small-scale farmers to grow improved variety seed (under EAP's supervision) and marketing the seed via an established input dealer.

Currently, EAP (the country's only certified bean seed producer) sells seed to commercial farmers at its campus and to NGOs for distribution to their project participants. Hondugenet (a private seed company) produces commercial seed, multiplied from certified seed, which it sells to commercial farmers via its agents in a few Department capitals. Based on the data collected, these two sources annually produce only enough seed to plant 4,503 ha 4.9% of Honduras's bean area (total bean area=91,600 ha, 1990-2000).

Conventional wisdom argues that the demand for certified improved variety seed is very limited since it's expensive compared to recycled seed--and the market is very thin (farmers will only buy an improved variety once and then plant saved seed). This study hypothesized that small-scale farmers are willing to buy improved seed, if it's sold at a lower price, marketed in smaller bags and sold at a nearby location. To assess small-scale farmers' demand for improved seed, a survey was conducted in two major bean producing Departments--El Paraiso (N=36) and Orlancho (N=36) with good/poor market access. The surveyed farmers planted a relatively small area of beans in postrera 2001 and primera 2002. About 68% planted saved seed, vs. seed obtained from other farmers (23%), NGOs (6%) and certified seed from a dealer (1.3%). About 72% had never bought certified seed because it was"too expensive" (62%), "produced own seed" (17%), "not available" (10%) and "bag is too large" (3%). Most farmers planted both improved varieties and traditional varieties (TVs) (58%), but 31% planted only TVs and 12% only planted improved varieties. TVs accounted for 60% of the bean area. Farmers said that if they bought seed from another farmer, they paid more for TVs (Lp 9/lb) than for IVs (Lp 8/lb). Most farmers stored saved seed separately from grain (76%), typically in a bag.

To assess farmer preferences for various varieties, farmers were shown numbered seed samples of Catrachita (preferred TV), Dorado (a widely grown IV, discounted in market for dark red color), Tio Canela 75 (a widely grown IV, lighter than Dorado), plus Carrizalito, Milenio and Amadeus 77 (three new IVs, lighter than Tio Canela). Farmers ranked (1st to 6th) each variety, according to their assessment of its characteristics (color; seed size, shape and weight). Farmers ranked Amadeus-77 highest and 72% ranked it as their first or second choice. Clearly, farmers assessed Amadeus 77 as

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

superior to Catrachita and while they ranked the other two new IVs lower than Catrachita, they ranked both higher than Tio Canela and Dorado.

Farmers may prefer a variety, but whether or not they will purchase seed depends on its price. To assess willingness to pay (WTP, effective demand), farmers were told to assume each variety yielded 1.3 mt/ha. Then, farmers were shown a seed sample and asked if they are WTP Lp 17/lb for the variety's seed. If no, they were asked if they were WTP Lp 15, Lp 13, Lp 11, Lp 9, or Lp 7 until a price was reached that they were WTP. This analysis showed that farmers' preference for Amadeus-77 translated into their WTP a price premium for seed of this improved variety. For other varieties, farmers' WTP more than Lp 8-9/lb was relatively low. Farmers preferred a 50 lb (57%) or a 20 lb bag (26%). These results show that while 72% of the farmers had never bought seed from a commercial source, many (depending on the price) were willing to pay more than Lp 8-9/kg (seed price, if bought from a neighbor) for Amadeus-77.

In 2002, Zamorano sold certified seed (Lp 14/lb) and Hondugenet sold commercial seed (Lp 14 /lb) at a price that few of the farmers were WTP. An alternative would be to contract small- scale farmers to produce commercial seed (under EAP's supervision to assure quality) and market it as "Zamorano Approved" seed. To assess the feasibility of this option, two possible seed production sites were visited. Data collected from these visits indicate that farmers are willing to multiply seed, if paid Lp 8-10/lb. A paper bag (20 lbs bag) costs about Lp 3, which would add Lp 0.15/lb to the packaged cost of the seed.

Seed demand will be limited, unless the seed is available where farmers purchase other inputs--typically the Department capital. To assess marketing options, the manager of three input suppliers--DuWest (Dupont), Hondugenet, CADELGA and Fertica--were contacted to assess interest in selling branded seed ("Zamorano Approved") via their agents. Only DuWest (DW) was interested. In addition, DuWest agreed to supply inputs (on credit) to the seed growers, who would repay their loan when DuWest bought the seed. Regarding selling price, DW's central office would add a 20-25% markup to the purchase price (delivered in Tegucigalpa) and their agents would add an additional 10-15% markup. If seed growers were paid Lp180/20 lb bag (Lp 9/lb), DW's agents would sell the seed to farmers for Lp 259/20 lb bag. At this price, about 40% of the survey farmers would be WTP for commercial seed. DW agreed to buy 22.7 mt of seed in Year one and increase their order in the following years, if it sold. Assuming a seed yield of 909 kg/ha, 25 ha would be required to supply DW's requirements in Year one.

Assessing the Constraints to Higher Bean Yields in Honduras: Guided by the Constraints to Higher Rice Yields methodology (used at IRRI), one zone (hilly area, Morocelí, 30 km from EAP) was identified as representative of a hillside bean growing environment with high potential for agronomic improvement. A rapid appraisal (RA) was carried out to identify farmers' typical bean production practices with respect to variety, fertilizer and weed management--three practices believed to most constrain higher productivity. Factorial trials (four replicates/farm) were established on the field of four typical farmer collaborators. Each factor was set (based on data collected during the RA) to represent recommended vs. typical farmer practices. The selected treatments are 1) variety (Amadeus-77 vs. farmers' variety, Seda), 2) fertilizer (200 lbs/mz of 18-40-0 + 50 kg/mz of urea vs. 100 kg/mz of 18-46-0), and 3) weed management (one application of Gramoxone + one weeding vs. one weeding). Four additional treatments were included on these farms (application of foliar fertilizer, Rhizobium innoculant, two applications of Karate insecticide at flowering + one week later, and two applications of fungicide). Also, supplemental trials were established on six other farmers' fields. Treatments in the supplemental trials (one replication) consisted of the package of recommended practices. In both types of trials, the collaborating farmers will manage the plots like their adjacent production field, applying their own preferred cropping practices except for the experimental factors. The trial data will be analyzed to assess the impact of each treatment/combination of treatments on yield and the profitability of the recommended practices vs. farmers' traditional practices.

Assessment of the Impact of Bean Research in Mexico: The study areas included Chihuahua, Durango and Zacatecas, which account for 62% (1.15 million ha) of Mexico's rainfed bean production area.

Adoption of improved varieties: In 2001, 455 semi arid bean farmers were surveyed to assess farmer adoption of IVs, yields of IVs vs. TVs and farmers' reasons for adoption/not adopting IVs. While the area planted to IVs varied by state (Chihuahua = 71%, Durango = 42%, Zacatecas = 8%), Pinto Villa and Pinto Mestizo accounted for 38% of the planted area in Chihuahua and Durango and their yields were 20.6% higher than traditional pintos (primarily Pinto National). However, yields of IVs of other market classes were not significantly higher than TVs. Econometric analysis indicated that the characteristics of adopters/non adopters were very similar--except almost all adopters participated in the Kilo per Kilo program.

Economic analysis: Economic analysis indicates that if a closed economy model is assumed, the financial/economic NPVs are positive and the internal rates of return (IRR) to research and extension are 17.5% and 21.4%, respectively. If an open economy model is assumed, the financial/ economic NPVs are positive and the IRRs are 21.3% and 20.7%, respectively. Results from both models suggest that public investment in bean research and extension has been highly profitable.

Policy implications: To promote agricultural development and improve the welfare of rainfed bean farmers and low income consumers, the Government of Mexico (GOM) should continue to invest in bean research and support/strengthen the Kilo per Kilo program by making certified seed more available (it accounted for only 25% of seed distributed), providing greater incentives to seed growers, reducing year to year variability in program funding and training farmers how to store saved seed. Finally, bean scientists should continue to collaborate with the Bean/Cowpea CRSP, continue to solicit feedback from consumers/processors regarding preferred varietal characteristics to insure that future varieties meet market requirements, give high priority to developing varieties in the deficit market classes (black, pinto) and continue to support collaboration between agronomists and social scientists to periodically assess on-farm performance of new releases. Regarding lessons for the CRSP, the significant impact of Mexico's bean research program is due to both the strength of the bean breeding program and GOM's Kilo per Kilo program. Scientists in other countries should press their Ministries of Agriculture to initiate similar programs to insure that farmes have access to recently released bean varieties.

Literature Cited

Mather, D., R. H. Bernsten, J. C. Rosas, A. Viana Ruano, D. Escoto and J. Martinez. 2003.The Impact of Bean Research in Honduras. Agricultural Economics 29(4).

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

Enhancement of Demand and Market Opportunities for Beans and Value-Added Products from Central America and the U.S.

Principal Investigators and Institutions
Richard Bernsten, Michigan State University

Collaborators and Institutions
David Schweikhardt and Judy Whipple, Michigan State University

Justification and Objectives:

Data are not available to adequately document: a) the structure of the bean sub-sector in Central America, b) the potential to expand domestic utilization of value-added products and c) opportunities to expand exports of beans and bean-based processed products within Central America and to the U.S. The goal of this research activity is to assess the status of the bean sub-sector as it affects the bean industry in the U.S. and Central America.

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

- Understand the structure of the bean sub-sector in Central America and opportunities to increase demand for value-added products.
- Assess the demand for value-added dry bean products from Central America in U.S. ethnic markets.
- Understand trends in U.S. dry bean imports and exports.

Research Approach, Results and Outputs

Structure of Bean Sub-sector in Central America: Beans account for 12% of Central America's (CA) crop area. Consumption is highest in Nicaragua (24.7 kg/person). During 1990-2001, Central America's bean area averaged 501,360 ha (Nicaragua=32%, Guatemala=26%, Honduras=18%). Over the decade, area declined in Costa Rica (-56%), Honduras and Guatemala, but increased in Nicaragua (111%) and El Salvador; production declined in Costa Rica (-52%), Guatamala (-18%) and Honduras (-21%), but increased in Nicaragua (171%) and El Salvador; average regional yield increased by 0.5%/year (from 694 kg/ha to 727 kg/ha).

Activities that add value to beans include cleaning/packaging beans in plastic bags and transforming beans into canned, powdered, or frozen products. The packaging industry is most developed in Costa Rica. Guatemala's processing industry is well developed, while its packaging industry is dominated by small firms. In El Salvador, Nicaragua and Honduras, the packaging industry is growing rapidly, driven by the incentive to sell to local supermarkets and export to regional markets. While 10 large canning firms operate in Central America (seven in Guatemala, three in Costa Rica, one in Honduras which markets a flexible pack), Guatemala's brands are most widely sold. Most bean processing firms have their own brand, but some recently began canning for other companies. Data collected from major supermarket chains in CA capitals indicated that they sell 67 different brands of value-added products (bagged, processed beans). In each country, supermarkets sold 6-15 different brands in plastic bags and 4-12 canned brands. Consumer demand for processed products is limited-primarily due to high cost; canned beans averaged US$2.49/kg vs. US$1.25/kg for bagged beans. While low income consumers give high priority to price, high/medium level income consumers are increasingly willing to pay a premium for quality characteristics. Also, demographic changes are influencing the demand for ready-to-use products.

Producers typically sell their surplus to traditional intermediary/traders, who transport them to urban markets for sale through the food retailing system (small full service stores, traditional central markets, self service stores, supermarkets). Intermediaries and wholesalers are major players in bean marketing and most consumers purchase beans at central markets/small stores, but concentration in CA's retail system is influencing how beans are sold and where consumers buy them. Regarding marketing margins, with the exception of Nicaragua, the greatest price difference (%) was observed between the wholesale and retail price (value-added price). Nicaragua presents an exceptional case with a small but rapidly growing retail sector. The difference between the wholesale and central market price was 23.3%, and 46% between the central market and the retail price. In El Salvador, where the food retail system is more developed, the difference between the central market and the wholesale price was 17% and 66% between the wholesale and retail price.

Central America is increasingly dependent on imports (up 18%/yr), but also exports beans to regional and niche markets in developed countries. The region's main exporters (1999-2001) were Nicaragua (42%) and Honduras (35%). The competitiveness of Central American beans varies by market class, country and year. Tariffs make Central America regionally competitive, but increase consumer prices.

To remain competitive in an increasingly globalized market, farmers will require higher yielding varieties-suggesting the need for breeding varieties with higher yields and traits that reduce risk (resistance to biotic and abiotic stresses). During the 1990s, the bean market experienced several structural changes including consolidation in the wholesale and retail market, expanding the export market, increasing demand for value-added products and growing consumer preferences for beans of superior quality. To insure that future varieties meet the quality preference of consumers, mechanisms should be established to involve market participants (wholesalers, processors, retailers, exporters) in establishing quality characteristics and evaluating lines before release. Given the limited adoption of certified/ commercial seed, there is a need to rigorously assess the strengths/weaknesses of existing seed schemes and identify lessons for strengthening these schemes. Despite efforts in all CA countries to increase farmers access to markets, farmers continue to face many obstacles that limit their access to market information (prices, market opportunities), including the high cost of obtaining this information. Furthermore, growing consolidation of the food retail system/packaging industry has created new challenges for bean farmers hoping to access urban markets. Most retailers/packaging firms have their own private standards, which farmers are either unaware of or fail to comply with. To meet this challenge, farmers need to establish strategic alliances with retailers and intermediaries-the main suppliers to packers, processors and retailers. While bean exports to countries outside of the region are currently limited by supply and market access constraints, niche markets have a potential to grow in the future, especially in developed countries where the demand for ethnic food is expanding rapidly. For example, Salvadorians have developed the U.S. market for Rojo de Seda (red silk) by targeting the Salvadorian community. Drawing on this example, a potentially promising export strategy is to establish farmer owned brands, targeting sales towards high income consumers in developed countries.

Demand for Value-Added Dry Bean Products from Central America in U.S. Ethnic Markets: During the decade, the U.S.'s Hispanic population increased by 57.9%-from 22.5 (1990) to 35.5 (2000) million. Today, Hispanics (13.2% of the population) are the largest group after whites. The 1.7 million ethnic Central Americans (ECAs) come from El Salvador (38.8%), Guatemala (22.1%), Honduras (12.9%), Nicaragua (10.5%), Panama (5.5%), Costa Rica (4.1%) and other not defined sources (6.1%). The ethnic CA population is highly concentrated in six states-CA (19%), FL (16%), NJ (16%), NY (11%), TX (4%) and NC (4%).

To document bean availability at Hispanic grocery stores, four cities with large ethnic Central American populations were selected for case studies--Chicago, Los Angeles, Washington, D.C. and Miami. In each city, a sample of Hispanic groceries (total of 23 small groceries) were visited. All of the groceries stocked both beans of Central American and non-Central American origin. Beans of non regional or U.S. origin were often displayed in a separate section of the store and labeled in both Spanish and English. Across these cities, 39 different brands (products sold by different distributors) were sold. Most brands of Central American origin were small red silks (N=13), followed by small reds (N=8) and blacks (N=3). Of the 13 non-Central American/ U.S. brands, 9 were blacks and 4 were small reds. Typically, beans are sold in one pound bags, with a few exceptions. Prices varied by origin/market class. Beans of Central American origin were significantly more expensive (mean black=$1.30/lb, small red=$1.26/lb, silk=$1.58/lb) than non CA/U.S. origin brands (mean black=$0.75/lb, small red=$1.00/lb).

To assess consumer demand for beans of Central American origin, a sample of the ethnic populations (70% female) were interviewed in the four cities (total N=98; El Salvador=32, Nicaragua=31, Guatemala=22, Honduras=10). About 87% reported buying beans--an average of 1.94 lbs/household/ week--but this varied by country of origin. Guatemalans reported consuming 2.13 lbs/wk, followed by Salvadorians (2.09 lb/wk), Nicaraguans (2.02 lb/wk) and Hondurans (1.06 lb/wk). Red bean consumers mainly bought beans from their country of origin or another CA country, but black bean consumers mainly bought non-regional beans, most likely because black beans from CA are not typically sold in Hispanic groceries and U.S. blacks are close substitutes. Of those surveyed, 50% only buy beans at a Hispanic shop, 38% also buy at a supermarket (mainly Guatemala, black beans) and 12% purchase at both types of stores. Red bean consumers reported that the most important attribute they sought was country of origin (58%) and color (28%). About 53% of the surveyed consumers also purchased canned beans--especially Guatemalans and Salvadorians (70%). Respondents who consumed canned beans reported that they buy more canned beans than when they lived in Central America--due to the convenience.

Insights regarding bean importation/distribution were obtained from key informants (importers/distributors). Central American beans are procured by small-, medium- and large-scale importers. Small firms purchase their supplies from wholesalers in Central America, import them in bulk, either contract bagging to a local firm or self bag and distribute to local Hispanic grocers. Medium firms typically buy beans from Central American wholesalers, although some firms contract farmers to grow a specific variety. These firms either have their own packing facilities or contract out packaging, and distribute to Hispanic grocers located in cities surrounding their base of operations. Most firms that sell beans from El Salvador fall into the medium firm category. Only one large importer was identified, Goya Foods, which contracts with growers in Central America, packs beans at their facilities and distributes them throughout the U.S. Key informants reported that Goya Foods has the largest market share of beans of Central American origin. Potential CA exporters (CA firms contacted) reported several constraints, including a lack of knowledge of a reliable importer/distributor in the U.S. interested in establishing a durable/continuous relationship, problems meeting importers' requirements (volume, quality standards, delivery schedule) and difficulties in obtaining payment from the importer. Thus, many Central American shippers sell FOB (require payment prior to shipment). Potential U.S. importers reported several constraints, including variable product quality, difficulties entering the market (gaining shelf space for a new product at Hispanic groceries; noted by small importers/distributors), limited knowledge of potential/new markets for beans of Central American origin and tax related and other regulations that they must meet to import from the region (especially Honduras).

Preliminary Policy Implications: Clearly, the Central American bean trade is dominated by Salvadorians. Interviews with U.S.-based Central American consulate staff indicated that only the El Salvador government actively promotes bean exports (provides U.S. importers/grocery stores with contact information regarding exporters/distributors of El Salvador products, maintains a website that promotes exports and has sponsored export promotions via the El Salvador press). Given that ethnic consumers express strong interest in purchasing beans from their country of origin, there appears to be an unmet demand for beans from countries other than El Salvador--especially Nicaragua and Honduras. Due to the similarity between Central American and U.S. black beans mainly consumed by Guatemalans, the potential to target beans imported from Guatemala to this community is limited. However, potential Central American exporters will require market information (market classes demanded, reliable importers who provide timely payment) in order to target these niche markets. Also, Central American exporters must be willing to make the investments required to insure that their products meet the quality, volume and continued supply requirements of the U.S. ethnic market.

Trends in U.S. Dry Bean Imports and Exports: USDA/Department of Commerce dry bean statistics define "dry beans" to include all Phaseolus species (*P. Vulgaris,* common bean; *P. lunatus* L, lima beans; *P. acutifolius* A. Gray, tepary beans; *P. mungo L*., mung beans/green gram *P. coccineus*, scarlet runner bean), *Vigna (V. unguiculata* L; cowpea), *Cicer arietinum* (chickpea/garbanzo) and *Cyamosis tetragonolobus* (gaur, uses as a thickening agent is reported in U.S. dry bean import statistics). Thus, dry bean data are misleading, if one is primarily interested in the trends related to common beans. For example, in a typical year, mung beans account for a significant share of U.S. dry bean imports. To redress this reporting bias, data for common beans were extracted from disaggregated USDA dry bean statistics. Thus, the analysis presented refers to trends with respect to only *P. Vulgaris* (beans refer to only common beans). However, in some instances, rather than identifying a specific market class, import statistics refer to Beans Nesoi (no specific market class categories reported)--which may include/refer to imports of species other than *ww*. Aside from the caveat noted above, these data are not directly comparable to USDA dry bean data. Initial research focused on generating a database of common bean statistics and identifying recent trends in bean production, exports and imports.

During 1992-2002, U.S. common bean (CB) production averaged 1,102,312 mt/year, ranging from 731,394 mt (2001) to 1,307,157 mt (1999)--mainly pinto (46% of production), navy (22%), kidney (9%), great northern (8%) and black (8%) beans. Over the period, there was no well defined increasing/decreasing trend.

During 1992-2002, CB exports averaged 311,546 mt/year, ranging from 228,085 (1992) to 448,060 mt (1998)--mainly navy (29%), pinto (27%), kidney (20%), great northern (11%) and black (7%) beans. In general, common bean exports trended upward from 1992-1998, but have shown a decreasing trend for 1998-2002--largely due to decreased exports to Mexico (e.g., pinto, kidney, black beans) and the United Kingdom (navy).

During the 1992-2002 period, U.S. common bean imports averaged 57,319 mt/year, ranging from a minimum of 24,435 mt (1992) to a maximum of 160,583 mt (2002). Over the 10 year period, there was a clear increasing trend in U.S. common bean imports. Regarding market class, "Beans Nesoi" (i.e, no market class specified) is the more important market class imported, which averaged 47% of total imports, followed by kidney (16%), pinto (13%), navy (10%) and black (6%) beans. Because such a large share of imports are "Beans Nesoi," the above described trends are difficult to interpret, since "Beans Nesoi" may include beans other than common beans. However, since 86% of these beans are imported from Canada (the rest are imported from Mexico and China), the implication is that most of the beans in this category are common beans. The increasing import trend observed for the 10 year period is related to increased imports of the Nesoi (Canada), black (China, Canada, Argentina), navy (Canada), pinto (Canada) and kidney (Canada, Mexico) beans.

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

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

Principal Investigators and Institutions:
Suzanne Nielsen, Purdue University; Ana Ruth Bonilla, Universidad de Costa Rica, Costa Rica

Collaborators and Institutions:
Richard Bernsten, Michigan State University; G. Flores, Escuela Agricultura de Panamericana, Honduras

Justification and Objectives

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 America and Caribbean (LAC) region. Inexpensive bean-based, value-added products with a long shelf life have excellent potential in the LAC region. Research to develop such products should include consideration of market potential, nutritional value, and consumer acceptance.

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

- Conduct appropriate research using various processing techniques to facilitate new product development.
- Assess consumer acceptance, nutritional value, physical properties and economic potential of bean ingredients and products.
- Conduct studies to investigate the "hard-to-cook" defect in beans.

Research Approach, Results and Outputs

The New Bean-Based Product Development: The concept of processing a savory bean paste/filling was investigated. The bean filling must satisfy certain specifications to be incorporated into a shelf-stable pastry, including a water activity of less than 0.7 and pH below 4.6. Traditional options to control water activity in existing sweet fillings include high fructose corn syrup and sugar. However, these ingredients are not suitable for a savory product.

Beans are prepared for incorporation into a filling matrix by soaking overnight, cooking, mashing the softened beans, and drying in a hot air oven. The dried beans then are ground into a fine flour, and account for approximately 25% of the filling formula. Other ingredients included in the formula as bulking agents and to control water activity are: corn syrup (26 DE), corn syrup solids, partially hydrogenated soybean oil, and glycerin. A limited amount of water is added to reduce viscosity. Minor ingredients present include lecithin to facilitate mixing of the lipid component and salt to enhance the savory flavor. The addition of starch also has been investigated, but it increases viscosity beyond processing limits without any benefit in controlling water activity. Wet ingredients are blended together and heated, then the dry ingredients are blended separately and added to the heated mixture. The paste is allowed to cool before further processing.

The current formula yields a thick bean paste with little flavor and a color dependent upon the seed coat of the beans being used. Any savory flavor can easily be added to the filling, thus giving it a great deal of versatility in flavor applications.

Assessment of Consumer Acceptance: At Purdue, sensory evaluation tests are being conducted on the bean-filled cereal bars to determine consumer acceptance of such a product. A survey is being conducted among Latin American students at Zamorano University to determine the most popular savory Latin American flavors. The top two choices will each be added to bean filling using control beans and bean filling using hard-to-cook beans (see below description of hard-to-cook beans under Additional Work in section below). The bean filling will be incorporated into corn dough, baked, and packaged for sensory testing or nutritional testing. Tests will be conducted to determine moisture, fat, protein, ash, and fiber contents. Cost information related to ingredients also will be calculated.

Two types of sensory tests were conducted in Honduras. Two population groups were tested -- Zamorano students, and residents of a village near Zamorano. The first test was for acceptance, utilizing a hedonic scale to rate key attributes and overall acceptability of the four fillings. The second test was a triangle test to determine if there is a significant difference between the filling made of control beans and the filling made of hard-to-cook beans. The triangle test was conducted for both flavors.

In Costa Rica, the previously formulated bean cookies were done with cooked beans and rice. At the present time, use of rice flour and different ways to prepare the beans are being evaluated. The beans are being treated as follows: 1) soaked and cooked, 2) raw bean flour, 3) soaked raw bean flour, and 4) ground soaked bean. Sensory evaluation has been started on the new cookie formulations. The process of judge selection and training is in process, but results are not yet available. Reagents have been ordered to start the physical-chemical analysis of the cookies. The methodology is being validated for determination of folic acid, fiber, trypsin inhibitors, and amylase inhibitors. Note, that since the new cookie formulations use raw beans the effect of baking on trypsin and amylase inhibitor activities are being tested.

Overcoming Hard-to-Cook Trait: A year-long storage study to research the hard-to-cook defect in beans is currently in progress. Red, black, and navy beans (*Phaseolus vulgaris*) are utilized in this study. Control beans are stored at refrigerated conditions while the hard-to-cook beans are stored in a chamber set at 30°C and 65% relative humidity. Once a month, beans are pulled for cook time tests, methanol extraction of phenolic compounds from seed coats and cotyledons, and FTIR (Fourier-transform infrared) analysis of soaking and cooking waters of the beans. At the end of six months, the hard-to-cook beans were placed in refrigerated conditions to examine the reversal of the hard-to-cook defect and the same set of tests will be conducted each month. At the beginning and end of the six months for the three variables (control, hard-to-cook, and hard-to-cook refrigerated), an extraction was performed to examine the soluble pectin fraction and water-insoluble residue of the cell wall by FTIR analysis.

Preliminary findings indicate that all three varieties of common beans stored in conditions described before to induce the hard-to-cook defect have significantly longer (50%) cooking times from the controls ($p < 0.05$). The 50% cooking times for the hard-to-cook variables for the red, black, and navy beans are 1.6, 1.6, and 1.7 times greater than the 50% cooking times for the controls, respectively. All spectra from FTIR analysis of the soaking and cooking waters are being collected and will be analyzed for statistical differences at the conclusion of the first six months of the storage study. Methanol extracts are being stored at -80°C until the concentration of phenolic compounds can be analyzed via HPLC. We expect to see differences in the concentration of such compounds as the hard-to-cook defect progresses.

Bean/Cowpea Collaborative Research Support Program
Latin America and Caribbean 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; Helen Jacobs, University of West Indies, Jamaica

Collaborators and Institutions

Sharon Hooper and Audrey Morris, Graduate students, and Maria Jackson, University of West Indies, Jamaica; Elizabeth Rondini, Ph.D. student and Rick Bernsten, Michigan State University; Lidia Rodriquez, University of Costa Rica, Costa Rica

Justification and Objectives:

Extensive research (WCRF 1997, Armstrong and Doll 1975, Doll and Peto 1981, NAS 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. Also, during the past two decades, several consensus reports by large groups of experts in the area of diet and cancer have been published (WCRF 2001, NAS 1982, 1989, WHO 1990). 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% (WCRF 2001, Doll and Peto 1981, Willet 1995).

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 (2001), funded by 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 to achieve the following objectives:

- Determine if bean and cowpea crude extracts contain phytonutrients that contribute to the inhibition of colon cancer.
- Determine if feeding beans will inhibit chemically-induced mammary cancer.

Research Approach, Results and Outputs

Study on Phytonutrients that Contribute to the Inhibition of Colon Cancer: Navy, black, small red beans and blackeye cowpeas were extracted with 60% ethanol/40% water, 70% ethanol/30% water, or 80% ethanol/20% water. The extracting solvents were brought to pH 2 by addition of 1 N HCl. An estimate of all phenolic compounds extracted by the aqueous ethanol solutions was made with the Folin Ciocalteau reagent. Gallic acid served as the standard. This test estimates all flavonoids, anthocyanins and non-flavonoid phenolic compounds. Antioxidant activity in the extracts was determined by the Oxygen Radical Absorbance Capacity (ORAC) assay. The capacity of the extracts to inhibit cyclooxygenase activity was measured by an ELISA technique with a commercial kit.

Total phenolic compounds in beans and cowpeas was estimated to be (mg of gallic acid equivalent per 100 g of fresh weight) black bean = 253; small red bean = 225; navy bean = 71; and cowpea = 75. The greatest phenolic content was found in the 60% ethanol/40% water extracts. The extracts are currently being screened for oxygen radical scavenging capacity.

Effect of Beans to Inhibit Chemically-induced Mammary Cancer: A rodent model of human breast cancer compared mammary cancer development in rats fed with black beans, navy beans, and light red kidney beans. Most of the dietary protein was provided by the beans. A control diet utilized casein as the protein source. The beans were cooked until soft, dried, and ground prior to diet formulation. All diets provided similar amounts of nutrients per kilocalorie and were nutritionally adequate. The fat content of the diets provided approximately 35% of the energy (similar to humans). Mammary cancer was induced by a single injection of 3-methyl-nitroso-urea. The injection was made when the female rat was 51-53 days of age. At this age, the mammary tissue is very sensitive to mutations because of the high mitotic rates that occur in the mammary alveolar. Beginning eight weeks after the injection, the rats were palpated weekly to identify the appearance of tumors. When a tumor reached 2.5 cm in diameter, the rat was sacrificed. Tumors were weighed and processed for pathological examination. A pathologist will classify the tumors and tumor parameters will be calculated (mean tumor latency and survival rates) in FY 04.

Approximately 80% of the rats have completed the study thus far. Although a clear trend has developed, the data should be considered "preliminary data." The diet with black beans and the diet with navy beans slowed the growth of mammary gland lesions into palpable tumors. This conclusion is further confirmed by the observation that the tumors in the rats fed black beans grew substantially slower and the tumors took longer to reach 2.5 cm in diameter than rats fed the control diet. The results suggest that navy beans may not be quite as effective in slowing mammary tumor growth as black beans and that eating light red kidney beans did not provide any protection since the tumor appearance and survival rates are similar for rats fed the control diet and rats fed light red kidney beans. None of the tumors have been classified. Mean tumor latency and mean survival will be determined after all tumors are classified in FY 04.

Literature Cited

Armstrong, B. and R. Doll. 1975. Environmental Factors and Cancer Incidence in Different Countries, with Special Reference to Dietary Practices. Int. Journal of Cancer 15:617-31.

Doll, R. and R. Peto. 1981. The Causes of Cancer: Quantitative Estimates of Avoidable Risks of Cancer in the United States Today. Journal of National Cancer Institute 66:1191-1308.

Hangen, L. and M. R. Bennink. 2001. Consumption of *Phaseolus vulgaris* (Black Beans or Navy Beans) Reduces Colon Cancer in Rats. Faseb Journal 15(4):A61.

National Academy of Sciences. 1982. Diet, Nutrition and Cancer. Washington: National Academy Press.

National Academy of Sciences, National Research Council (U.S.). 1989. Committee on Diet and Health, Health Implications for Reducing Chronic Disease Risk. Washington, D.C.: National Academy Press.

Willett, W. C. 1995. Diet, Nutrition and Avoidable Cancer. Environmental Health Perspective 103 (Suppl 8):165-70.

World Cancer Research Fund/American Institute for Cancer Research. 1997. Food, Nutrition and the Prevention of Cancer: A Global Perspective, Menasha, WI: Banta Book Group.

World Health Organization. 1990. Diet, Nutrition and the Prevention of Chronic Diseases. Technical Report series no. 797, Geneva: WHO.

Bean/Cowpea Collaborative Research Support Program
Latin America and Caribbean 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; Eduardo Peralta, INIAP, Ecuador

Collaborators and Institutions

Diane Ruonavaara and Jim Kelly, Michigan State University; Nelson Mazón, Ángel Murillo and Carlos Monar, INIAP, Ecuador; José Isacaz, FAO-PESA-Ecuador

Justification and Objectives:

In Ecuador, women and the ethnic minorities have limited access to improved varieties of beans and related management technologies and inadequate knowledge of, and access to, good quality seeds. The primary challenges facing farmers in the cultivation of beans is low yield (0.5 - 0.8 t/ha) caused mainly by diseases (roya, *Uromyces appendiculatus; antracnosis, Colletotrichum lindemuthianum*), management practices, poor soils and climatic variations (drought, excess rain, etc.).

The parish of La Concepción, located in the valley of the Rio Mira, Carchi, is home to a large population of Afro-Ecuadorians. This zone has been systematically ignored by state and federal governments and receives very little assistance from non-governmental organizations. The valley of Rio Mira is primarily an agricultural zone in which beans provide the main source of family income and sustenance. According to the last farm census, Ecuadorian farmers produced approximately 19,000 ha of dry beans of which approximately 17,000 ha were produced in the valleys of the Sierra and of these, 7,000 ha were produced in the valleys of the Rio Chota and Rio Mira. In the province of Carchi, approximately 3,100 ha of bush beans were cultivated, a high percentage in the valley of the Rio Mira.

Given that the parish of La Concepción requires immediate support to improve its agriculture and due to the importance of the beans in this zone, the Bean/Cowpea CRSP initiated the process of Participatory Research (PR), focusing on the bean production through Local Committees of Agricultural Investigation (CIAL). PR provides a means for professional researchers and farmers to work together in identifying and researching problematic situations in the area of agriculture and in developing sustainable solutions. CIALs whose members are elected by the community provide the organizational framework for joint experimentation and research with direct benefits to farmers and rural communities.

The report highlights progress made in research activities 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.

Research Approach, Results and Outputs

Formation and Implementation of CIALs: Two CIAL's were formed in the township seat of La Concepción and in Santa Lucía. Given that the two CIALs are at different stages of development and that a CIAL responds to the specific interests and needs of each community, the detailed results for each CIAL are reported separately.

CIAL *"La Cuenca del Río Mira,"* in La Concepción, Carchi: The township of La Concepción is located in the Cuenca del Río Mira, Carchi. There are 19 communities in the township including the township seat. The population of this township is mainly Afro- Ecuadorian and the main agricultural base is the cultivation of the beans. Visits to the community were initiated in early 2002 by INIAP to affirm the community's interest in collaboration.

The CIAL methodology includes seven steps--Motivation, Elections of the CIAL, Rural Participatory Diagnostic (RPD), Planning of Trials, Evaluation of Trials, Analysis of the Results and Reporting to the community. Following this methodology, a community meeting was held in La Concepción on June 24, 2002, with thirty community members attending, including five women, twenty-five men and four technicians from INIAP. The INIAP representatives introduced and explained the purpose and function of the CIAL. The community members decided that they were interested in forming a CIAL; eighteen community members were identified to participate, five were elected as CIAL leaders.

A baseline study was initiated using both Rural Participatory Diagnostic (RPD) and a written questionnaire. As part of the RPD, community members identified major institutions and their relationship to the community and drew a representation of the current community, including its main features and agricultural crops. The baseline survey of 80 families provides a profile of the communities of the township of La Concepción. The survey indicated that beans are the primary crop in the township of La Concepción. Beans are the main food crop for families, a main source of family income, and one that has less cost and risk. Farmers indicated that in the past year they grew 13 varieties. Most farmers who cultivate beans save seeds from the previous harvest (80%), while only 17.5% buy seeds and 2.5% trade with other farmers, all of which tend to be of poor quality and a mix of land races. In general, the management of beans is low input, and few farmers can afford to use fertilizer and pesticides.

The planning meeting for the field trial was held August 28, 2002. Eight farmers participated along with two INIAP technicians. Through a dialogue between participants and INIAP technicians, the following objective for the trial was identified to select good performing bean varieties that are adapted to the soils and climate of La Concepción, that are disease resistant and that are good for consumption. INIAP offered 20 new lines (F7) for the trial from which farmers selected 15 lines to trial. One local land race was also evaluated as a control.

Before beginning the trials, farmers identified the following as the main problems in the cultivation of beans in the township of La Concepción: Insects and disease, low yields per hectare, market constraints, and lack of credit. Four CIAL members took part in the participatory evaluation of the trial with three technicians from INIAP. These CIAL members were trained in the definition and importance of variables or data that would be collected in the trials.

Three participatory evaluations were done at three stages of flowering stage, pod fill, and harvest. With the results of these three evaluations and yield data, the farmers selected six lines as the best including Calima Negro. Once the participatory evaluations were completed, the results were shared with the community and plans were made for the next CIAL cycle. Twenty-five farmers, including eleven women and fourteen men, and two INIAP technicians participated in this stage.

Before planting, soil samples were taken in the respective plots in order to analyze the nutrient content, organic matter and pH. The results indicate that the soils of La Concepción are low in phosphorus, sulfur, zinc, copper, iron, manganese, sodium and organic matter. Accordingly, a presentation was given to the CIAL members that covered the importance of nutrients for the yield of beans and the various mechanisms to alleviate these deficiencies. Typically, farmers apply nitrogen even though it is not needed. As a result of this presentation, farmers were concerned and wanted to compare traditional technology and the technologies recommended by INIAP through comparison trials.

The CIAL "*Nueva Esperanza," Santa Lucia, La Concepcion, Mira, Carchi:* Based on the experiences of community members from Santa Lucia in various activities they attended in the CIAL of La Concepción, the community invited INIAP to work in the community. A new CIAL was formed in Santa Lucía on July 19, 2003. Following the CIAL seven-step methodology, seventeen farmers from two communities of Santa Lucía and El Chamanal and two INIAP technicians participated in the motivational meeting. The decision was made to form a CIAL. The second stage, the Rural Participatory Diagnostic (RPD), was held on August 9, 2003 with 23 men and women farmers from the communities that make up the CIAL of Santa Lucía. As in La Concepción, the RPD focused on identifying community resources, relationships to local and regional institutions and a visioning process. Santa Lucia and El Chamanal were included in the earlier baseline survey.

A participatory cost benefit analysis was done to help farmers understand the cost and profits related to the production of beans and also to understand the value of their own labor. According to the cost/benefit analysis, in 2003 farmers lost $271.00 per hectare when family labor costs were included. From this exercise, farmers realized that increasing yields would increase the potential for higher profits.

Using RPD, the CIAL members did a gender analysis of labor. Men prepare the soil, are responsible for the sale of the crop, manage large animals and participate in communal work groups, while women are responsible for the preparation of the food and participate in meetings to assist the school. Other activities (planting, irrigation, harvesting, thrashing, cleaning house, purchases, money management, etc.) are shared among men and women.

Planning of the trials was carried out on September 6, 2003, with 11 farmers from Santa Lucía, El Chamanal and Hato El Chamanal participating. The CIAL agreed to adopt the evaluation of bean varieties in the area of Santa Lucía as the main theme for trials. CIAL members identified the following goal for their first trial: The selection of new and improved varieties that are higher yielding, more disease resistant, that are better for consumption and more marketable than existing local varieties. They arrived at this objective by reflecting upon what they hope to gain through the trials: Improved economic opportunity, better quality seeds than local seeds, develop new varieties, increase yields, increase profitability and marketability, assess disease resistance of different varieties, identify varieties that are good for consumption.

Improve the Artisan Local Seed Production and Distribution System: Three training activities were carried out based on the knowledge of INIAP technicians and the baseline survey. The excessive use of pesticides is a major problem in the production of beans in La Concepción. Therefore, INIAP technicians provided training on pesticide management focusing on the health dangers, negative environmental impacts, the classification of pesticides according to toxicity and recommendations for good management practices during transportation, applications and storage. A second training was held on the major diseases and insects related to the cultivation of beans and best management practices such as the resistant varieties, cultivation practices, and appropriate pesticide application. A third training focused on soil nutrients and management practices for improving the major soil deficiencies in the area--phosphorous, zinc, iron and organic matter.

Día de campo-- Demonstration of management techniques: Thirty-one participants, including ten female farmers, eighteen male farmers, and three technicians from INIAP attended the Día de Campo held on May 7, 2003. The Día de Campo topics included the nutritional and economic importance of beans, best management practices, and a visit to the field trials being carried out through the CIAL.

Multiplication of seed: The secretary of the CIAL planted a plot of approximately 900 m2 with the line Mil Uno which he recognized as a variety that has good characteristics. He intends to sell seeds to community members that will increase the supply of good quality seeds in the community of La Concepción. He harvested 250 k that signifies a per hectare yield of 2800 k or approximately three tons. The farmers are very enthusiastic about this line of beans. A long-term objective for the community is that the CIAL become a main source of good quality seeds for the community and a source of funds for the CIAL.

Seed fair In La Concepción: A Seed Fair was held in La Concepción with 55 competitors, including 37 men and 18 women from 9 communities in the valley of Rio Chota. In total, 183 samples were presented. Of the 183 samples presented, 166 correspond to beans (*Phaseolus vulgaris*), eight to guandul (*Cajanus cajan*), six of zarandaja (*Dolichos lablab*) and three of cowpea (*Vigna unguiculata*). Forty-two common names were identified, of which thirty-eight correspond to common beans, two of cowpeas and one of each of the other two species. Thirty-six varieties of beans and one variety of cowpeas were collected and stored in the Local Seed Bank in La Concepción. The cultivars are catalogued with an accession number and a descriptor of each cultivar.

To encourage farmers and promote the importance of a local seed bank, a certificate of recognition was given to each participant attending the Fair. Additionally, prizes were given to the 20 participants who presented the greatest seed diversity, three prizes went to the exhibitors with the best presentation and six prizes to those who presented the most special varieties.

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

Genetic Improvement of Bean Adaptation to Low Fertility Soil

Principal Investigators and Institutions
Jonathan Lynch, Pennsylvania State University; Juan Carlos Rosas, Escuela Agrícola Panamericana, Honduras; Rodolfo Araya Villalobos, Universidad de Costa Rica, Costa Rica

Collaborators and Institutions
James Beaver, University of Puerto Rico; Jorge Acosta, INIFAP, Mexico; Stephen Beebe and Matthew Blair, CIAT, Colombia; Kathleen Brown, Pennsylvania State University

Justification and Objectives:

The research activities of this component are premised on three well-established facts: a) low soil fertility, especially low P, Al toxicity, and Mn toxicity, is a principal, pervasive constraint to bean production in Latin America and Africa, b) the vast majority of bean producers cannot afford to correct soil fertility problems through intensive fertilization, amendments, or prolonged fallows, and c) bean genotypes vary substantially in their ability to grow and yield in low nutrient soils, making it feasible to increase yields in infertile soils through genetic improvement. The overall goal of this component is to develop new bean genotypes with better yield in low fertility soils.

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

- Identify bean genotypes with greater P efficiency.
- Understand physiological traits conferring P efficiency in bean.
- Evaluate Mn tolerance in bean breeding lines.

Research Approach, Results and Outputs

Identifying Bean Genotypes with Greater P Efficiency: An important objective of this first year was to identify and prepare field sites for low P screening and research. This effort began in December 2002, and now good low P research sites have been established in Costa Rica and possibly also in Honduras.

Once these sites were identified, chemical and biological assays of P availability for bean growth were undertaken. At Zamorano, the P content from 25 samples varied from 3 to 6 ppm (Mehlich 3), confirming the acceptable conditions of this plot for conducting low P studies. A baseline experiment was established at Zamorano by the end of May (first planting season). Bean plantings in this plot showed vegetative growth responses to P. This plot will be valuable because it is located on the Zamorano field station with excellent access and infrastructure. On the other hand, it is small and the heavy soil texture does not facilitate root analysis. A detailed study of bean root growth in this field is currently in progress.

Seed increase plots of 22 low P and drought tolerant bean lines from CIAT, the University of Costa Rica, MSU and Zamorano, were established under irrigation. This field increase included the following tolerant lines: BAT 881, G21212, RAB 651, RAB 655, BF 19, BF 29, BF 49, BF 54, CRF 61, VAX 1, VAX 6, SEA 5, MAR 1, MD 23-24, BAT 477, A774, UCR 55, G3513, DICTA 17, B98311, TLP 19 and TLP 35. Using good management practices, good quality seed from these lines were harvested in late April for further studies.

Two RIL populations were planted for seed increase: the DOR 364 x G19833 population from CIAT, and the B98311 x TLP 19 black bean population developed by J. Kelly at MSU. The first population presents low adaptation and the lines show large differences in growth habit, flowering, maturity and yield. The second population presents better agronomic adaptation and in general seems to be more valuable for further studies. Seed of this population was sent to Costa Rica and PSU. A selected group of lines from these RIL populations will be used in a low P and drought experiment to be conducted at Zamorano during the second planting season of 2003.

A baseline experiment was established at Zamorano in 2003. The experiment included 25 lines (the lines increased in the previous quarter plus the commercial lines Tio Canela 75, Catrachita and Milenio). These lines were planted in low and high P plots (0 and 130 kg/ha of 0 -46- 0 fertilizer) using four replicates. During the first four weeks after planting,

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

the growth differences between the low and high P were very obvious. After flowering, these differences became less obvious. Some differences in growth were observed among lines in the low P plot.

A set of low P and drought tolerant genotypes were included in crosses to develop a recurrent selection program to increase yield under the presence of these abiotic constraints in the region. The initial crosses are being made and the F_1 from single crosses were obtained by the end of May; further crossing with commercial cultivars and elite lines were performed in the Fall. Families will be advanced by single seed descent and F_4 families will be tested under replicated low P and drought trials in 2004. The most tolerant F_5 families will be used as progenitors in the second crossing cycle. Families with good commercial traits will be further evaluated and incorporated in regional trials.

Understand Physiological Traits Conferring P efficiency in Bean: Targeted selection and breeding for P efficiency would be facilitated by the identification of specific adaptive traits. In this activity, we began the process of validating the physiological utility of specific candidate traits for P efficiency in beans in field and greenhouse environments, including adventitious rooting, topsoil foraging, and root hairs. Substantial genetic variation for traits of interest were found and good progress towards validating their utility was made. Progress was also made in developing a genetic map for adventitious rooting under low P.

For adventitious rooting, RILs from G19839 x G2333 were evaluated, which previous research has shown contrast in adventitious rooting under low P conditions (Miller et al., 2003). In the greenhouse at Penn State University (PSU), the four replicates of the two parents and 10 contrasting RILs were planted in 20 l containers of solid media with either high P or stratified low P (i.e., low P in the subsoil and medium P in the topsoil). At four weeks biomass, root architecture, and root respiration was assessed. Genotypes ranged from 13 to 39 adventitious roots per plant (Genotype effect significant at $F = 3.89$, $p = 0.0006$). The study will be repeated in early 2004.

Mapping and QTL analysis for the RIL population between two contrasting genotypes for adventitious root formation, G2333 and G19839, were carried out in collaboration with Dr. M. Blair at CIAT. This included the DNA extraction and quantification for both parents and their RIL population, SSR primer evaluation in both parents for determining polymorphisms between them, then SSR primer evaluations on RIL population with all polymorphic markers, and finally a construction of a first draft map and a preliminary QTL analysis for shoot and root traits in the greenhouse (at PSU) and field (CIAT) experiments under high and low P conditions. The second visit to CIAT focused on evaluating both parents and the RIL population with the most reliable and consistent RAPD markers among several segregating populations currently mapped in CIAT's Bean Molecular Marker group in order to fill as much as possible all important gaps found with the SSR alone during the first step. Additionally, 15 SCAR markers highly linked to bean disease resistant genes, e.g., bacterial blight, anthracnose, and BCMV, which have well known locations on specific linkage groups, were evaluated.

Sixty-six out of 94 SRR markers were polymorphic between both parents, 20 were monomorphic, and only eight had no amplification. Regarding RAPD an SCAR markers, 29 out of 51 RAPD markers evaluated were polymorphic between both parents and only five SCARs were polymorphic as well. After all marker evaluation, we came up with 154 marker loci including one morphological marker, which is flower color (V gene located on b6 linkage group). Before mapping, the whole set of markers were tested for deviation from the expected Mendelian segregation (11) ratio by chi square analysis. SSR and RAPD markers had a 47.9 and 57.1% of segregation distortion respectively and the total percentage of skewness for all markers was 53.6%. After the segregation analysis two subsets of markers were defined--distorted and non-distorted markers. The total length for the draft map was 1123.8 cM with an average interval of 9.37 cM, which is a reasonable length from the estimated 1200 cM of the bean genome.

Linkage analysis was assessed using MAPMAKER/EXP 3.0b computer software and previous maps by Florida, Davis, Paris, and CIAT groups were taken into account for ordering common SSR markers. Mapmaker was independently applied to both subsets of markers using a LOD score value of 5.5 in order to obtain highly likely linkage groups and a lower LOD (3.1). Mapmaker was applied to regroup previously defined linkage groups that can be linked. With this strategy, 120 marker loci were mapped in 11 linkage groups. Another 34 remain unassigned to a linkage group but they could fit in some small gaps, which in our map never exceeded 32 cM, if more markers were included in the near future.

For QTL analysis, 16 root and shoot traits were analyzed in the RIL population in both high and low P conditions, including adventitious root number and shoot biomass in both field and greenhouse conditions, root mass for each root type, root length and specific root length for adventitious and basal roots, dry matter proportion by root type and the relative values as a percentage of control (high P) for almost all traits. All traits were normally distributed except adventitious length and adventitious dry matter ratio, which were transformed to root square and arcsine respectively before QTL analysis. Transgressive variation in all parameters was observed. The WinQTL Cartographer computer program was used to identify and locate putative QTL for all traits. Seventeen significant QTLs were found in chromosomes b2, b3, b5, b6, b8, b9, and b10. Among all linkage groups, b9 was the one with a large amount of putative QTLs, seven in total, all of them mostly related with basal root dry matter production and length in HP and adventitious number in high and low P under field conditions.

For topsoil foraging, 20 RILs (four replicates) of G19833 x DOR 364 were evaluated for root architecture in Costa Rica (Fraijanes) at low and high P. Unexpected spatial variation in field fertility obscured clear patterns in this data, but there were some interesting trends in number of adventitious roots (the most shallow root type) changing under low P for certain genotypes. Additionally, while all plants had decreased shoot dry weight under low P, certain genotypes had less proportional loss in size compared to their high P counterparts.

For root hairs, we evaluated 20 RILs (four replicates) of G19833 x DOR 364 in addition to three local genotypes (UCR 55, Bribri, Huestar) as checks, in Fraijanes at low and high P. At 2, 3, 4, and 5 weeks after planting, segments of basal and lateral roots were collected and later analyzed at PSU for root hair length and density. The microscopic analysis of over 1200 samples has just been completed, and the data analysis is ongoing. We found that hair length was substantially increased by low P (from 0.35 to 0.85 mm), was stable over time, and varied substantially among genotypes (0.30 mm to 0.62 mm). The 100% difference in root hair length among related lines is very promising, since this trait should be directly associated with P efficiency.

Several preliminary experiments were also planted in the field in Costa Rica under both phosphorus conditions. A third set of RILs was planted for evaluation and initial root architecture characterization. This third set, "L 88," is the result of a cross between P efficient (TLP-19) and drought tolerant (B98311) parents bred by J. Kelly. Fourteen genotypes from this population were planted under low and high P with two replications to obtain yield data in the field. Selected RILs segregated for low P tolerance. Overall, they seemed well adapted and vigorous, especially as compared to the G19833 x DOR 364 RILs growing beside them in the same field. Another group of seven genotypes, selected for their drought tolerance, were planted at Fraijanes to compare their performance under both low and high P. In this unreplicated trial, G19839, G21212 and SEA5 all appeared to do comparatively better under low P. Finally, two local genotypes, "Bribri" and "UCR 55," were planted at different depths to compare the effect of different seed sowing depths on the development of root systems.

Evaluating Bean Lines for Mn Tolerance: The goal in Year One was to evaluate a set of genotypes for Mn tolerance and validate a quick screening method for Mn tolerance in the field. Seventy genotypes of regional importance were successfully evaluated, finding substantial genetic variation in Mn tolerance. Although field results are still being evaluated, it appears that the rapid field screening method is capable of detecting coarse differences in Mn tolerance. These two results are important because they show that selection for Mn tolerance can substantially improve genetic adaptation to this important soil constraint, and they also provide an inexpensive means for regional bean scientists to screen germplasm in the field. This is particularly important for Mn since the severity of Mn toxicity is influenced by rainfall and light intensity and thus, is very difficult to control in field conditions.

Seventy genotypes were screened in solution culture with added 200 MμMnSO4 in the greenhouse at PSU. Genotypes evaluated consisted of advanced breeding lines from J. Rosas with the addition of several RIL parents and three check genotypes known to be either Mn tolerant or Mn susceptible. Plants were ranked for symptoms of chlorosis and necrosis. This ranking was then correlated with photosynthesis and chlorophyll a and b content. The majority of the genotypes were grouped into the "intermediate" category for Mn tolerance, a few were deemed "tolerant," and about a third were considered "susceptible." The majority of these genotypes were then planted in the field for a foliar application of MnSO4 at both Zamorano and at the Fabio Baudrit station in Costa Rica. The first trial at Zamorano was preliminary to calibrate conditions. The second trial was planted in a low fertility red soil with high Mn content. A set of 65 genotypes was planted on April 1, 2003; 26 days after planting, plants were sprayed with a 5% MnSO4 solution. Toxicity reaction was observed at 26, 28, 29, 30 and 32 DAP. Only five lines were tolerant to Mn, six lines were susceptible and the rest had an intermediate reaction. Among the susceptible lines were Porrillo Sintetico and Carioca. An analysis of foliar samples taken from various plants from this experiment gave a toxic level (1300 ppm) of Mn content. In Costa Rica, the same 65 genotypes were planted at the Fabio Baudrit station and were treated as for Zamorano. Data from both field sites and the greenhouse show some genotypes consistently performing either well or poorly under Mn stress. Specific genotypes of interest for their consistent tolerance of Mn include small blacks ICTA Ligero, BAT 450 and Negro INIFAP, small red G2333, and other Morales. Preliminary data was also collected on this group of genotypes for adventitious rooting.

Bean/Cowpea Collaborative Research Support Program
Latin America and Caribbean 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; Juan Carlos Rosas, Escuela Agrícola Panamericana, Honduras

Collaborators and Institutions

Aurelio Llano, INTA, Nicaragua; Danilo Escoto, DICTA, Honduras; Carlos Atilio Pérez, CENTA, El Salvador; Rodolfo Araya, University of Costa Rica; Emmanuel Prophete, CRDA, Haiti; Julio Cesar Nin and Graciela Godoy, CEDAF, Dominican Republic; Feiko Ferwerda, University of Puerto Rico; Jonathan Lynch, Pennsylvania State University; Rick Bernsten, Michigan State University; James Steadman, University of Nebraska; Jorge Acosta, INIFAP, Mexico

Justification and Objectives:

The development of bean cultivars with enhanced levels of disease resistance and greater abiotic stress tolerance has proven to be an effective strategy to increase bean production in both the U.S. and the Central America/Caribbean region. The bean breeding programs at Zamorano and the University of Puerto Rico (UPR), supported by the Bean Cowpea CRSP, have had significant impact throughout the Central America/Caribbean region. Collaboration with PROFRIJOL and CIAT scientists permits regional testing of promising breeding lines. Using conventional and participatory plant breeding methods and marker-assisted selection, the bean breeding programs at Zamorano and Puerto Rico have continued to develop valuable bean germplasm and cultivars for the U.S. and Central America/Caribbean.

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

- Develop and release bean cultivars with improved adaptation to the biotic and abiotic conditions of lowland agro-ecological zones in Central America, the Caribbean and the U.S.
- Increase web blight, rust, and BGMV resistance in beans using modern approaches for genetic improvement (e.g., interspecific crosses, marker-assisted selection, etc.).
- Increase genetic tolerance to terminal drought in bean lines for rainfed bean growing areas in Central America.

Research Approach, Results and Outputs

Contributions of the Bean/Cowpea CRSP to cultivar and germplasm development were documented in a paper published in Field Crops Research (82:87-102). The paper identifies 11 bean cultivars and six germplasm lines developed and released by Bean/Cowpea CRSP breeders for the lowland production regions of Central America and the Caribbean. All of the lines have enhanced levels of disease resistance and a few cultivars such as Tio Canela 75, Morales and JB-178 have had significant impact in the Central America/Caribbean region.

Several new bean varieties were released in 2003 in the region. These include:

Amadeus-77: A small red bean cultivar with early maturity, erect architecture and disease resistance, released in Honduras, El Salvador, Nicaragua, Costa Rica and Panama.

Carrizalito: A small red bean cultivar with good yield potential and resistant to Bean Golden Yellow Mosaic (BGYM) was also released in Honduras in 2003.

Bribri: A small red bean cultivar with good yield potential, adaptation to low fertility soils and moderate levels of resistance to web blight and angular leaf spot was released in Costa Rica in 2000 and registered in Crop Science in 2003.

From 2001 to 2003, five small red bean cultivars were developed for the Yorito and Yojoa Lake regions in Honduras using participatory plant breeding (PPB) techniques. The PPB developed cultivars have greater seed yield, better architecture and more disease resistance than traditional landrace cultivars. The segregating populations were managed by farmers who selected for seed yield potential, erect architecture, disease resistance, early maturity and commercial seed type.

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Due to greater seed yield and more stable performance, many of the improved bean cultivars released in Central America during the last 10 years have been adopted by farmers. This has contributed to greater food security in the region. With the exception of Amadeus-77, recently-released small red bean cultivars currently are not the most preferred seed type for Central American and U.S. ethnic markets. We expect that Amadeus-77 will be widely used by farmers to reach the premium quality markets. The selection of small red beans with excellent seed quality will remain a priority of the Bean/Cowpea CRSP bean breeding program. During 2003, small red bean populations were developed from 'elite x landrace' crosses. The inbred backcross method is being used to transfer desirable seed traits from landrace cultivars into elite small red breeding lines.

Several small red and black-seeded bean breeding lines developed by the CRSP lowland bean breeding team are being tested in on-farm trials. For example, promising lines from single plant selections of the small red line SRC1-12-1 are potential entries for on-farm validation trials in El Salvador, Nicaragua and Honduras. More than 60 Central American Bean Adaptation Nurseries (VIDAC) and Bean Yield and Adaptation Trials (ECAR), including both small red and black-seeded bean lines, were distributed to 11 countries in Central America and the Caribbean. Results from regional performance trials, which are used to justify the release of future cultivars, are valuable to maximize the impact of the lowland bean breeding team.

Since 2002, the bean breeding program at Zamorano has focused on combining improved disease resistance and adaptation of elite small red bean breeding lines with seed types of landrace bean cultivars having premium market value. The bean breeding program at the University of Puerto Rico has focused on the development of white, red mottled and light red kidney lines with enhanced levels of disease resistance and tolerance to abiotic stress such as high temperature. A light red kidney bean with BGYM resistance and heat tolerance will be released in Puerto Rico as 'Rosada Mocana.' This line has excellent seed quality and yields more than the local landrace variety 'Colorado del Pais.'

The University of Puerto Rico (UPR) and Zamorano bean research teams collaborate in the identification of new sources of disease resistance and in the development of bean germplasm with multiple disease resistance. This effort is coordinated with the plant pathologists to insure that resistance complements other disease management strategies. Dr. Graciela Godoy-Lutz has provided leadership in screening black- and white-seeded bean lines for BCMN resistance.

Bean lines from the first cycle of recurrent selection have greater web blight resistance than the check cultivar 'Talamanca.' In Haiti, two white-seeded lines with BGYM and BCNM resistance have early maturity, high yield potential and moderate levels of resistance to rust. Black-seeded lines with BGYM and BCNM resistance were well adapted to a high temperature environment in Puerto Rico. Resistance to pod deformation caused by BGYM was found to be controlled by a single dominant gene (Bgp-1). Two genes from the P. *coccineus* accession G35172 were identified that confer resistance to BGYM. A recessive gene (bgm 3) provides resistance to chlorosis whereas a dominant gene (Bgp-2) prevents pod deformation in the presence of BGYM. Marker-assisted selection was used to identify bean breeding lines with BGYM and common bacterial blight resistance. *Macroptilium lathyroides* was identified as an alternative host of bean golden yellow mosaic virus. Bean breeding lines were screened in Central America and the Caribbean for tolerance to drought, low soil fertility and high temperature.

The Zamorano and UPR bean breeding programs focus on the development of lines that combine resistance to BGYM with resistance to other important diseases such as common bacterial blight (CBB) and angular leaf spot (ALS). Several small red breeding lines derived from the cross Tio Canela/VAX6 have a high level of resistance to Xap isolates from Honduras. Marker-assisted selection was used to detect the presence of the SU 91 and SAP 6 SCAR markers for common bacterial blight resistance and the SR2 SCAR marker for the presence of the bgm 1 gene for BGYM resistance. Further field testing of these breeding lines in Comayagua is required to confirm the BGYM resistance of these lines.

Zamorano researchers are developing small red- and black-seeded bean breeding lines that combine Andean and Mesoamerican genes for resistance to ALS and resistance to BGYM. During 2003, F_8 lines from the ALS 9951 population were tested with *P. griseola* isolates from several sites in Honduras; a group of ALS resistant lines carrying the Phg 2 gene (marker NO2) and possibly the Andean gene were identified. In addition, some of these lines have the bgm-1 gene for BGYM resistance (identified with the SR2 marker). Currently, the population ALS 9951 is being tested for ALS resistance on a farm near Zamorano and a higher altitude location. The ALS 9951 population has already been inoculated with two *P. griseola* races (63-59 and 15-17). During the upcoming year, the ALS 9951 population will be screened for BGYM resistance in Comayagua.

Drought continues to be a major factor limiting bean production in the Central America and the Caribbean. Zamorano researchers initiated a recurrent selection program to recombine the most promising sources of drought tolerance. In 2002, we crossed drought tolerant lines with small red lines having high yield potential and stable performance using a partial diallel design. Eighty one populations, and a total of 1,582 families (an average of 20 F_4 families/population), were screened under moderate drought stress. A total of 85 F_4 lines were harvested in bulk based on yield per se and agronomic value. The F_5 plants from these selections were advanced and increased without selection in the first growing season of 2003. A replicated F_6 line drought trial (ERSEQ 2003) has been planted during the second growing season of 2003 in Honduras, Haiti and Nicaragua. The next cycle of recurrent selection will include the best lines from the ERSEQ 2003 trials and improved drought tolerant lines from CIAT and the MSU bean research programs.

In collaboration with J. Lynch, Zamorano researchers initiated triple and double crosses among sources of tolerance to low soil fertility with small red- and black-seeded elite bean breeding lines and cultivars. Some of the sources of tolerance to low soil fertility also perform well under drought. A goal of the bean breeding program is to use parents that are both drought tolerant and efficient in the use of limited available soil nutrients or fertilizer.

Salagnac, Haiti, has many constraints to bean production including acid soils, low soil fertility and Al and Mn toxicity. BGYM, BCMN, rust, anthracnose, angular leaf spot and powdery mildew are also endemic at this location. Bean lines that perform well at Salagnac generally do well at other locations in Haiti. PRF 9657-61-4 from Zamorano was the most promising small red line in nurseries planted at Salagnac in July 2003. The black-seeded lines, B 2059, PPB 22-40 and BCN 20-05-136. were tolerant to low soil fertility and were highly resistant to BGYMV. Other promising small red lines were PRF 9922-15 R, BCH 9911-31, ALS 20-20-42, ALS 20-22-13 ALS 9951-81-R1, ALS 9951-101-R1, ALS 9951-110, X0104-52-5-6-2, MN 53-18.

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

Develop Sustainable Disease Management Strategies for Bean Rust and Web Blight

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

Collaborators and Institutions
James Beaver, University of Puerto Rico; Myrna Alameda, University of Puerto Rico; Angela Alleyne, University of Nebraska

Justification and Objectives:

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. 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 Central America/Caribbean and the U.S. with enhanced levels of rust resistance.

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

- Develop resistance gene deployment strategies for BGYM, rust and web blight compatible with integrated disease management systems.
- Develop molecular markers for disease resistance genes in beans to permit marker-assisted selection and develop molecular markers for bean pathogens to study virulence.

Research Approach, Results and Outputs

Resistance Gene Deployment Strategies: The bean rust mobile nursery was deployed in Nebraska, but the high temperatures and drought conditions in 2003, were not favorable for rust development. In some isolated rusted Nebraska bean fields, resistance genes Ur-4, -6 and -7 were susceptible while Ur-3, -5, -9 and -11 as well as gene combinations were resistant. In only one field was there evidence of a breakdown of Ur-3. This field had a variety trial that included pinto Chase and moderate size uredinia were found and confirmed in the greenhouse inoculation test. Isolates from rusted bean leaf samples from Michigan produced an identical pattern for resistance and susceptibility compared to isolates from Nebraska except that Ur-3 was resistant to all pathotypes. The hint of a loss of Ur-3 resistance, which is now the primary rust resistance in a number of recently released varieties in the Midwest and high plains, indicates the need for multiple genes for rust resistance to be deployed in new varieties. Crosses have been made between the best performing Nebraska advanced common blight resistant pinto/great northern lines and the recently released BelMiNeb-RMR 13 with bean common mosaic and four gene rust resistance.

There has been a trend in the DR in recent years for Andean origin rust resistance to be effective for a couple of years and then not be effective for one or two years. In 2003, all the single rust resistance genes were ineffective except Ur-11 which has not shown any susceptibility to pathotypes in the DR or Haiti in the past five years. Rust resistant gene combinations with Ur-11 are being deployed in red mottled, black- and white-seeded breeding lines for Hispanola. Angel Murillo, a former CRSP trainee, used the mobile rust nursery to characterize the virulence patterns of bean rust in Ecuador. The bean rust mobile nursery also will be deployed in East and Southern Africa-- Kenya, Malawi, Mozambique, but data are not yet available.

In Puerto Rico, the only single rust resistance gene consistently effective is Ur-11. Ur-3+ (Mexico 235) and CNC are generally resistant and rust resistance gene combinations are showing no signs of uredinial development (sporulation). Guatemalan pathotypes produced disease reaction patterns nearly the same as those from Puerto Rico. However, in Honduras the Ur-3+ gene was the most consistent single gene with resistance to 80% of the isolates tested and Ur-11 was next with 70% effectiveness. Some rust resistance gene combinations have been totally effective while some two gene combinations have not been effective in Honduras.

The Agricultural Research Service, U.S. Department of Agriculture, the Michigan Agricultural Experiment Station and the University of Nebraska Agricultural Research Division released six rust and bean common mosaic resistant, high yielding, upright short vine, type II, white-seeded, great northern dry bean (*Phaseolus vulgaris*) germplasm lines, BelMiNeb (BMN)--Rust and Mosaic Resistant (RMR)-8, -9, -10, -11, -12 and -13 in 2003. BMN RMR-8, -9, -10, -11, -12 and -13 are the first and only great northern bean lines to combine four genes for resistance to the common bean rust pathogen, *Uromyces appendiculatus*, with two genes for resistance to the viruses causing bean common mosaic (BCMV) and bean common mosaic necrosis (BCMNV). All six lines are homozygous for their rust (Ur-3, -4, -6, and -11) and mosaic resistance genes (I, bc-3), which provide resistance to all 90 races of the bean rust pathogen that have been identified and maintained at Beltsville, and to all known strains of BCMV and BCMNV.

A total of 69 pathotypes of *U. appendiculatus* from southern Mozambique were identified on the new set of 12 bean differential lines/cultivars chosen in the 2002 South African bean rust workshop and the susceptible pinto bean U.I. 114. Reaction on P114 was included because the virulence of isolates from the same field collection on this cultivar often differed from the reaction on the 12 differentials. Most of the Andean lines with rust resistance genes were susceptible to these isolates, and Montcalm showed a susceptible reaction to all isolates. However, the Andean cultivar, Redlands Pioneer, showed a resistant reaction to 34 isolates (49%). Most of the cultivars grown in southern Mozambique are susceptible and are of Andean origin beans. Genes from Middle American origin were resistant to most of the isolates. The Ur-11 gene was resistant (no sporulation) to all 69 isolates. Ur-3, Ur-5 and Ur-11 rust resistance genes were also reported to be useful sources of resistance to rust pathogen populations from South Africa. For cultivar development in southern Mozambique, one or more of the Middle American Ur-3, Ur-5, Ur-11 genes and the unknown gene of CNC should be incorporated into adapted germplasm as sources of resistance to the common bean rust pathogen.

Web blight (WB) of dry beans is caused by *Thanatephorus cucumeris* (Anamorph: *Rhizoctonia solani*). This disease is endemic in the Central American and Caribbean region. *R. solani* is a complex species composed of subgroups within Anastomosis Groups. At least six subgroups cause symptoms of web blight. Variability among these subgroups comes from virulence, fungicide resistance, optimal growth temperature and epidemiology (disease development rate, fungal propagule type, dissemination and survival). New subgroups of *R. solani* were determined by the following tests: a region of the *R. solani* genome, the internal transcribed spacer region of the ribosomal DNA, was amplified by PCR and restriction length polymorphism was used to compare 45 web blight pathogen isolates from South and Central America plus the Caribbean in comparison to data reported by Carling et al. (Carling, D.E., Kuninaga, S. and Brainard, K.A. 2002. Phytopathology 92:43 50) specific primers from amplified product sequences; sequence comparison to all known *R. solani* reported in GenBank; and virulence as determined by the detached leaf test (DTL).

New subgroups AG-1-IE, AG-1-IF and AG-2-2 WB are associated with distinct web blight symptoms. Isolates of AG-2-2 from wild *Phaseolus spp.* and commercial varieties have similar sequence and other characteristics. Isolates within each subgroup are similar regardless of geographic origin or gene pool of the bean host. Genetic variation of the web blight pathogen can affect disease management and should be considered for dry bean breeding programs that attempt to incorporate WB resistance and other disease management strategies such as use of mulch to suppress inoculum splash dispersal. The bean lines, BAT 93 and VAX 6 and the cultivar, Talamanca, have shown levels of WB resistance in field trials in Zamorano, Honduras and Isabela, Puerto Rico with VAX 6 having the highest resistance. In the DLT, their reaction to the isolates was not different from the susceptible checks. Significant differences in lesion area were obtained between two *R. solani* isolates BV-1 and PR-5; these differences may be due to genetic variability since they belong to different subgroups (BV-1 is AG-1-1F and PR-5 is AG-1-IE). The sensitivity ratio and the co-efficient of variation (CV) ranked the order of the methods similarly. The use of digital imagery to measure the lesion area was slightly better than the use of hand measurement. Data transformation improved the test by reducing the CV by almost 50%. The results of this research indicated that the DLT can be very useful to test virulence among WB isolates of different subgroups and from different regions.

Before the DLT method is used to assess WB resistance in Nebraska, the reason why lines with high levels of resistance in the field do not express it under the controlled conditions needs to be examined.

The bean common mosaic necrosis (BCMN) and bean common mosaic (BCM) can have negative impacts on bean yields. Symptoms of these two rust diseases were first observed in the southwest region of the Dominican Republic in 1999, and subsequently detected in farmers' fields in the eastern part of the country in 2003. Since 2000, the LAC Bean/Cowpea CRSP researchers have conducted several multistage testing for virus strain determination. When foundation seed was tested for BCMNV, the percentage of infected seed ranged from 0.2 to 22.1% and 60% of the seed lots were infected with the strain NL-8. The hypothesis is that the foundation seed from farmer fields was mixed with off types that developed mosaic symptoms. The contamination of foundation seed is the likely source of the increased incidence of the virus. As a result of the accurate identification of the BCMNV and finding the source of the infection, the seed department within the Secretaria de Estado de Agricultura in the Dominican Republic, disposed of 10,000 quintals of contaminated seed in 2003, which otherwise would have been distributed among farmers contracted by that agency for seed increase. The timely report and efforts by the CRSP host country researcher in convincing the government to dispose of the contaminated seeds prevented the spread of the BCMNV throughout the island.

Development of Molecular Markers for Disease Resistance Genes: Of 49 field samples of *U. appendiculatus* collected on wild, weedy, landrace and breeder developed commercial bean varieties in Honduras during 2002, 46 pathotypes or virulence patterns have been characterized. The pathotypes were more virulent on resistance genes of Andean origin than on resistance genes from the Middle American gene pool. Overall, 70% and 80% of the isolates were virulent on Ur-9 and Ur-6 resistance gene of Andean origin, respectively. However, pathogen specificity for a gene pool was not evident. Some of the field samples have been difficult to characterize due to wild bean host specificity. For this reason, a wild bean seed increase was planted. These seeds were collected from each of the wild bean plants where rust samples were collected. The rep-PCR technique was used to characterize molecular markers associated with avirulence or virulence to the Ur-6 rust resistance gene on isolates from two bean rust pathogen populations from Colorado and Nebraska. These populations were collected in 1981 to 1992, when Ur-6 resistance was overcome by virulent pathotypes of *U. appendiculatus* within less than 10 years of release of the resistant cultivar, Olathe. This characterization resulted in the identification of a DNA sequence in *U. appendiculatus* coding for proteins, which are associated with gene activation in plants, animals, fungal and bacterial species. Results from preliminary studies of molecular screening of rust isolates from Honduras and Argentina using rep PCR grouped the isolates by host type (wild, landrace or commercial). These results suggest a co-evolution process between *U. appendiculatus* and *P. vulgaris*. To aid in the screening process for new sources of resistance to common bean rust and to better understand the molecular basis of rust resistance genes in natural populations of *P. vulgaris*, genotypic characterization of wild beans with a set of degenerate primers to target the conserved motif of resistance genes is planned. This technique has been successfully employed to isolate resistance gene analogs (RGAs) from potato, soybean, rice and lettuce.

We were able to identify RAPD markers linked to the Ur-7 gene for specific resistance to rust race 59 using bulked segregant analysis in an F_2 population from the Middle American (MA) common bean cross GN1140 (resistant x GN Nebr. #1 (susceptible) and to map the Ur-7 gene on an existing linkage map constructed using recombinant inbred lines (RILs) from the MA cross GN BelNeb RR-1 x A55. A single dominant gene controlling specific resistance to race 59 was found in the F_2 and confirmed in the F_3. Coupling phase markers OAD12.550 and OAF17.900 with no recombination to the gene were found. These coupling phase markers were also present in pinto US 5 from which the rust resistance of GN1140 was derived. Repulsion-phase marker OAB18.650 was the most closely linked to the gene at a distance of 7.6 cM. All linked markers detected in the F_2 population also segregated in the RILs and were located on linkage group 11 of the existing linkage map. The results of this study support the hypothesis that Ur-6 and Ur-7 rust resistance genes are different.

Crosses have been made between sources of rust resistance in PIs, 260418 and 181996 and pinto U.I. 114 to study inheritance. Recombinant inbred populations are available to find molecular markers for Ur-6 and other rust resistance genes.

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

Development of Improved Bean Cultivars for Highland Production Regions

Principal Investigators and Institutions:

James Kelly, Michigan State University; Jorgé Acosta Gallegos, INIFAP, México; Eduardo Peralta, INIAP, Ecuador

Collaborators and Institutions:

Matthew Blair, CIAT, Colombia; James Beaver, University of Puerto Rico

Justification and Objectives:

The most serious constraints to bean productivity in Ecuador and other highland areas in Latin America are anthracnose, rust (biotic stress factors) and drought (an abiotic stress factor), according to recent surveys conducted by INIAP and CIAT. Improved bean cultivars are needed which tolerate the specific drought conditions which exist in bean growing areas in Ecuador, México and the U.S.

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

- Strengthen bean breeding in Ecuador by establishing field screening nurseries to evaluate performance, adaptation, disease resistance and consumer markets through stronger collaborative ties with CIAT and México.
- Broaden the genetic base of the Regional Drought Screening Nursery and evaluate the nursery at sites in Ecuador and México.
- Initiating the introgression of new resistance sources into local germplasm.
- Use farmer participatory breeding methods to improve bean varieties grown by farmers in the Mira and Chota Valleys of northern Ecuador.
- Continue complementary bean improvement efforts in the U.S.

Research Approach, Results and Outputs

Strengthening Bean Breeding Program in Ecuador: In the large-seeded red and purple mottle nurseries planted for performance and adaptation in Ecuador, none exceeded the Yunguilla (red mottle) check whereas four lines exceeded the purple mottled check Mil Uno in rust resistance, seed quality and yield. Fifty-seven lines were selected for stable resistance to rust and 14 exhibited intermediate resistance to rust. Among these four lines: (Yunguilla x Mil Uno)-18, (Yunguilla x Mil Uno)-21, (Yunguilla x Cargabello)-7 and (Yunguilla x AFR 612)-7, were superior to the commercial checks in resistance to rust, yield and seed quality. Among 109 F_4 lines in the first selection cycle, 29 were selected that included 20 red mottles, and 9 canarios (yellow). In the advanced F_6 trial, only one line, ARME6 x AFR612-3, was selected based on yield and seed quality. In a group of lines derived from Paragachi x Je.Ma., 15 lines selected with rust resistance ranged in yield from 1124 to 1764 kg/ha whereas the Je.Ma. parent only produced 840 kg/ha.

Work continues in the collection and evaluation of climbing beans in canario, solid red and red mottle seed types. Thirty-one accessions collected at a bean fair in Cotacachi were evaluated for agronomic and resistance traits and seeds were catalogued in a germplasm bank. Climbing beans flower in 100-135 days and mature in 145-220 days in these high altitude sites where disease resistance is essential. In the breeding program, the following climbing lines: PHAE 1712, PHAE 1713, PHAE 1716, PHAE 1717 with canario seed coat color were selected for resistance to rust and anthracnose, while less importance was given to yield. The local varieties: Canario Patate, Canario Saraguro and the line PHAE 1280 were selected to possess seed superior to the check I-416, with the objective of incorporating rust and anthracnose resistance into these materials. In the solid red nursery the lines: OBO-V-15 x OBO-V-23-08-01, PHAE 521, PHAE 1728, PHAE 1631 and PHAE 1726 with resistance to rust anthracnose were selected. Seed type of OBO-V-15 x OBO-V-23-08-01 was superior to the check and the yield per plant was similar to line PHAE 1726. None of the red mottles were superior to the check TOA I-412, except the line OBO-V x G 12669. This line will be evaluated in the next year to confirm its adaptation and disease resistance. In Mexico, Marcela was released in the Flor de Junio class. Marcela has excellent seed quality combined with high yield potential and acceptable maturity. Yield exceeding 4T/ha has been reported for Marcela grown

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

under irrigation in Guanajuato.

Regional Drought Screening Nurseries: Common bean (*P. vulgaris*) is an important food crop grown under rainfed conditions in Latin America where drought is a major limiting factor for production. The objective of this study was to assess the role of phenological adjustment and shoot biomass distribution on seed yield of drought-stressed common bean. Four cultivars differing in growth habit, gene pool origin, and contrasting responses under drought, were tested at two locations in Mexico: Cotaxtla, Veracruz (lowlands) where the effect of terminal (end-of-season) drought was evaluated, and Texcoco, State of Mexico (highlands), where the effects of intermittent and terminal drought were evaluated. Seed yield, plant shoot biomass, and days to flowering and to physiological maturity were recorded. Leaf relative water content was recorded after the onset of the intermittent drought treatment in Texcoco. The drought intensity index was 0.37 in Cotaxtla compared to 0.49 and 0.58 under terminal and intermittent drought, respectively in Texcoco. Days to flowering and to physiological maturity showed a negative and significant relationship with seed yield. Under drought stress, a significant reduction in the harvest index was observed in susceptible cultivars. All cultivars showed higher values of shoot biomass accumulation, pod and seed number, seed weight and relative water content at the basal nodes of the plant across locations and moisture treatments. Cultivar Pinto Villa exhibited the highest biomass accumulation and seed yield across treatments and locations. Significant reduction in number of days to maturity was observed under drought, mainly in resistant cultivars, Pinto Villa and G4523. Maturity acceleration, coupled with a high seed-filling rate, contributed to lessen the impact of drought stress in resistant common bean cultivars. The two resistant lines, Pinto x G4523, have been crossed and a 121-entry RIL population developed for widespread regional drought testing. In addition, the regional drought trial of 20 entries was evaluated at Tumbaco, Ecuador in 2003. The nursery included many lines from Mexico previously identified as sources of drought tolerance. Five lines, Canario 60, Raz 68, Bayomex, Azufrado6 and Azufrado32, were identified for further testing in Ecuador based on adaptation, vigor under stress and rust resistance.

Introgression of New Resistance Sources into Local Germplasm: Detecting differences in root architecture and growth patterns among common bean (*P. vulgaris*) genotypes may provide unique selection criteria for genetic resistance to *Fusarium* root rot. Genetic variation in root system architecture was quantified for contrasting bean types under disease pressure in the field and under greenhouse conditions for ten genotypes that represented four common bean classes (kidney, cranberry, black, and snap bean). Genetic variation existed in root architecture among common bean classes and was highly significant under field conditions in Michigan. Variation in root traits was minimal under environmentally controlled, greenhouse conditions. Results from the field evaluation were consistent with a role for adventitious roots in root rot resistance, where the three most resistant genotypes accumulated large amounts of biomass in adventitious roots. A slightly negative relationship between number of adventitious roots and root rot rating was observed ($r = -0.06$; $P < 0.05$). In the field environment, total root system dry weight was correlated to fine ($r = 0.74$; $P < 0.001$) and intermediate ($r = 0.66$; $P < 0.01$) root classes. Root diameter was also positively correlated with root rot resistance, suggesting that larger diameter adventitious and basal roots are beneficial under disease stress. Plasticity of root system response was high, indicating the value of screening in the field environment. Since black beans offer unique characteristics in the improvement of large-seeded red mottle beans for root traits, 73 black bean lines from EAP, Honduras were evaluated for local adaptation in Ecuador. Seven lines displayed a favorable combination of adaptation and rust resistance but none exceeded the check variety, ICA Pijao. A more diverse group of black beans will be evaluated in the future.

Farmer Participatory Breeding Method: A total of 56 bean producers from 10 different communities in the Mira and Chota valleys were interviewed in May of 2003. Ten women and 46 men participated in the survey. The questions used in the interview are included as an attachment. Ninety-six percent of the farmers reported problems with whitefly and 85% reported problems with rust. Nearly all the farmers who reported problems with rust or whitefly used chemical control to treat the problem. Overall 98% of the farmers reported using some sort of chemical control for pests or diseases of beans. Farmers frequently cited yield and disease resistance as traits for improvement in beans. Although farmers were not specifically asked about abiotic stresses, a number mentioned drought as a problem particularly in the large-seeded red and purple mottle types. Data is currently being analyzed and a full interpretative summary will be published at a later date.

LAC6-A1

Bean Improvement Efforts in the U.S.: Two bean varieties were released by MSU during 2003. Seahawk navy bean combines high yield potential, improved levels of resistance to white mold and acceptable canning quality. Growers reported yields of Seahawk in excess of 4t/ha in production fields of 50 ha in 2003. Seahawk is the first navy bean with enhanced levels of resistance to white mold. Merlot, a small red bean was a collaborative release with USDA-ARS. Merlot is the first upright small red variety with rust and virus resistance, combined with excellent seed quality and canning traits. Demand for seed of Merlot has been high as it represents a significant advance in this market class.

Since the serious outbreak of anthracnose in North Dakota (the number one bean producing state) in 2001 and the continued presence of anthracnose in the adjacent province of Manitoba, marker-assisted backcrossing has been used to introduce resistance into the pinto market class where none currently exists. Breeding line USPT-ANT-1 was released collaboratively with USDA-ARS in 2003 and represents the first pinto germplasm with resistance to anthracnose. The original source of resistance was identified and characterized at MSU along with a tightly linked marker, which facilitated the rapid introgression of the resistance gene into susceptible pinto bean germplasm.

Bean/Cowpea Collaborative Research Support Program
Latin America and Caribbean 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; Jorge Acosta Gallegos, INIFAP, Mexico; Eduardo Peralta, INIAP, Ecuador

Collaborators and Institutions:
Dr. George Abawi, Cornell University; Jose Ochoa, INIAP, Ecuador

Justification and Objectives:

The characterization of the race structure of the major fungal pathogens, chiefly anthracnose and rust, and the development of gene deployment strategies to extend genetic resistance to both pathogens is needed in Ecuador. 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, it is believed that the anthracnose races present in Ecuador would most likely be Andean in origin. However, surveys need to be conducted to confirm these preliminary observations and access the genetic diversity of the pathogen present in Ecuador.

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

- Initiate the collection of isolates of anthracnose, rust and root rot pathogens in Ecuador.
- Initiate the characterization of pathogenic variability of anthracnose, rust and root rot isolates collected in Ecuador.
- Develop drought tolerant recombinant inbred line (RIL) populations for testing in Ecuador, Central America and East Africa.
- Use of tightly linked molecular markers as a tool to rapidly integrate new resistance sources into commercial varieties through marker-assisted backcrossing.

Research Approach, Results and Outputs

Two isolates of *C. lindemuthianum* were collected from INIAP's Santa Rosa sub-station. An effective method for long-term storage of such isolates was employed so that these characterized isolates will be available for future inoculations. Similar long-term storage of rust isolates is planned. Collection of root rot pathogens will be initiated in 2004.

The two isolates of *C. lindemuthianum* collected were characterized as race 4 and race 0 using the set of 12 anthracnose differential cultivars. The isolates were also inoculated on a set of six local cultivars: Paragachi, Je.Ma, San Antonio, Mil Uno, ACE-2, and CAP-9 to identify potential resistance sources. Races of anthracnose previously characterized by Falconi et al. (2003) demonstrated that races 0, 3, 4 and 256, 260 and 1346 were present in Ecuador and the most prevalent races 4 and 256 were selected for screening. Race 0 has little pathogenic virulence whereas race 260 represents a combination of races 4 and 256. The cultivars Mil Uno, Paragachi are highly susceptible to both races whereas Yunguilla is resistant. Four lines POA10, TM3, TM4 and TM5 with acceptable red mottle seed type were selected as resistant to anthracnose. Preserving the unique seed quality of future resistant varieties through marker-assisted backcrossing will be important.

The pathogenic variability of rust was determined at Tumbaco and Imbabura using the new 12-member differential set consisting of six Middle American (MA) and six Andean genotypes. With the exception of Aurora where a mixed reaction was detected, all the MA genotypes showed resistance to the local isolates at both locations. In contrast, all Andean genotypes were defeated at Tumbaco, whereas PC-50, Redland Pioneer and Golden Gate Wax showed resistance at Imbabura. This strongly suggests the need to integrate MA genes for rust resistance into future bean varieties in Ecuador.

In the lowland regions of Latin America, a large proportion of beans are sown at the beginning of a dry season where a guaranteed terminal (end-of-season) drought will reduce yields. This study was undertaken to identify lines within two black bean recombinant inbred line (RIL) populations with resistance to terminal drought. The two RIL populations of 150 entries were developed from crosses between a drought resistant line, B98311 from Michigan, with TLP 19 and VAX 5, two lines from CIAT with improved disease resistance and adapted to growing conditions in Latin America. The RIL populations were evaluated in experiments conducted in Zamorano, Honduras and Veracruz, Mexico under drought stress and well-watered (non-stress) treatments. Yields were reduced in each experiment by the drought and the fungal pathogen, *Macrophomina phaseolina*. Drought stress, disease pressure and low yields contributed to high co-efficients of variation, which made it difficult to select superior lines. Selection was based on rank of geometric mean (GM) yield calculated from the yield in the stress and non-stress treatments. One RIL, L88-63 ranked first in GM yield at both locations and out-yielded site means by 134% and 153% at Veracruz and Zamorano, respectively. Subsequent testing in Honduras and Michigan confirmed the high yield potential and broad adaptation of L88-63. Breeding beans for drought resistance in lowland tropical environments should also include breeding for resistance to *M. phaseolina.* A second RIL population of 121 individuals derived from the cross of Pinto Villa x G4523 were evaluated for local adaptation in Tumbaco (2400 masl), Ecuador; Sandovales, Aguascalientes (2000 masl) and Celaya, Guanajuato (1665 masl), Mexico. Among the 121 RILs, 24 were selected for resistance to rust and earliness in Ecuador and within this group six were selected for further testing under terminal drought stress. In Mexico, the RILs were evaluated for reaction to root rot where the parents scored intermediate. As expected, most of the RILs were intermediate (68), 49 were susceptible and only 4 were resistant. Those parental cultivars are considered to be drought resistant and since they belong to different gene pools, this population was developed with the aim of accumulating different mechanisms for drought adaptation and root rot tolerance.

The Co-42 gene from G2333, which confers broad-based resistance to anthracnose, was backcrossed into six Ecuadorian varieties: Paragachi, ARME-2, ACE-1, Cocacho, Yunguilla, and Je.Ma and materials were advanced to the BC_2 and BC_3 generations for testing in Ecuador. The BC_2F_2 and BC_3F_1 populations from these six crosses were grown at the Santa Catalina Research Station from February to June of 2003. Over 500 plants were field inoculated with race 4 and individuals with anthracnose resistance and desirable seed traits were selected for further testing. In addition to the direct screening for resistance in the field the SAS13, SBB14 and SH18 SCAR markers tightly linked to the Co-42 gene were used to indirectly select for the resistance gene. An additional 120 BC_2F_2 and BC_3F_1 individuals were screened with the markers at the Santa Catalina Research Station. Spanish language protocols appropriate for the equipment, personnel and resources available at the station were developed for DNA extraction and marker-assisted selection in beans. This technology is now available for use by the breeding group at INIAP to use in future efforts of marker-assisted backcrossing to enhance disease resistance of all new bean varieties.

Following a similar strategy, marker-assisted selection was used to introgress the Ur-11 gene for rust resistance into Cocacho and Yunguilla using the resistance source BelDakMi-RMR-18. This work was conducted in Puerto Rico as part of a Master thesis. The GT2450 SCAR marker was used to indirectly select for the Ur-11 gene and segregation patterns in both crosses followed an expected 3:1 ratio. In addition, the SW13 SCAR marker was deployed to select for the I gene for resistance to bean common mosaic virus. A total of 76 F_2 were selected based on marker-assisted selection for rust and these will be tested for adaptation, seed type, quality and actual reaction to rust during future field testing and generation advance in Ecuador.

Literature Cited:

Falconí, E., J. Ochoa, E. Peralta and D. Danial. 2003. Virulence Pattern of *Colletotrichum lindemuthianum* in Common Bean in Ecuador. Annual Report of the Bean Improvement Cooperative 46:167-168.

Cross-Cutting Activities

U.S. AND HC INSTITUTIONS PARTICIPATING IN CROSS-CUTTING ACTIVITIES BEAN/COWPEA CRSP

Michigan State University (MSU)
Purdue University
Other U.S. and Host Country Institutions

Ongoing assessment needs to be an integral part of the implementation of a Value-Chain strategy. Assessment provides a mechanism for evaluation of research/training effectiveness as well as direction and is therefore valuable for making mid-course adjustment decisions. One type of evaluation is the assessment of the impacts of technological outputs on different sub-sectors within the value-chain. This form of assessment involves the monitoring of economic, environmental, natural resource, and social impacts of technologies which are adopted by different sub-sectors within the production chain, including both up- and down-stream effects.

The Bean/Cowpea CRSP is committed to ongoing assessment of impacts of CRSP research and training activities. Towards this commitment, impact assessment is a separately funded "Cross-Cutting" activity within the Bean/Cowpea CRSP. During this grant period, the primary focus of the Cross-Cutting activities is ***broadening access by women and minorities to technology and information, and the impact assessment of those technologies and countries which have not been subjected to assessment during the last grant period***. In the first year of the new Grant (FY 2003), the cross-cutting research component focused on the assessment of impacts of bean breeding research in Michigan. The results of this study are highlighted in this section.

Bean/Cowpea Collaborative Research Support Program
Cross-Cutting Research Activities

The Impact of Bean Research in Michigan

Principal Investigators and Institutions:
Richard Bernsten, Michigan State University

Collaborators and Institutions:
Jim Kelly and Mywish Maredia, Michigan State University

Justification and Objectives:

The bean breeding program at Michigan State University (MSU) supported by the Bean/Cowpea CRSP has generated several improved bean varieties which have been widely adopted by farmers and used by private seed companies as parents in their commercial releases. However, the impact of this program has not yet been formally documented. This study is needed to demonstrate the impact of Bean/ Cowpea CRSP investment in breeding research in Michigan and surrounding states, including the release of varieties and germplasm.

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

- Provide an overview of Michigan dry bean industry, bean breeding research inputs and outputs.
- Assess the impact of bean breeding in Michigan.

Research Approach, Results and Outputs

Trends in Michigan Dry Bean Production: Michigan, the second largest dry bean-producing state in the U.S. (after North Dakota), accounts for 15% and 12% of total U.S. bean acres and production, respectively for the last three years (2000-2002). Until 1987, Michigan was the leading producer of dry beans--when it was surpassed by North Dakota. However, Michigan is still an important player in the bean industry–being the leading producer of navy (which accounts for 33% of Michigan production), black (37%), cranberries (8%), and light red kidneys (6%). Over the past three years (2000-2002), Michigan's annual production averaged 3.3 million cwt on 223,000 acres. However, since 1987, both acreage and production has decreased at an annual rate of 2% and 3%, respectively. Michigan's bean area is highly concentrated in the Saginaw Valley and the Bay Thumb area of central and east-central Michigan. Seven counties–Huron, Tuscola, Bay, Gratiot, Sanilac, Montcalm, and Saginaw--account for about 85% of total production (Huron County=30%). While prices have fluctuated greatly from year-to-year, since the 1980's they have trended downward at an annual rate of 1-4%.

Structure of the Michigan Bean Industry: Key players in the Michigan bean industry include growers, elevators/ dealers, canners and a variety of public agencies. According to the 1997 U.S. Agriculture Census, 2,100 farmers grow beans. The elevators/dealers subsector, which both supplies growers inputs and purchases their grain, is highly concentrated. Just three firms control about 80% of the market–the largest being ADM Agri Sales, followed by Cooperative Elevators Company (Pigeon Cooperative) and Con Agra (Klein-Berger Company). Processors/canners who add value to Michigan beans are mainly located in other states and the United Kingdom. An estimated 90% of MI's bean crop is sold to the canning market--45% to Bush Brothers (U.S.) and the rest to Heinz and Hillsdown Holdings' HL Food Ltd. (UK) and other U.S. private label companies, including Hunt-Wessen, Campbell Soup, B&M, Hanover and Allen Canning. Key public agencies that facilitate and support the bean industry include: Michigan State University (breeding), the Michigan Crop Improvement Association (MCIA) for seed multiplication, the Michigan Bean Commission (MBC) for production research and the Michigan Bean Shippers Association (MBSA) for marketing.

Structure of the Michigan Bean Seed Industry: Varieties grown by Michigan farmers are bred by MSU, other universities and private seed companies (mainly Asgrow, Gen-tec, Syngenta and ADM). Breeder seed produced by MSU and other public institutions is first multiplied by MCIA and then further multiplied by elevator companies, who sell certified seed directly to growers. On the other hand, breeder seed produced by private companies is multiplied by elevator companies for direct sale to growers. Virtually all certified seed planted by Michigan farmers is multiplied under irrigation in the western U.S. (e.g., Idaho, Minnesota,

Abstraeted from FY 02B-03 Annual Technical Progress Report. For information on this and other activities of the Bean/Cowpea CRSP, please visit: www.isp.msu.edu/crsp

Wyoming, California and Washington).

Investment in MSU Breeding Program: During the period 1982-2002, external investments in MSU's bean breeding program totaled $3.6 million (average of $182,000/year) in nominal terms. Funding support for MSU's breeding shows an increasing trend over time. These investments come from five major sources: the Bean/Cowpea CRSP (38%), USDA regional and annual grants, contribution from growers and elevators (collected by MBC), state funding (Project GREENE) in recent years (1999 onward) and income from the sale of foundation seed by the MCIA.

Benefits of MSU's Bean Breeding Program: Benefits associated with MSU's bean breeding program include varietal releases, adoption of these varieties by farmers in Michigan and other states and farmer adoption of private varieties which incorporate MSU's germplasm.

Outputs of MSU's Bean Breeding Research Efforts: Since 1980, MSU's bean-breeding program has produced 29 varieties (across 8 market classes), which have been released in the market. Thus, the breeding program has been exceptionally productive–generating approximately four new varieties (across all market classes) every three years. MSU's breeding program has released varieties in eight different market classes: navy (nine varieties--Swan Valley, Neptune, Bunsi, C-20, Laker Mayflower, Huron, Newport, Mackinac); black (six varieties--Domino, Black Magic, Blackhawk, Raven, Phantom, Jaguar), cranberry (two varieties-- Cardinal and Cran028), pinto (three varieties - Sierra, Aztec, and Kodiak), great northern (two varieties –Alpine and Matterhorn), light red kidney (three varieties--Isabella, Chinook and Chinook 2000), dark red kidney (two varieties--Isles and Red Hawk) and white kidney (Beluga). Moreover, two older MSU varieties --Michigan Improved Vine (released in 1966) and Montcalm (1977) are still widely planted by Michigan growers.

Adoption of Bean Varieties in Michigan: Data to estimate bean varietal adoption by Michigan farmers were obtained from two sources: actual sales records (1998-2002) provided by elevator companies two adoption estimates (1985-2001) provided by key informants. Analysis of these data indicates that in the last five years, MSU-bred varieties accounted for a weighted average (by importance of each market class) market share of 17%, across all market classes. With respect to market classes, the weighted market share was highest for dark red kidney (85%), followed by great northern (78%), alubia/white kidney (49%), cranberry (33%), light red kidney (26%), black (18%), navy (6%) and pinto (<1%). In terms of acreage, this translates to a total of 48,280 acres of MSU varieties harvested/year. Blacks accounted for the greatest annual total acres (16,760 acres), followed by cranberry (8,580 acres), dark red kidney (8,080 acres), navy (6,000 acres), light red kidney (4,320 acres), great northern (4,290 acres) and pinto (140 acres). Based on key informant's insight, with respect to trends in adoption from 1985 to 2001, MSU varieties show an overall downward trend in adoption--mainly due to the declining area planted to navy and black beans. However, MSU varieties still continue to dominate in dark red kidney, great northern, and white kidney market classes.

Adoption data identified dominant varieties that have been consistently planted across many years since their release. These varieties, by market class and source are: navy--Vista, Gen-tec (with a 53% market share for the last five years); black--T-39, UC-Davis (50%); cranberry--Michigan Improved Vine, MSU (33%) and SVM Taylor, ADM (28%); pinto--Othello, USDA (89%); light red kidney--Cal Early LRK, UC-Davis (59%); dark red kidney-- Red Hawk, MSU (47%) and Montcalm, MSU (37%); great northern--Matterhorn, MSU (77%); and white kidney--Beluga, MSU (about 50%).

Many of these popular varieties are old releases, some of which were released as early as 3-4 decades ago. For example, Taylor (with 10% adoption in cranberry) was released in 1964; Michigan Improved Vine in 1966; T-39 in 1975; Montcalm in 1977; and SVM Taylor in 1986.

The weighted average age of varieties planted in Michigan during the past three years varied greatly by market class (i.e., black=20 years; cranberry=19 years; pinto=14 years; navy=11 years, dark red kidney= 10 years; light red kidney=10 years; great northern=4 years). These data indicate that for some market classes (e.g., black and cranberry), Michigan farmers are not adopting newer varieties–despite the steady flow of newly released varieties. This could be explained by the consistently higher yields of older varieties, compared to the newer releases. For example, newer varieties in market classes such as black do not out-yield T-39, which was released more than 25 years ago.

To test this hypothesis, statistical tests for significant differences in yield (data source: county yield trial from 1984-2002) were performed to assess the relationship between yield and the observed adoption pattern (i.e., to determine if yield advantage explains the adoption rate for each variety). Adjustments were made to account for difference in the year that the varieties were entered in the county trials. These results indicate that average yield (across counties) alone does not explain the observed adoption patterns. For instance, in the black market class, there are no significant yield differences (5% confidence level) between varieties widely adopted (e.g., T-39) and other less popular varieties. Similarly, in Navy there are several varieties that statistically yield no differently from the most widely adopted varieties—Vista and Schooner, but their adoption is significantly lower than these two varieties in Michigan.

Insight regarding factors other than yield that may explain the adoption patterns were suggested by key informants. For navy beans, the dominance of Vista may be due to marketing arrangements by Gen-tec and ADM. This hypothesis is collaborated by the result of a survey of 214 Michigan bean growers, which found that growers rely on elevators as their source of information/advice regarding which varieties to plant. Another explanation may be the "first-comer advantage" of Vista–since none of the more recently-released varieties significantly out-yield Vista, growers are unwilling to risk trying a new variety. For black beans, key informants reported that the dominance of T-39 is due to both yield stability/consistency across years and the "first-comer advantage" (same story as for Vista). Furthermore, farmer adoption of other black varieties (e.g., Blackjack and Blackhawk) may be explained by their greater resistance to anthracnose--an important disease for black beans). Furthermore, farmers who plant MSU varieties may prefer their upright architecture, which facilitates direct harvesting–thereby reducing production costs. For dark red kidney beans, key informants suggested that the dominance of Red Hawk and Montcalm is likely due to their greater resistance to anthracnose and halo blight–two important diseases for dark red kidney beans. For pinto, while there is no difference between Othello and the other varieties (except Buster), Othello may have a "first-comer" advantage. Moreover, it matures earlier (compared to mid- and full-season maturing other varieties) and it has the highest canning quality index (4, compared to 2-3 for other varieties).

Spillover Effects: The Adoption of MSU-bred Varieties in Other States. According to sales data provided by elevators, during 1998-2002, a total of 116,102 cwt of MSU-bred varieties were sold in other states, which is 1.6 times larger than the total volume sold in MI during the past five years. The bulk of these sales were attributed to six varieties--Montcalm (53,291 cwt), Red Hawk (24,573 cwt), Mayflower (18,161 cwt), Beluga (8,426 cwt), Matterhorn (4,824 cwt) and Chinook 2000 (3,275 cwt). According to the elevators, they sold these varieties mainly in Minnesota, North Dakota, Ontario and New York.

Impact Evidence From Pedigree Information on Private Sector-Released Varieties: Many commercial varieties, which were bred by private sector seed companies and universities (other than MSU) and grown by Michigan farmers, are crosses which incorporate MSU germplasm/varieties. Based on key informants' interviews, varieties with MSU germplasm in their background and planted in 1998-2002 (unless otherwise noted), include: navy--Vista (53% adoption in Michigan for the last five years,75% MSU germplasm, i.e., C-20 & PI326418); Albion (4% adoption, 50% Seafarer), Avanti (8% adoption, 50% C-20 and 50% Seafarer), Crestwood (6% adoption, 50% Sanilac), Midland (1% adoption, 75% Seafarer); Fleetwood (< 1% adoption, 50% Sanilac), Norstar (1% adoption, 50% C-20 and 25% Sanilac); dark red kidney--California (7% adoption, 50% MSU germplasm), Drake (6% adoption, 25% MSU germplasm), Guardian and Camelot (adopted in 1988 with 1% adoption each, based on key informant data, 50% MSU germplasm); great northern--Moonbeam (19% adoption, 50% MSU germplasm); pinto--Buster (4% adoption, 50% MSU germplasm), Vision (2% adoption, 50% MSU germplasm); and cranberry--Cran-75 (adoption in 1988 to 1992 with 5% adoption, based on key informant data, 50% MSU germplasm). In terms of total acreage, Michigan growers planted approximately 76,100 acres/year over the past five years to these private varieties--of which at least 25% of their parentage was derived from MSU germplasm. By market class, the total acres was greatest for navy (73,000 acres), followed by dark red kidney (1,240 acres), great northern (1,050 acres) and pinto (810 acres) beans.

Extending Regional Impacts Through Training

U.S. AND HC INSTITUTIONS PARTICIPATING IN TRAINING ACTIVITIES BEAN/COWPEA CRSP

Michigan State University (MSU)
Oregon State University (OSU)
Pennsylvania State University (PSU)
Purdue University (Purdue)
Texas A&M (TX A&M)
University of California-Riverside (UC-R)
University of Georgia (UGA)
University of Nebraska (UN-L)
University of Puerto Rico (UPR)

Abubakar Tafawa Balewa University (ATBU), Nigeria
Bunda College of Agriculture, Malawi
Eduardo Mondlane University (EMU), Mozambique
Escuela Agricola Panamericana (EAP), Honduras
Sokoine University of Agriculture (SUA), Tanzania
Universidad de Costa Rica (UnCR)
University of Free State (UFS), South Africa
University of Ghana-Legon (UGL), Ghana
University of Pretoria (UP), South Africa
University of West Indies (UWI), Jamaica
University of Zimbabwe, Zimbabwe

In many developing countries, human resource development is hampered by shortages of people, facilities, and funds to train adequate numbers of researchers to plan and conduct the essential production, utilization and marketing components of an effective agricultural sector. The Bean/Cowpea CRSP has made human resource development a principal and integral part of its overall technology development and transfer efforts. Through its degee training support, the CRSP provides career-preparation opportunities for not only HC and U.S. students but also for students from non-participating developing countries who are able to make unique contributions to CRSP goals. Bean/Cowpea CRSP-supported degree and non-degree training programs have increased the number and efficiency of bean and cowpea workers around the world. Training programs foster collegial relationships which last a lifetime. They help establish and maintain networks of researchers which enhance communication among researchers as well as the exchange of information and technologies. This section provides an overview of the degree and non-degree training activities supported by the Bean/Cowpea CRSP in FY 2003.

Bean/Cowpea Collaborative Research Support Program
Training Activity Report

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

Degree Training

All Bean/Cowpea CRSP degree training is closely linked to research activities and aligned with CRSP project research objectives. The degree training is done under the supervision of CRSP principal investigators and forms an integral part of the annual workplans of each regional project.

In 2002, the Bean/Cowpea CRSP started the first year of the new grant with a strong commitment to human resource development by allocating significant resources (more than 20% of total CRSP budget) to degree training programs across all three regional projects. Table 1 provides a summary status of degree trainees as of the end of FY 2003. A total of 61 trainees were "active" or had completed their degree program by the end of FY 2003. Ten degree training activities were either delayed or discontinued and did not occur as planned.

Table 1: Status of Degree Trainees as of the End of FY 2003

1. Degrees completed:	**12**
2. Active:	**49**
Total (Active and Completed)	**61**
3. Delayed/Pending:	**5**
4. Discontinued:	**5**

The pool of 61 CRSP "trainees" include all the degree seeking students that are supported by the Bean/Cowpea CRSP totally (i.e., commitment from the CRSP for the entire duration of a degree program), partially (i.e., for one or more semesters to complete thesis research or partial support throughout the degree program) or indirectly (i.e., through leveraged funding from other sources). In FY 2003, the distribution of CRSP trainees by type of support is as given in Table 2.

Table 2: Level of Support Provided to Degree Trainees

Numbers trained with the following level of CRSP support:		
•	Full	31
•	Partial	24
•	Indirect	6

Forty-one of these 61 trainees were male and 20 were female. The distribution of these 61 trainees by Regional Project and region of origin is given in Table 3. As can be seen, the Bean Cowpea CRSP continues to emphasize training students from the developing world. Thirty-five trainees supported by this CRSP in FY 2003 were from Sub-Saharan Africa, 16 from Latin America and Caribbean region and 8 from the U.S. Also, a majority of the trainees (79%) were from 13 CRSP host countries (Table 3).

Twenty different institutions–nine in the U.S. and 11 in host countries--have participated in Bean/Cowpea CRSP degree training activities in FY 2003. The distribution of degree trainees trained in the U.S. versus HC institutions is almost 50-50. Thirty trainees supported in FY 2003, were trained in a U.S. university and 31 at a university in a participating host country. The Bean/Cowpea CRSP strongly encourages training students in their home or neighboring countries to achieve economies.

The level of degree training supported is given in Table 4. Of the 61 degrees supported, 21 were Ph.D.s, 32 were for Masters and eight for Bachelors level training. More than 85% of the degrees supported are at the post-graduate level indicating the continued commitment of this CRSP in building human resources and capacity to conduct bean, cowpea and related research in developing countries. All the Bachelors level degree training has been supported in host country insitutions (e.g., EAP and UG-L) and indicates the partial research support given to students in their last year of a Bachelors degree program.

Table 3: Distribution of Degree Trainees by Regional Project and Region/Country of Origin

Numbers Trained by Regional Project:	
• WA Regional Project	20
• ESA Regional Project	15
• LAC Regional Project	25
• Cross-Cutting	1
Region of Origin of CRSP Trainees:	
• West Africa	17
• East/Central/Southern Africa	18
• Latin America/Caribbean	16
• U.S.	8
• Asia	2
Numbers Trained From:	
• CRSP Host Countries	48
• U.S.	8
• Non-Host Countries	5

As indicated in Table 4, academic programs supported by the Bean/Cowpea CRSP cut across many disciplines with the majority in the plant and natural sciences (25 out of 61) (e.g., plant breeding, agronomy, soil science, plant pathology, entomology, etc.), followed by an equal number in food science and human nutrition (18), and social sciences/extension (18).

Table 4: Distribution of Degree Trainees by Degree Level and Discipline

Numbers trained for:	
• Bachelors/equivalent degree	**8**
• Masters/M.Phil degree	**32**
• Ph.D. degree	**21**
Numbers trained in	
• Plant and natural sciences	**25**
• Food science and nutrition	**18**
• Social science/extension	**18**

Non-Degree Training

Non-degree training and short-term training are considered important for attaining the CRSP 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 as part of the annual workplans of each regional project.

Table 5 provides a summary of all the non-degree short-term training activities supported by the Bean/Cowpea CRSP in FY 2003. These activities range from a few days training programs (e.g., workshops) to a few weeks and months of individualized training in lab techniques or training in a field setting. These types of short-term training programs are an important tool for the CRSP to achieve the goal of human resource development through support of opportunities for continuing education.

Table 5: Summary of Short-term Training Activities Supported by Bean/Cowpea CRSP, FY 2003

Description	Location	Duration	Beneficiaries	Number of Beneficiaries		
				Male	Female	Total
Training workshop focused on the statistical analysis of price and quality data.	Accra, Ghana	1 week	Bean/Cowpea CRSP economists working in WA and ESA Regional Projects.	8	5	12
A practical sensory training course entitled "Six Steps to Sensory Evaluation."	Maputo, Mozambique	3 days	Educators, researchers, and students of Eduardo Mondlane University.	14	11	25
Field Practical Training support for senior undergraduate students	Dodoma region, Tanzania	6 weeks	Undergraduate students in nutrition program at SUA	4	11	15
Statistical analysis of technology adoption and determinants	Montelimar, Nicaragua	5 days	INTA agricultural economics and gender staff	3	5	8
Research training/internship on field research techniques and use of equipments.	Purdue University	6 months	Student intern and a graduate student	0	2	2
A web-based tutorial on diagnosis of nutritional disorders in common bean	Penn State University	1 year	Bean researchers, plant nutritionists and agronomists worldwide	NA	NA	NA
Short-term lab training in isolation, culture, inoculant production, inoculation, and evaluation of reaction of bean pathogens.	University of Nebraska-Lincoln	2 weeks	Mr. Jorge Venegas, Research Assistant, EAP	1	0	1
Training of Senior Breeders in the application of molecular tools to cowpea improvement.	University of California-Riverside	2 weeks	Issa Drabo and J. Ouedraogo (Burkina Faso), N. Cisse (Senegal), O. Boukar (Cameroon), F. Padi (Ghana), M. Ishiyaku (Nigeria), J. Ehlers (UC-R), P. Roberts (UC-R)	8	0	8

List of Publications Resulting from Bean/Cowpea CRSP Research Activities in FY 2003

Publications Focusing on Beans

REFEREED PUBLICATIONS

Beaver, J. S., J. C. Rosas, J. Myers, J. Acosta, J. D. Kelly, S. Nchimbi-Msolla, R. Misangu, J. Bokosi, S. Temple, E. Arnaud-Santana and D. P. Coyne. 2003. Contributions of the Bean/Cowpea CRSP to Cultivar and Germplasm Development in Common Bean. Field Crops Research 82(2-3):87–102.

Blair, M. W., M. C. Giraldo, L. Duran, J. Beaver and J. C. Nin. 2003. Phaseolin Characterization of Caribbean Common Bean Germplasm. Annual Report of the Bean Improvement Cooperative 46:63-64.

Bracero, V., L. Rivera and J. S. Beaver. 2003. DNA Analysis Confirms Macroptilium Lathyroides as Alternative Host of Bean Golden Yellow Mosaic Virus. Plant Disease 87:1022-1025.

Castellanos-Ramos, J. Z., H. Guzmán-Maldonado, J. D. Kelly and J. A. Acosta-Gallegos. 2003. Registration of 'Flor de Junio Marcela' Common Bean. Crop Science 43:1121.

Coyne, D. P., J. R. Steadman, G. Godoy-Lutz, R. Gilbertson, E. Arnaud-Santana, J. S. Beaver and J. R. Myers. 2003. Contributions of the Bean/Cowpea CRSP to Management of Bean Diseases. Field Crops Research 82:155-168.

Ender, M., J. M. Kolkman and J. D. Kelly. 2003. Use of Inbred Backcross Method to Introduce Resistance to White Mold from Exotic Germplasm into Common Bean. Annual Report of the Bean Improvement Cooperative 46:13-14.

Esquivel, A. and A. Bonilla. 2003. Evaluación de un método para el anélisis de fitatos en frijol. REVITECA (submitted).

________. 2003. Efecto del remojo en agua de frijol negro (Phaseolus vulgaris) a adiferentes tiempos Y temperatures sobre la concentración de fitatos. REVITECA (submitted).

Estevez de Jensen, C., J. A. Percich and P. H. Graham. 2002. Dry Bean Root Rot Control with Bacillus subtilis in Minnesota. Field Crops Research 74,107-115.

Estevez de Jensen, C. et al. In press. Integrated Management of Edaphic and Biotic Factors Limiting Yield of Irrigated Soybean and Dry Bean in Minnesota. Field Crops Research.

Falconí, E., J. Ochoa, E. Peralta and D. Danial. 2003. Virulence Pattern of Colletotrichum lindemuthianum in Common Bean in Ecuador. Annual Report of the Bean Improvement Cooperative 46:167-168.

Frahm, M. A., E. F. Foster and J. D. Kelly. 2003. Indirect Screening Techniques for Drought Resistance in Dry Beans. Annual Report of the Bean Improvement Cooperative 46:87-88.

Frahm, M., J. C. Rosas, N. Mayek, E. Lopez, J. A. Acosta-Gallegos and J. D. Kelly. In press. Resistencia a sequia terminal en frijol negro tropical. Agronomia Mesoamericana.

Godoy-Lutz, G., J. R. Steadman, B. Higgins and K. Powers. 2003. Genetic Variation Among Isolates of the Web Blight Pathogen of Common Bean Based on PCR-RFLP of the ITS-rDNA Region. Plant Disease 87:766-771.

Gonçalves-Vidigal, M. C., V. Vallejo and J. D. Kelly. 2003. Characterization of the Anthracnose Resistance in the Differential Cultivar Widusa. Annual Report of the Bean Improvement Cooperative 46:175-176.

Graham, P. H. 2003. Nodule Formation in Legumes. In: The Desk Encyclopedia of Microbiology. ISBN 0-12-621361-5, pp 713-722.

Graham, P. H. et al. 2003. Addressing Edaphic Constraints to Bean Production: The Bean/Cowpea CRSP Project in Perspective. Field Crops Research 82:179-192.

Graham, P. H., A. E. Hall and D. P. Coyne (Eds). 2003. Contributions and Impacts of the Bean/Cowpea CRSP Project 1982-2002. Field Crops Research 82:79-242.

Graham, P. H., M. Hungria and B. Tlusty. In press. Breeding for Better Nitrogen Fixation in Grain Legumes: Where do the Rhizobia Fit In. Crop Management (electronic journal).

Graham, P. H., J. C. Rosas, C. Estévez de Jensen, E. Peralta, B. Tlusty, J. Acosta-Gallegos and P. A. Arraes-Pereira.

2003. Addressing Edaphic Constraints to Bean Production: The Bean/Cowpea CRSP Project in Perspective. Field Crops Research 82:179-192.

Graham, P. H. and C. P. Vance. 2003. Legumes: Importance and Constraints to Greater Utilization. Plant Physiology 131:872-877.

Hosfield, G. L., J. D. Kelly, J. Taylor and G. V. Varner. 2003. Notice of Naming and Release of Merlot, a New, Upright, Disease Resistant Small-Red Bean (Phaseolus vulgaris, L.) Cultivar. Annual Report of the Bean Improvement Cooperative 46:243-244.

Hungria, M., I. C. Mendes, M. F. Loureiro, J. C. Rubens and P. H. Graham. In press. Inoculant Preparation, Production and Application. In: D. Werner (Ed.) Nitrogen Fixation Research: Origins and Progress. Volume 7.

Kelly, J. D., P. Gepts, P. N. Miklas and D. P. Coyne. 2003. Tagging and Mapping of Genes and QTL and Molecular Marker-Assisted Selection for Traits of Economic Importance in Bean and Cowpea. Field Crops Research 82:135-154.

Kelly, J. D., G. L. Hosfield, G. V. Varner, M. A. Uebersax, M. Ender and J. Taylor. 2003. Registration of 'Seahawk' Navy Bean. Crop Science 3:2307-2308.

Kelly, J. D., M. Ender, J. Taylor, G. L. Hosfield, M. A. Uebersax and G. V. Varner. 2003. Notice of Naming and Release of Seahawk, a New Mid-Season, Upright, White Mold Tolerant Navy Bean Cultivar for Michigan and the Great Lakes Region. Annual Report of the Bean Improvement Cooperative 46:245-246.

Kolkman, J. M. and J. D. Kelly. 2003. QTL Conferring Resistance and Avoidance to White Mold (Sclerotinia sclerotiorum) in Common Bean (Phaseolus vulgaris). Crop Science 43:539-548.

Mainville, D. Y. 2003. Disasters and Development in Agricultural Input Markets Bean Seed Markets in Honduras After Hurricane Mitch. Disasters 27(2)154-71.

Masangano, C. and C. Miles. In press. Factors Influencing Farmer's Adoption of Kalima Bean (Phaseolous vulgaris, L.) Variety in Malawi. Journal of Sustainable Agriculture 24(3).

Mather, D. L., R. Bersten, J. C. Rosas, A. Viana and D. Escoto. 2003. The Economic Impact of Disease-Resistant Beans in Honduras. Agriculture Economics (accepted).

Mather, D., R. H. Bernsten, J. C. Rosas, A. Viana-Ruano, D. Escoto and J. Martinez. 2003. The Impact of Bean Research in Honduras. Agricultural Economics 29(4) (forthcoming).

Maurer, B. A., B. F. Ozen, L. J. Mauer and S. S. Nielsen. 2003. Analysis of Hard-To-Cook Red and Black Common Beans Using Fourier Transform Infrared Spectroscopy. Journal of Agriculture Food Chemistry (submitted).

Mauer, G., G. Flores and S. S. Nielsen. 2003. Development of Bean-Based Granola Bars and Cereal. Cereal Foods World (submitted).

Miklas, P. N., J. D. Kelly and S. P. Singh. 2003. Registration of Anthracnose-Resistant Pinto Bean Germplasm Line USPT-ANT-1. Crop Science 43:1889-1890.

Miles, C. and M. Sonde. 2003. Niche Market Dry Bean Variety Trial. HortScience 38(5):774.

______. 2003. Dry Bean Varieties and Niche Markets in the U.S. BIC 46: 117-118.

______. 2003. Growing the Dry Bean Market: WSU and Bean/Cowpea CRSP Work to Expand the Viability of Beans in Africa and at Home. Agrichemical and Environmental News, August Issue, No. 208, http://aenews.wsu.edu/Aug03AENews/Aug03AENews.htm.

______. 2003. Survey of WA Dry Bean Production. BIC 46:119-120.

Misangu, R. N., S. Nchimbi-Msolla and S. O. W. Reuben. 2002. Resistance of Arcelin Incorporated Bean (*Phaseolus vulgaris* L) Hybrids against the Bean Bruchid *Zabrotes subfasciatus* (Boh). Tanzania Journal of Agricultural Sciences, Vol. 4, No.1: 23-27.

Mkandawire, A. B. C., R. B. Mabagala, P. Guzman, P. Gepts, R. L. and Gilbertson. 200-. Genetic Diversity of xanthomonads Causing Common Bacterial Blight of Bean Suggests Host/Pathogen Co-Evolution. Accepted for publication in Phytopathology (letter of acceptance available).

Mukeshimana, G. and J. D. Kelly. 2003. Evaluation of Rwandan Varieties for Disease Resistance. Annual Report of the Bean Improvement Cooperative 46:145-146.

Osorno, J. M., J. S. Beaver, F. Ferwerda and P. N. Miklas. 2003. Two Genes from Phaseolus coccineus L. Confer Resistance to Bean Golden Yellow Mosaic Virus. Annual Report of the Bean Improvement Cooperative 46:147-148.

Padilla-Ramírez, J. S., R. Ochoa-Márquez, E. Acosta-Díaz , J. A. Acosta-Gallegos, N. Mayek-Pérez and J. D. Kelly. 2003. Grain Yield of Early and Late Dry Bean Genotypes Under Rainfed Conditions in Aguascalientes, Mexico. Annual Report of the Bean Improvement Cooperative 46:89-90.

Padilla-Ramírez, J. S., R. Ochoa-Márquez, R. Rosales-Serna, J. A. Acosta-Gallegos and N. Mayek-Pérez. 2003. Reaction to Root Rot Pathogens of Common Bean Germplasm in Aguascalientes, México. Annual Report of the Bean Improvement Cooperative 46:217-218.

Park, S. O., D. P. Coyne and J. R. Steadman. 2003. RAPD Markers Tightly Linked to the Ur-6 Gene of Andean Origin Controlling Specific Resistance to Rust in Common Bean. Annual Report of the Bean Improvement Cooperative 46:185-186.

_______. 2003. Survey of Molecular Markers Linked to the Ur-7 Gene for Specific Rust Resistance in Diverse Bean Cultivars and Breeding Lines. Annual Report of the Bean Improvement Cooperative 46:193-194.

Park, S. O., D. P. Coyne, J. R. Steadman and P. W. Skroch. 2003. Mapping of the Ur-7 Gene for Specific Resistance to Rust in Common Bean. Crop Science 43:1470-1476.

_______. 2003. Mapping of the Ur-7 Gene for Specific Resistance to Rust in Common Bean. Annual Report of the Bean Improvement Cooperative 46:191-192.

Park, S. O., K. M. Crosby, D. P. Coyne and J. R. Steadman. 2003. Development of a SCAR Marker Linked to the Ur-6 Gene for Specific Rust Resistance in Common Bean. Annual Report of the Bean Improvement Cooperative 46:189-190.

Pastor-Corrales, M. A., J. R. Steadman and J. D. Kelly. 2003. Common Bean Gene Pool Information Provides Guidance for Effective Deployment of Disease Resistance Genes. Phytopathology 93:S70.

Román Avilés, B. and J. S. Beaver. In press. Inheritance of Heat Tolerance in Common Bean of Andean Origin. Journal of Agriculture, the University of Puerto Rico 87:.

Rosales-Serna, R., J. Kohashi-Shibata, J. A. Acosta-Gallegos, C. Trejo-López, J. Ortiz-Cereceres and J. D. Kelly. 2003. Biomass Allocation and Yield in Drought-Stressed Common Bean under Differential Rhizosphere Confinement. Annual Report of the Bean Improvement Cooperative 46:75-76.

_______. 2003. Plant Water Status in Drought-Stressed Common Bean under Differential Rhizosphere Confinement. Annual Report of the Bean Improvement Cooperative 46:77-78.

Rosas, J. C., O. Gallardo and J. Jiménez. 2003. Mejoramiento genetico del frijol comun mediante enfoques participativos en Hondura. Agronomia Mesoamericana 14 (1):1-9.

Rosas, J. C., J. C. Hernández and R. Araya. 2003. Registration of 'Bribri' Small Red Bean (Race Mesoamericana). Crop Science 43:430-431.

Snapp, S., W. Kirk, B. Román-Avilés and J. Kelly. 2003. Root Traits Play a Role in Integrated Management of Fusarium Root Rot in Snap Beans. HortScience 38:187-191.

Steadman, J. R., G. Godoy-Lutz, J. C. Rosas and J. S. Beaver. 2002. Uso de un vivero movil como guia para desplegar gene de resistencia a la roya de frijol comun. Agronomia Mesoamericana 13:41-44.

Steadman, J. R. and J. Janick. 2003. Dermot P. Coyne - Bean Breeder, Geneticist, Humanitarian. Dedication Chapter, pp. 1-19. In: Plant Breeding Reviews, Vol. 23. Jules Janick (ed.). John Wiley & Sons, Inc., New Jersey.

Teixeira Caixeta, E., A. Borém and J. D. Kelly. 2003. Microsatellite Markers for Common Bean. Annual Report of the Bean Improvement Cooperative 46:157-158.

Vallejo, V. A., H. E. Awale and J. D. Kelly. 2003. Characterization of the Anthracnose Resistance in the Andean Bean Cultivar Jalo EEP558. Annual Report of the Bean Improvement Cooperative 46:179-180.

THESES

Acevedo, M. 2003. Estudio de herencia y busqueda de un marcador molecular para la resistencia a la deformacion de vainas causada por el Virus del Mosaico Dorado Amarillo de la Habichuela. M.S. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico, p. 54.

Gonzalez-Ramirez, H. 2003. Economic Evaluation of Bean-Research Investment in Mexico. Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Mather, D. 2003. Three Essays: The Economic Impact of Disease-Resistant Beans in Honduras; Impact Assessment of Maintenance Research Technologies: The Case of Disease-Resistant Beans in Honduras; Factors Influencing the Adoption of Disease-Resistant Bean Varieties in Honduras. Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Murillo Ilbay, A. 2003. Uso de germoplasma exótica para ampliar la base genética para resistencia a roya y otras enfermedades de fréjol común (Phaseolus vulgaris L.) de Ecuador. M.S. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico.

Osorno, J. M. 2003. Herencia de una nueva fuente de resistencia al virus del mosaico dorado amarillo de la habichuela (Phaseolus vulgaris L.). M.S. Thesis, University of Puerto Rico, Mayaguez, Puerto Rico, p. 75.

Publications Focusing on Cowpeas

REFEREED PUBLICATIONS

Afoakwa, E. O., S. Sefa-Dedeh and E. O. Sakyi-Dawson. 2003. Effects of Cowpea Fortification, Dehydration Method and Storage Time on Some Quality Characteristics of Maize-Based Traditional Weaning Foods. Submitted to Journal of Food, Agriculture, Nutrition and Development. (In Review).

Asare, E. K., S. Sefa-Dedeh, E. O. Sakyi-Dawson and E. O. Afoakwa. In press. Extrusion of Sorghum and Sorghum-Cowpea-Peanut Mixtures: Process and Product Characteristics. Submitted to the International Journal of Food Science and Technology.

________. In press. Application of Response Surface Methodology for Studying the Product Characteristics of Extruded Rice-Groundnut-Cowpea Blends. Submitted to the International Journal of Food Science and Technology.

Enwere, N. J. and Y.-C. Hung. 2000. Effect of Cowpea Seed Drying Temperature and Wet Milling on the Rheological Properties of Moin-Moin Paste and Gel. Journal of Tropical Agriculture Food Environment and Extension 1:42-51. (Not previously reported)

Hall, A. E., N. Cisse, S. Thiaw, H. O. A. Elawad, J. D. Ehlers, A. M. Ismail, R. L. Fery, P. A. Roberts, L. W. Kitch, L. L. Murdock, O. Boukar, R. D. Phillips and K. H. McWatters. 2003. Development of Cowpea Cultivars and Germplasm by the Bean/Cowpea CRSP. Field Crops Research 82: 103-134.

Henshaw, F. O., K. H. McWatters, J. O. Akingbala and Y.-C. Hung. 2002. Functional Characterization of Flour of Selected Cowpea (Vigna unguiculata) Varieties: Canonical Discriminant Analysis. Food Chemistry 79:381-386.

Kethireddipalli, P., Y.-C. Hung, K. H. McWatters and R. D. Phillips. 2002. Effect of Milling Method (Wet and Dry) on the Functional Properties of Cowpea (Vigna unguiculata) Pastes and End Product (Akara) Quality. Journal of Food Science 67(1):48-52).

Kethireddipalli, P., Y.-C. Hung, R. D. Phillips and K. H. McWatters. 2002. Evaluating the Role of Cell Wall Material and Soluble Protein in the Functionality of Cowpea (*Vigna unguiculata*) Pastes. Journal of Food Science 67(1):53-59.

Langyintuo, A. S., J. Lowenberg-DeBoer, M. Faye, D. Lambert, G. Ibro, B. Moussa, A. Kergna,

S. Kushwaha, S. Musa and G. Ntoukam. 2003. Cowpea Supply and Demand in West and Central Africa, Field Crops Research 82:215-231.

Langyintuo, A. S., G. Ntoukam, L. Murdock, J. Lowenberg-DeBoer and D. J. Miller. Consumer Preference for Cowpea in Cameroon and Ghana, Agricultural Economics (forthcoming).

McWatters, K. H., M. S. Chinnan, R. D. Phillips, L. R. Beuchat, L. B. Reid and Y. M. Mensa-Wilmot. 2002. Functional, Nutritional, Mycological, and Akara-Making Properties of Stored Cowpea Meal. Journal of Food Science 67(6):2229-2334.

McWatters, K. H., J. B. Ouedraogo, A. V. A. Resurreccion, Y.-C. Hung and R. D. Phillips. 2003. Physical and Sensory Characteristics of Sugar Cookies Containing Mixtures of Wheat, Fonio (Digitaria exilis) and Cowpea (Vigna unguiculata) Flours. International Journal of Food Science Technology 38:403-410.

Murdock, L. L., D. Seck, G. Ntoukam, L. Kitch and R. E. Shade. 2003. Preservation of Cowpea Grain in Sub-Saharan Africa -- Bean/Cowpea CRSP Contributions. Field Crops Research 82:169-178.

Murdock, L. L. and R. E. Shade. 2004. Toxicity of Dietary Avidin to the Cowpea Bruchid, Callosobruchus maculatus Walp. Journal of Stored Products Research (submitted).

Ouédraogo, J. T., B. S. Gowda, M. Jean, T. J. Close, J. D. Ehlers, A. E. Hall, A. G. Gillaspie, P. A. Roberts, A. M. Ismail, G. Bruening, P. Gepts, M. P. Timko and F. J. Belzile. 2002. An Improved Genetic Linkage Map for Cowpea (*Vigna unguiculata* L.) Combining AFLP, RFLP, RAPD, Biochemical Markers and Biological Resistance Traits. Genome 45, 175-188.

Patterson, S. P., K. H. McWatters, Y.-C. Hung, M. S. Chinnan and R. D. Phillips. 2002. Physico-Chemical Properties and Consumer Acceptability of Akara (Fried Paste) Made from Three Cowpea Cultivars. Food Research International 35:691-696.

Patterson, S. P., R. D. Phillips, Y.-C. Hung, M. S. Chinnan and K. H. McWatters. 2003. Enhanced Convenience of Akara Preparation with a Two-Stage Frying Process. Foodservice Research International 14:35-51.

Pedra, J. H. F., A. Brandt, R. Westerman, N. Lobo, H.-M. Li, J. Romero-Severson, L. L. Murdock and B. R. Pittendrigh. 2003. Transcriptome Analysis of the Cowpea Weevil Bruchid: Identification of Putative Proteinases and Alpha-Amylases Associated with Food Breakdown. Insect Molecular Biology 12:405-412.

Phillips, R. D., K. H. McWatters, M. S. Chinnan, Y.-C. Hung, L. R. Beuchat, S. Sefa-Dedeh, E. Sakyi-Dawson, P. Ngoddy, D. Nnanyelugo, J. Enwere, N. S. Komey, K. Liu, Y. Mensa-Wilmot, I. A. Nnanna, C. Okeke, W. Prinyawiwatkul and F. K. Saalia. 2003. Utilization of Cowpeas for Human Food. Field Crops Research 82:193-213.

Sefa-Dedeh, S., B. Cornelius, E. Sakyi-Dawson and E. O. Afoakwa. 2003. Application of Response Surface Methodology to study the Quality Characteristics of Cowpea-Fortified Nixtamalized Maize. Journal of Innovative Food Science and Emerging Technologies 4, pp. 109-119.

THESES

Aduayom, Dédé. 2003. Evaluation of the Potential for the Adoption of Mucuna Cover Crop in the Gaya Area of Southern Niger. M.S. thesis, Dept. of Ag. Economics, Purdue University, West Lafayette, IN.

Boukar, O., 2002. Characterization and Mapping of Striga Resistance in Cowpea, Ph.D. thesis, December 2002. Purdue University, W. Lafayette, IN

Langyintuo, A. 2003. Cowpea Trade in West and Central Africa: A Spatial and Temporal Analysis. Ph.D. Dissertation, Purdue University, W. Lafayette, IN.

Thiaw, S. 2003. Association between slow leaf-electrolyte-leakage under heat stress and heat tolerance during reproductive development in cowpea. Ph.D. Dissertation, University of California, Riverside, CA. 100 p.