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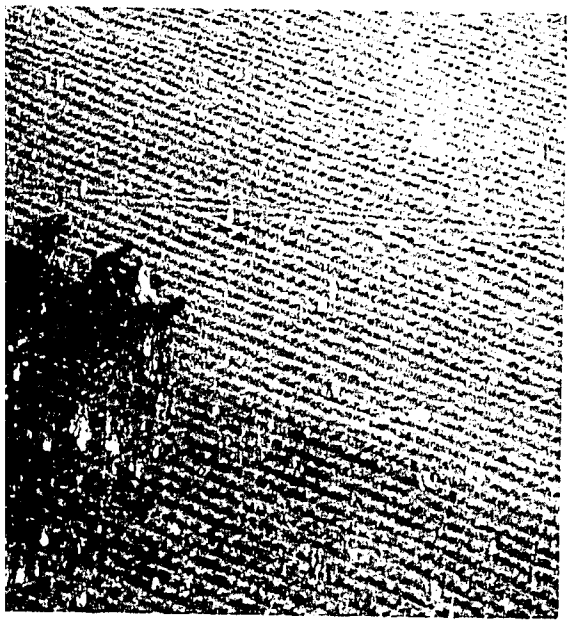
1988 ANNUAL REPORT

technical summary



THE BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

MICHIGAN STATE UNIVERSITY

1988 ANNUAL REPORT

Technical Summary

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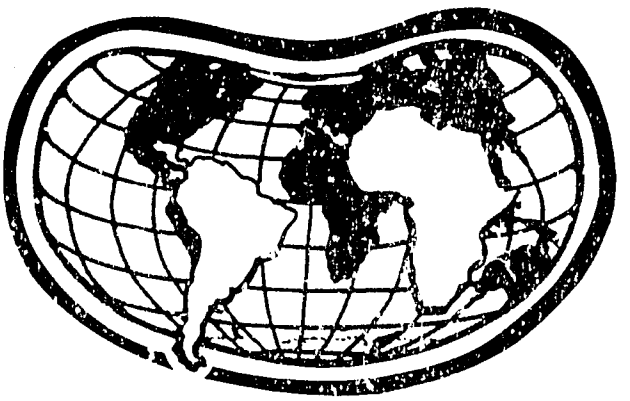
Michigan State University



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INTRODUCTION

The Bean/Cowpea CRSP is a coordinated research effort which addresses hunger and malnutrition in Africa and Latin America. The focus of the 1988 Annual Report is on collaboration, the characteristic of this research approach which distinguishes it from the more traditional agricultural research being carried out at local, national, regional and international research institutions. This approach includes financial collaboration for the research in that U.S. and Host Country (H.C.) institutions, as well as the Agency for International Development (A.I.D.), provide monetary or in-kind support necessary for the scientists to address problems of production and utilization of beans (*Phaseolus vulgaris*) and cowpeas (*Vigna unguiculata*).

The focus of the Bean/Cowpea CRSP is on collaborative research between scientists from different countries and different disciplines. Through this collaboration, research outcomes are generated to effectively address the universally persistent problems of production and utilization of beans and cowpeas.

Given the geographic distances between the nations involved; the philosophic, cultural and linguistic distances between scientists and disciplines; the time required for biologically based research efforts and the multiplicity of outcomes, effective collaboration has of necessity been gradual. Nonetheless, it has been a substantial achievement.

In each research project attention is primarily focused on a particular aspect of the production effort (varieties, disease, insects) or utilization (storage, processing, nutrition) of beans or cowpeas identified in the Global Plan (Figure 1). Since initiation of this program in 1980, collaboration among scientists of different nationalities and disciplinary orientations has grown well beyond the original scope of the individual projects. Collaboration to address the identified problems has expanded beyond the basic teams as projects have begun to interact with one another, and the nations share their respective findings.

This report reflects the sum of the collaborative effort. It also demonstrates an exponential increase in understanding the complexities of bean- and cowpea-related sciences as the work to solve problems across continental and national borders, among culturally diverse peoples, proceeds.

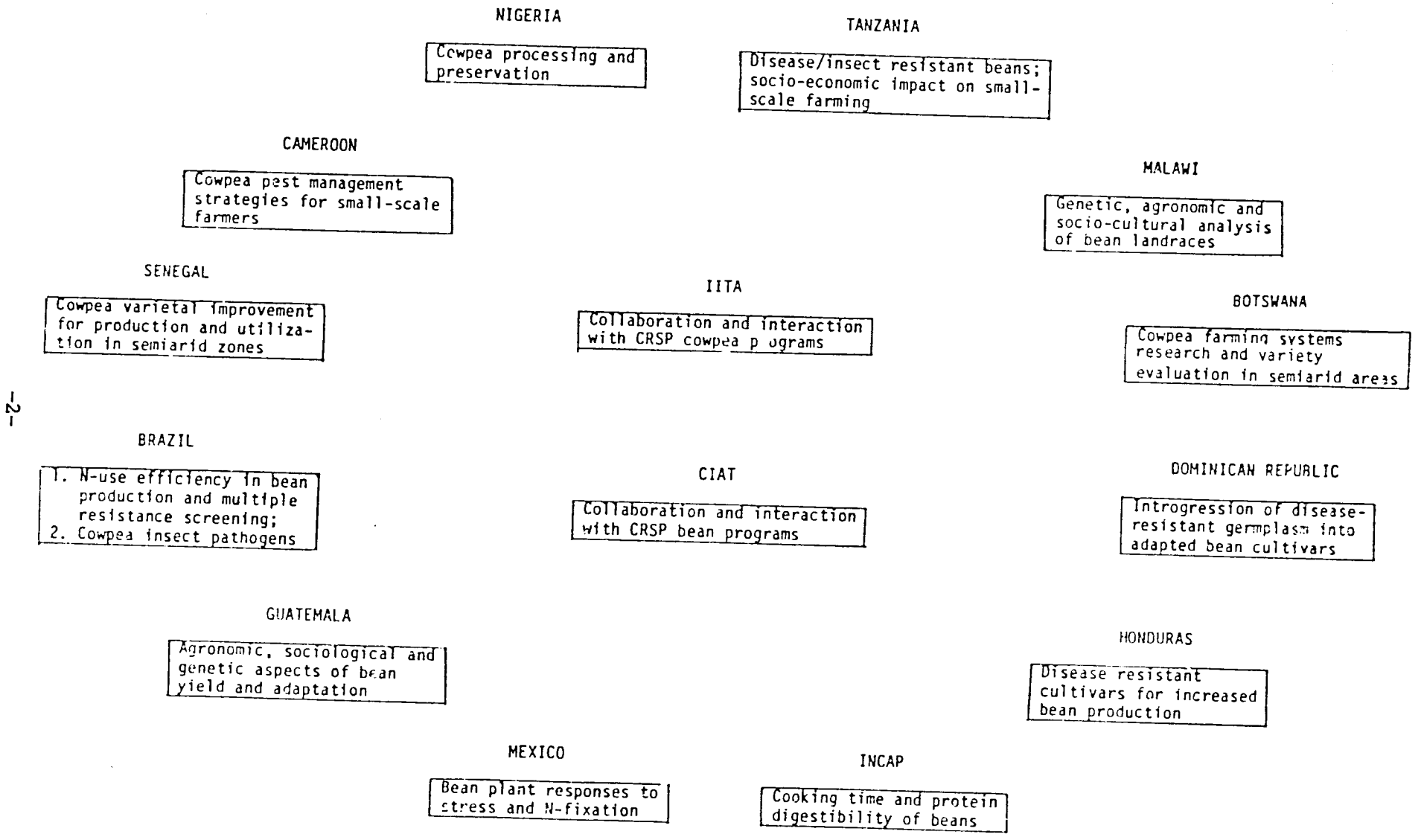
One of the unique aspects of the CRSP is the extensive linkages which are forged over time and which support a two-way flow of information. As the partners in this scientific effort exchange data on a collegial basis, the benefits of their research enrich both the U.S. and Host Countries and contribute to the development of sustainable agricultural production systems.

The 1988 Annual Report of the Bean/Cowpea CRSP presents evidence of research achievements which support increasing production of beans and cowpeas, increasing the income and livelihood of smallholder producers, and improving the nutritional status of the rural and urban poor.

Results from research related to drought tolerance, farmers' practices, new varieties, insect control and hard-to-cook characteristics have been noteworthy in 1988. In addition, the socioeconomic research carried out in several of the projects has contributed to a better understanding of the context within which production and utilization occur.

FIGURE 1

BEAN/COWPEA CRSP GLOBAL RESEARCH PLAN
Extension Years FY 86-89



PROJECT HIGHLIGHTS

DROUGHT TOLERANCE

The drought in 1987-88 in the U.S. and Africa had an impact on research in a number of projects, accenting the need for drought tolerance in bean and cowpea cultivars in the U.S. as well as in the developing countries. The Annual Reports of many of the CRSP projects reflect the effect drought had on their research and on farmers' production. Attention to drought tolerance has been an objective of several CRSP projects.

The focus in the Mexico/MSU project is on identification of genetically-conditioned tolerance to drought in both the bean plant and its *Rhizobium* symbiont to improve productivity. Valuable bean germplasm has been collected and screened. Several bean cultivars have been identified with drought tolerance and will be used by plant breeders around the world. Two dry bean cultivars, 'Bayo Victoria' and 'Pinto Villa,' developed by the collaborative efforts of the CRSP show field tolerance to drought and are being made available for planting in farmers' fields in 1989 in Mexico.

Work is also progressing to develop beans for Michigan which combine drought stress tolerance with locally required agronomic characteristics. The Michigan State University scientists involved in this Mexico project noted that the dry summer experienced in the U.S. in 1988 emphasized the need for drought tolerant cultivars that are adapted to the long day lengths of Michigan and are of the type required by established markets.

In the Senegal project, the research focus is on improved cowpea cultivars, management and storage in semiarid zones. Drought also reduced yields here and led to the study of intercropping the spreading and erect varieties as a means of stabilizing yields of cowpea grain and hay. With the decreased production of peanut and millet due to the drought, cowpea production has increased dramatically in Senegal since 1985. The average yearly production value of cowpeas was $11 million in the 1970-79 period while, since 1985, the yearly production value increased to $29 million. Average yields increased 60 percent from 293 kg/ha in 1970-79 to 470 kg/ha in 1985-87 and the area planted increased from 63,000 ha to 103,000 ha in the same period. Certain cowpeas also provide a quick (only 60 days) crop for the farmer's production system.

In Honduras, the drought caused a 30 percent deficit in seed supply, resulting in a 400 to 500 percent increase in the price of seed. To provide some short-term relief, the Escuela Agricola Panamericana (EAP--the Pan-American Agricultural School) produced five tons of a recently released variety for distribution. EAP is collaborating with the Ministry to develop a seed certification program for beans in Honduras.

In Tanzania, many of the CRSP researchers' field experiments failed because of drought, an occurrence which directed attention to the most drought-tolerant cultivars and production practices. The drought conditions helped scientists recognize and assess farmers' traditional risk-averting strategies.

In Nigeria, the drought reduced cowpea production so much that there was a dramatic increase in the price of cowpeas, which made production of cowpea meal in the CRSP's project-financed village mill an uneconomic venture. Results of this utilization research will be evaluated in the next year if cowpea production is better.

FARMERS' PRACTICES

The 1988 Bean/Cowpea CRSP Annual Reports from the projects reflect a growing awareness by U.S. scientists of the wide variety of conditions and problems which affect research outcomes in developing countries. This leads to an appreciation of the wisdom of farmers' traditional practices. In Tanzania a survey of bean disease management methods on smallholder farms explained why farmers sole-crop beans in the February-May growing season but intercrop them in the September-December season. This more complete understanding of the socio-biological interactions taking place at the smallholder level can guide biological scientists in designing appropriate research to benefit growers.

Studies of farmers' practices regarding plant population densities and bean spacing arrangements in Tanzania support a better understanding of the small-scale farming enterprise. Farmers assess costs of labor, time and fatigue involved in different planting arrangements and the effects of these factors on subsequent weeding and harvest. The Principal Investigator (PI) suggests that these considerations, which had been previously overlooked by agricultural research, go beyond yield/acre or yield/plant in assessing cultivar behavior.

The recognition of cowpea storage as a process--a series of different activities--which low-resource farmers in Northern Cameroon follow in a variable pattern has brought insight into the effect traditional materials (ash from cooking fires or local botanicals) can have in protecting cowpeas from insect damage in storage. This has enabled the scientists to identify appropriate new technologies to support the traditional process.

In Malawi, research has documented that growers determine the composition of their bean mixtures by deliberate selection of plant and seed types, resulting in an enormous range of genetic diversity appropriate for varying ecological settings. Growers, both men and women, know the beneficial and detrimental characteristics of numerous seed and plant types within their local areas and select from the array of available beans to meet their specific needs.

"Mini-kit" experiments evaluating improved cowpea varieties were conducted by farmers in Northern Senegal with 35 trials in 1987 and 1988. Selected lines which have resistance to mosaic viruses, bacterial blight and cowpea weevil are being evaluated in advanced yield trials in 1988. Spreading and erect cowpea varieties are being studied to provide small farmers with both straw for animal fodder and grain for human consumption. The farmers involved in the "Mini-kit" experiments are essentially producing certified seed. Through the use of sealed drums for storage, producers are able to make high quality seed available to neighboring farmers. These experiments are also training a cadre of farmers to work with local officials on certified seed production. With the use of sealed drums, farmers are not using the large amounts of toxic pesticides they normally do to store their seeds.

INSECT CONTROL

Insect pests are major constraints to production of beans and cowpeas. The insect pathogens being studied as cowpea pest management tools in Brazil should eliminate much of the chemicals used for insect control. Collaboration among a number of research institutions in Brazil has increased awareness of insect diseases as potential biological controls.

In an effort to protect the environment, the CRSP project in Brazil has collected over 270 pathogenic microbes which are being

screened as potential agents for controlling destructive insects. Two microbes are being evaluated in Brazil and the U.S. for the control of leafhoppers and soil insects. *Zoophthora (=Erynia) radicans* has shown excellent preliminary results in controlling *Empoasca* leafhoppers in Illinois and New York. *Beauveria bassiana* has shown promising results in controlling *Diabrotica* larvae. Biological control of this pest is a very attractive alternative to dependence on large amounts of insecticides. The CRSP is continuing to develop biological control methods for important pests for small-scale farmers in developing countries as well as for U.S. farmers.

In Cameroon, research is focusing on simple, low-cost technologies which would reduce insect-caused losses of stored cowpeas. *Bruchicius atrolineatus* has been identified as the source of serious losses around harvest time in Northern Cameroon. Wild species of cowpea have been collected and screened for insect resistance. Two entries were found to be resistant to storage insects. In addition, preliminary results suggest that a simple double-bagging technology can dramatically reduce losses to storage insects. Results from on-farm testing indicate this low-cost technology can be utilized by small farmers to control storage insects and is also appropriate for storage of other grains.

NEW VARIETIES

In the Dominican Republic the widely adopted and high-yielding red mottled dry bean PC-50 developed by CRSP scientists is expected to be grown on most of the acreage devoted to red mottled beans in 1989. In addition to its superior yield and wide adaptability, PC-50 has excellent seed quality and appearance, and rust resistance stability due to its pubescent leaves. A government subsidy to produce basic seed resulted in the price of seed beans being twice the price of market beans, providing an adequate supply for planting.

Five black bean breeding lines with enhanced capability for N_2 fixation have performed well in trials throughout Brazil and will be released as germplasm by Centro Nacional de Pesquisa de Arroz e Feijao/Empresa Brazileira de Pesquisa Agropecuaria (CNPAF/EMBRAPA) and the University of Wisconsin-Madison. This project has developed simplified criteria for estimating N_2 fixation in germplasm selection and has generated superior N_2 fixing lines for Wisconsin.

Higher yielding genotypes have been developed in Guatemala and Cornell University using the Yield System Analysis (YSA) developed in this project.

As part of their CRSP activities, the Senegal project has over 1300 cowpea accessions collected from many countries at Riverside, California. Because most of these accessions are not in the USDA (United States Department of Agriculture) collection, USDA has provided funds for the production of disease-free seed from the University of California-Riverside (UCR) collection. A computerized system is being installed and the database and seed of the UCR germplasm collection will be provided to the USDA collection at the Regional Plant Introduction Station in Griffin, Georgia.

Small-red breeding lines of beans with dense leaf pubescence have been developed through the Honduras/University of Puerto Rico project collaboration. Breeding lines which combine resistance to rust disease with early maturity are currently being developed.

Bean diseases have been identified as a major yield constraint in most tropical countries. In Brazil, germplasm with resistance to the bean golden mosaic virus (BGMV) has been evaluated and breeding lines developed

with good pod formation. The molecular characterization of the BGMV is being studied at the University of Wisconsin-Madison. Findings suggest there may be two distinct strains of BGMV. One line, LM 30630, with tolerance to at least one of the strains of BGMV is in the final process of evaluation before it is released and is included in the Preliminary Yield Trials in all states in Brazil.

HARD-TO-COOK CHARACTERISTIC

Aspects of the hard-to-cook phenomenon in beans and cowpeas is addressed by several of the production-oriented projects as well as those oriented principally to utilization. The effect of collaboration is development of varieties which do not have the hard-to-cook characteristic, as well as reduction of the hardening problem in storage and preparation practices.

The INCAP/Washington State University project involves collaborators from several universities (Kansas State, Michigan State and Washington State) in the U.S., as well as scientists at the Instituto de Nutricion de Centro America y Panama (INCAP). The hard-to-cook defect is being investigated in a number of separate studies which have identified (1) the chemical changes that coincide with the development of bean hardness, (2) the addition of a chemical to inhibit the development of hardness and (3) the effect of a range of storage times on hardness. Further, these studies have conducted varietal trials with selection for rapid cooking time and carried out an assessment of physical and chemical changes which take place during the storage of beans that may affect cooking time.

Cowpea storage practices, storage temperatures and humidities are being investigated at the University of Georgia. Storage under actual field conditions is the focus of the Cameroon/Purdue University project with a focus on reducing losses to insect pests. Technology developed in this project may also affect the hard-to-cook characteristic. The sealed drum storage being tested in Senegal may contribute additional information on the hard-seed issue.

Genetic variation in cooking time is being studied at Michigan State University by a Ph.D. candidate from Malawi. Soaking time in relation to cooking time after various storage conditions is being investigated by a Ph.D. student in Tanzania. The CRSP food scientists are also working on improving the nutritional quality of bean protein. Research results indicate that the protein and procyanidin concentrations are quantitatively inherited.

SOCIOECONOMIC RESEARCH IN THE CRSP

Collaboration across disciplines has led to a better understanding of the socioeconomic constraints affecting production and utilization of beans and cowpeas. Melding the concerns of social scientists with concerns of biological scientists enables each to address better the research issues associated with the alleviation of hunger and malnutrition, the major goal of the CRSP. As noted above, this cross-disciplinary collaboration was demonstrated in an analysis of responses by Tanzanian smallholder farm men and women to bean spacing recommendations. The analysis led the Principal Investigator (a plant pathologist) to point out the need for researchers to better understand why in terms of labor, time and fatigue the smallholders use the spacings they do instead of those recommended. He suggested that scientists need to consider these issues when they look for ways to improve smallholders' yield output. "So, if small farmers don't use those spacings or fertilizer

input levels that we test on station trials, why are we using them?" he asked.

The 'bricks' of understanding, built one by one in each project, create a center of knowledge which supports the scientists in their efforts to identify appropriate technological improvements for beans and cowpeas. The 1988 Annual Reports of CRSP scientists include the following:

* In Brazil, it was found that 50 percent of the cowpeas marketed move out of the production area via truck drivers who pass through NE Brazil and purchase a few sacks to sell in urban areas for personal profit. Other market sources are wholesalers (15 percent), producers (15 percent) and cooperatives (20 percent). The produce is sold to retailers (57 percent), other wholesalers (39 percent) and final consumers (9 percent). Of the consumers, 57 percent said cowpea price determined their willingness to purchase or to switch to flour, rice and vegetables.

* The research in Tanzania centers on understanding the methods of smallholder families and the constraints in their farming systems. Farming two-three hectares (five to seven acres), these smallholders produce crops with two major inputs--land and labor. Their priorities are first to produce their family food supply and second to sell surplus production. Women provide at least half of the agricultural labor on most smallholder farms. Women work as many hours as men in agriculture and also prepare the food, perform other household chores, care for children and fetch water and fuel (firewood). Women and children were found to be primarily responsible for selecting the seed; husbands and wives jointly decide which crops to plant. Most families plant several different crops, some of which are intercropped. For example, maize is the major food staple in Tanzania where more than half the farm is planted to maize intercropped with beans. The CRSP research found that:

-- Most families use very little hired labor. Some families own or rent oxen, and a few hire tractors for plowing and planting. Most of the plowing, sowing, weeding and harvesting is done manually. In most areas additional land is available, but insufficient family labor hinders the expansion of agricultural production. Low prices for farm produce are another major constraint.

-- Farmers use different bean varieties in different agro-ecological zones. Although some of the farmers interviewed purchased certified seed, most saved their own seed. Over time, these seeds contain many different types. Some mixing is deliberate to reduce the risk of crop failure and to provide plants that mature at different times.

-- Families prefer different varieties of beans for consumption, sale and storage. Beans are normally cooked for 1.5 to 2 hours with onions, salt and spices. CRSP food scientists have demonstrated that soaking beans for several hours before cooking substantially reduces cooking time.

-- Yields on university or government research stations differ greatly from those on farmers' fields. Farm families either cannot afford the fertilizers and pesticides used on the experimental plots or those items are unavailable in the area. It was learned that the female family members do not have access to the most up-to-

date information on prices, planting dates and varieties or other services provided by extension service personnel, who are primarily male and usually interact with the male farmers.

-- Surveys of marketing activities in Mgeta, Tanzania were made to attempt to establish an estimate of amount and type (dry, green shell and green pod) of beans being shipped or sold locally. The complexities of the endeavor and the multiple markets in that one geographical area suggest it will be very difficult to monitor the impact of new cultivar introduction. In different areas of this large country, harvest is at different times of the year. It was documented that high transportation costs increase consumer prices. The Dar es Salaam market (the largest urban area) establishes the market price. In Tanzania, where cattle are an integral part of the smallholder farming system, the economic value of bean straw as cattle feed was considered important.

-- Compared with traditional varieties, the first on-farm trials of an experimental High Yielding Variety (HYV) showed significantly higher yields for the HYV but also greater fluctuation in yields from farm to farm. Stability of yield is important to smallholder families who depend on their production for the family food supply. The bureaucratic processes involved in the release of new cultivars were studied, leading to the biological scientist's awareness of the political obstacles which would affect the opportunity to get new cultivars released in Tanzania.

* In Nigeria, a baseline study to assess the reaction of rural women to innovation in cowpea preservation, processing and consumption was carried out in Anambra State. The data found that over 75 percent of the families consumed cowpeas weekly and 98 percent consumed them bi-weekly. Cowpea meal was used in certain cultural rituals. Cowpeas were found to be inadequately preserved and principally processed by manual grinding. Problems identified were storage insect infestation, inaccessibility of commercial mills, and utilization/consumption problems. These findings guided the scientists in developing the research reported in their 1988 Annual Report and in planning for the Fiscal Year (FY) 89-92 extension period.

  Major benefits of this research will be the reduction of women's time and energy in preparation of cowpea products and an inexpensive, nutritional food for their families. This year's report notes that more people are developing interest in cowpea cultivation with the expected increased national production to be well over one million metric tons per annum.

* In the sociocultural component of the Malawi project, perceptions of women who choose bean varieties at planting, both from seed stock on hand and from stock available at local markets, have been assessed. The social science work, supported by the study of component shifts in heterogeneous bean populations, has given a clear picture of the primary role of women in the maintenance of diversity. This information will be used in developing bean breeding strategies which will sustain diversity, documented to be important in the country, and meet smallholders' needs.

Intensive interviews with farmers in the Central Region of Malawi found that women played an important role in bean cultivation as well as being responsible for storage, processing and food preparation of beans. Four factors were identified to explain the maintenance of large varietal inventories in Malawi. They are: (1) Women are aware of the value of diversity as a form of food security. (2) Women have a multiplicity of needs (such as date of maturity, taste, storage and market qualities) which they meet by maintaining a diversified planting stock. (3) Some bean varieties were kept because they had been grown for many years and are part of people's agricultural heritage. (4) In some cases, lack of access to preferred seed seemed to account for keeping some less preferred varieties. The women in this study gave names for 85 percent of the 220 varieties of beans they grew. In many cases, the names correlated with various qualities of the beans, such as color, taste and cooking time.

* Surveys on women's roles in production and utilization of beans and cowpeas have been done in the Nigeria, INCAP, Cameroon, Brazil/ Boyce Thompson Institute (BTI), Malawi, and Tanzania projects. An example of one of the findings is that in many areas of Tanzania, 25 percent of the smallholder farms are operated by females with no adult male present to assist with farming or to contribute income. CRSP research has shown that the female-headed households (FHHs) plant smaller areas of crops, and household members consume less food and have less income than male-headed households (MHHs). The FHHs also plant different crops and allocate a greater percentage of their land to food crops than MHHs. The findings of these studies assist the CRSP scientists in better understanding the systems within which their research will be used and in targeting their research to the problem areas where the new technology potentially has the most usefulness.

In some of the research projects of the CRSP, information specifically on women's activities in the production and utilization of beans and cowpeas has been collected and analyzed. This has strengthened efforts of the PIs, both U.S. and H.C., in framing their research to address gender-related issues affecting smallholders' lives.

WOMEN IN DEVELOPMENT PROGRAM

The Bean/Cowpea CRSP is mandated to conduct agricultural research that will benefit small-scale farmers and women in developing countries by improving their nutritional status and standards of well being. As one means of achieving this goal, the CRSP has incorporated a Women in Development (WID) component in its program. The WID program in the Bean/Cowpea CRSP provides support to the individual projects on gender and social science related concerns and assists the Principal Investigators in identifying research scientists to meet specific project needs in these areas. The WID program has functioned as a resource providing information to Principal Investigators on the social organization of agriculture and women's roles in bean and cowpea production and consumption. Thus, its greatest impact has been on the CRSP research and training program rather than directly on Host Country populations. The program is staffed by a half-time WID Specialist.

Overall, the WID component has strengthened the collaborative effort through:

1. The development of a cadre of U.S. and H.C. agricultural scientists, nutritionists and food technologists who are increasingly conscious of the multi-faceted constraints to agricultural production in developing countries and who are aware of the relevance of gender and class issues in agricultural research.

2. The design of project research agendas that reflect an understanding of the sociocultural and economic constraints faced by women and other small-scale agriculturalists. This has included development of ways to overcome constraints to bean and cowpea production and utilization that take into account the limited resource base available to smallholders and to other urban and rural poor in the Host Countries. Included here are investigations to improve nitrogen fixation and reduce fertilizer needs, research to overcome the hard-to-cook phenomenon in beans and reduce family fuel needs, and breeding cultivars with improved nutritional content and digestibility. It also included consideration of women's time and labor constraints in the design of new technologies and improved varieties.

   In 1988 specific activities of the WID Specialist have included collaboration with the Cameroon project researcher on the design of the cowpea storage surveys being undertaken in Cameroon; discussions concerning the status of the cowpea production and marketing surveys that were carried out in Brazil; assistance in identifying a researcher who could provide input on gender differences in acceptance of cowpea "Mini-kit" recommendations in Senegal; discussions regarding a potential replacement for the agricultural economist for the Tanzania project when she retires in 1989; and discussions regarding bean breeding strategies and the importance of early maturity for small-scale farmers in Honduras. In addition, work progressed on the Malawi Women in Agriculture Resource Guide, which should be completed during FY 89.

3. The recruitment of women in the student training program and the promotion of greater awareness of the relevance of gender in agricultural research among participants in CRSP student workshops.

In FY 88, the Women in Development Specialist was involved in the FY 89-92 extension process by writing a WID extension proposal and preparing for and participating in the extensive reviews of the WID program and the Management Office. In addition, work also focused on reviewing the FY 89-92 project extension proposals submitted by the PIs and participating in Technical Committee deliberations concerning these proposals. As part of this process, each PI was contacted and, where appropriate, suggestions were made regarding ways in which work plans could be modified to better assure that proposed research outcomes would be relevant to the needs of H.C. women and small-scale farmers.

TRAINING

Collaboration among scientists is significantly strengthened by the CRSP training component. Training research scientists through degree and short-term programs has increased the number and efficiency of bean and cowpea workers around the world. These linkages, established through graduate study at the various CRSP institutions, extend collaboration among CRSP scientists well beyond the life of any particular project.

By 1988 100 students (63 males and 37 females) have earned advanced

degrees through the CRSP program (Figure 2). In 1988, 8 students (5 male/3 female) received masters degrees; 6 students (3 male/3 female) received Ph.D. degrees and 5 students (3 male/2 female) received B.S. degrees (Table 1). There are 107 students (55 male/52 female) funded by the Bean/Cowpea CRSP presently enrolled in advanced degree programs (Figure 3). As the figures show, training for women has been a very high priority of the Bean/Cowpea CRSP.

Dr. Susan Nchimbi is an example of the future opportunities for collaboration stemming from this program. Funded by the Tanzania/ Washington State University (WSU) CRSP project, she received her Ph.D. at the University of Wisconsin, where she did her research under the guidance of Dr. Fred Bliss, the Principal Investigator in the Brazil/ University of Wisconsin CRSP project, and studied with research colleagues from the Brazil project. She has returned to Sokoine University (Tanzania) to take a leadership role in the bean breeding component of that project.

Another example is the scientists from the Dominican Republic, trained at the University of Nebraska (UNL) and the University of Puerto Rico (UPR), who have graduated and returned to participate in their national bean research program and particularly strengthen the collaboration among these three institutions.

Short-term training provides specialized skill building opportunities for bean and cowpea research scientists. This year thirteen scientists, including two from Uganda and two from Malawi, participated in a one-week microcomputer workshop in Tanzania. Each participant learned how to use MSTAT, a microcomputer statistical and data management package to design, manage and analyze their research.

FIGURE 2: BEAN/COWPEA CRSP

M.S. AND PH.D. DEGREES COMPLETED BY 9/30/88
GENDER DISTRIBUTION (TOTAL 100)
HOST COUNTRY, U.S., OTHER

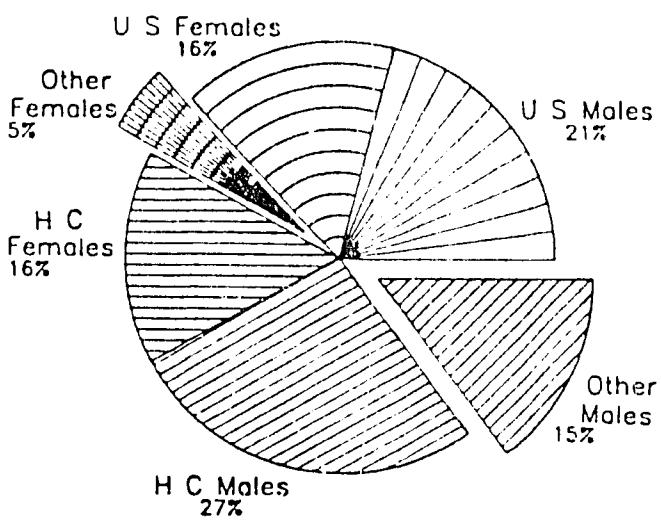


FIGURE 3: BEAN/COWPEA CRSP

M.S. AND PH.D. DEGREES IN PROGRESS 9/30/88
GENDER DISTRIBUTION (TOTAL 100)

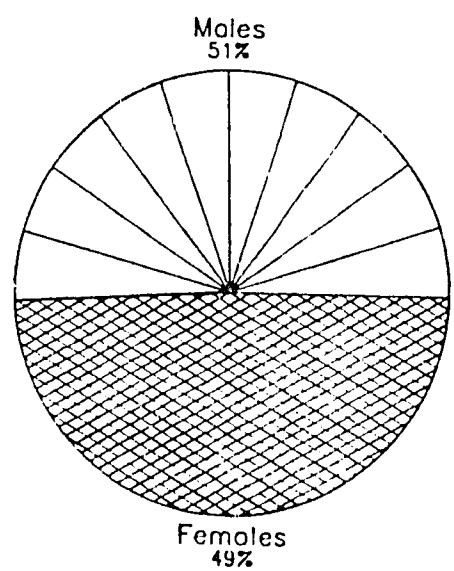


TABLE 1

BEAN/COWPEA CRSP STUDENTS WHO COMPLETED TRAINING IN FY 88

NAME	CITIZENSHIP	GENDER	LOCATION OF STUDIES	COURSE OF STUDY
15 Persons	Brazil		Brazil	Microbiological Control of Insects
Angeles, Rosendo	Dominican Rep.	M	UNL	Plant Pathology (M.Sc.)
Jimenez, Juan	Dominican Rep.	M	UNL	Horticulture (M.Sc.)
Ayeh, Eric	Ghana	M	Tanzania	MSTAT Computer
Monterosso, V.	Guatemala	M	Cornell	Veg Crop (M.Sc.)
Joseph, Ena	India	F	WSU	Food Science (Ph.D.)
Mloza-Banda, Henry	Malawi	M	Tanzania	MSTAT Computer
Acosta, Jorge	Mexico	M	MSU	Crop Science (Ph.D.)
Elizondo-Barron, J.	Mexico	M	MSU	Crop Science (Ph.D.)
Anyika, J.	Nigeria	F	U of Nigeria	Home Science and Nutrition (B.Sc.)
Damola, Theresa A.	Nigeria	F	UGA	Food Science (M.Sc.)
Ezimah, P. O.	Nigeria	M	U of Nigeria	Food Science (B.Sc.)
Ikeme, P. O.	Nigeria	F	U of Nigeria	Home Science and Nutrition (M.Sc.)
Njoku, E. N.	Nigeria	M	U of Nigeria	Food Science (B.Sc.)
Nnanna, Ifendu A.	Nigeria	M	UGA	Food Science (Ph.D.)
Ohajunwa, U. G.	Nigeria	F	U of Nigeria	Food Science (B.Sc.)
Thiaw, Samba	Senegal	M	UCR	Plant Science (B.Sc.)
Fute, Jonas	Tanzania	M	Tanzania	MSTAT Computer
Gadial, Anna	Tanzania	M	Tanzania	MSTAT Computer
Kallunde, Sibuga	Tanzania	F	Tanzania	MSTAT Computer
Mayona, Cosmos	Tanzania	M	Tanzania	MSTAT Computer
Mwandemele, Osmund	Tanzania	M	Tanzania	MSTAT Computer
Nchimbi, Susan	Tanzania	F	UWI	Horticulture (Ph.D.)
Nuhikambele, V. R. M.	Tanzania	M	Tanzania	MSTAT Computer
Nwalyego, Frederica	Tanzania	F	Tanzania	MSTAT Computer
Runkulatile, Henry	Tanzania	M	Tanzania	MSTAT Computer
Brunner, Bryan	U.S.	M	UPR	Agronomy (M.Sc.)
Due, Jean	U.S.	F	Tanzania	MSTAT Computer
Mackey, Julie	U.S.	F	WSU	Food Science (M.Sc.)
Scully, Brian	U.S.	M	Cornell	Veg Crop (Ph.D.)
Silverstein, Lori	U.S.	F	WSU	Food Science (Ph.D.)
Mabasirve, Margaret	Uganda	F	Tanzania	MSTAT Computer
Male-Kayiwa, Beatrice	Uganda	F	Tanzania	MSTAT Computer

COLLABORATION

Evidence from the projects' Annual Reports reflects the lasting strength of collaboration as it enriches the potential for successful research across national boundaries, across disciplinary biases and across production and utilization constraints. Over the years, the collaboration between scientists from different institutions and on different projects addressing related constraints has become a source of strength greater than would be possible for most individual research programs. Through collaboration, scientists are professionally enriched; scientific institutions are strengthened; international research centers are able to significantly expand their scientific efforts; and the local producers, the small farmers--men and women of many nations, benefit.

Evidence of collaborative efforts and their effectiveness are presented in scientists' 1988 reports as follow:

* The Honduras project involves collaboration among the University of Puerto Rico, the University of Nebraska and the Escuela Agricola Panamericana. Project research for FY 89 was planned with the participation of representatives from both universities and the EAP. Research activities of the project are also coordinated with other bean research being conducted at the EAP, such as the projects which deal with biological nitrogen fixation (BNF), drought tolerance and weevil resistance. The existence of a plant breeding program at the EAP provides the mechanism through which bean germplasm with greater BNF capacity or enhanced drought tolerance can be utilized. At the UPR the project collaborates with the BNF laboratory. The antagonistic relationship between *M. phaseolina* and *Phizobium* is currently being studied by the BNF laboratory. The Bean/Cowpea CRSP project supports this research by providing bean genotypes and plots for testing this relationship in the field. The project also collaborates with the USDA/ARS (Agriculture Research Station) bean research project located at the Tropical Agriculture Research Station (TARS). Current collaboration includes the evaluation of different sources of resistance to common blight. The project continues to cooperate with the CIAT (International Center of Tropical Agriculture) bean research program. Cooperative disease nurseries are planted in both Honduras and Puerto Rico. The performance of the most promising small-red breeding lines developed by the project are tested in several Central American countries in CIAT-coordinated regional performance nursery trials. The project maintains contact with bean research programs in other Central American countries through participation in the annual meetings of the PCCMCA (Central American Cooperative Program for the Improvement of Food Crops). The project recently received a seed request from the bean research program in El Salvador for promising small-red breeding lines.

* The Bean/Cowpea CRSP projects in the Dominican Republic (DR) and Honduras continue to be closely linked. Both countries have benefited from an exchange of germplasm and scientific expertise. Honduras will benefit from Pompadour non-specific rust resistance identified in the DR. A red mottled line from the DR provided a source for both the "I" gene for resistance to bean common mosaic virus (BCMV) and red seed color. Previous studies by CIAT indicated extremely tight linkage between red color and susceptibility to BCMV. The dense

pubescence found in the Pompadour bean germplasm collection may provide non-specific resistance to rust. The DR/UNL project also collaborates with the other Bean/Cowpea CRSP projects which deal with diseases. A group of bean lines known to vary in leaf pubescence density were sent to Dr. James Teri through Dr. Matt Silbernagel for use in Tanzania to obtain additional information concerning their rust reaction in East Africa. The project also has collaborated with Dr. Doug Maxwell in the University of Wisconsin project's collection of plant samples in the DR and PR for BGMV. The project works closely with the CIAT bean research program. A Regional Adaptation Nursery was prepared in collaboration with CIAT. Several cooperative nurseries are conducted both in the DR and PR. Travel is planned so that trips to the DR by CIAT and CRSP personnel coincide. CIAT staff participate in the annual project planning meeting. Results from research conducted in the DR may be useful in Jamaica also. Two representatives from Jamaica attended the 1988 Regional Review, Evaluation and Planning Meeting in Costa Rica. A proposal resulted for UPR to assist in the development of a bean breeding program in Jamaica funded by the Jamaican Agricultural Development Foundation. A joint SEA/IICA (Secretary of State for Agriculture/Inter-American Institute for Cooperation on Agriculture) extension/farming system effort will begin soon in the DR. Both UNL and UPR cooperate with USDA Beltsville and Mayaguez in bean rust research and germplasm exchange.

* Puerto Rico is an ideal location for developing tropically adapted bean populations with enhanced levels of disease resistance. Since more than one generation can be grown each year, the expected rate of genetic gain in Puerto Rico is greater than most breeding programs in temperate climates. Moreover, variable rainfall patterns in Puerto Rico permit the sequential selection for resistance to different bean diseases such as rust and common blight. The hot temperatures that prevail during the summer months in Puerto Rico also provide a good environment for selecting beans with more heat tolerance. At the same time, UNL strengthens the plant pathology research capabilities through their excellent facilities for working with single pustule isolates of bean rust and for more sophisticated laboratory techniques used to study the genetic variability and epidemiology of bean rust.

* CIAT and IITA (International Institute of Tropical Agriculture) are the two International Agricultural Research Centers (IARCs) associated with this CRSP. Representatives of their legume programs have participated in CRSP planning and served on the CRSP Technical Committee from the CRSP's inception. Dr. Shiv Singh of IITA and Dr. Douglas Pachico of CIAT serve as the current IARC representatives. In Tanzania, CIAT (Arusha) collaboration has been strong and very effective. They are helping with the on-farm trials, the regional BCMV nursery, the beanfly studies and the 'Lyamungu 85' study. With the CRSP, they co-sponsored the 7th Annual Bean Workshop at Sokoine University of Agriculture (SUA).

* In the Cameroon project, CRSP agronomist Mr. Georges Ntoukam has been an active participant in the Semiarid Food Grain Research and Development Project (SAFGRAD) Cowpea Network. The CRSP/Institut de la Recherche Agronomique (IRA) project has been identified as a center for expertise in cowpea storage entomology.

* In February, Dr. Moffi Ta'Ama of the Cameroon project acted as liaison between the CRSP and the Grain Legume Improvement Program (GLIP) at IITA and participated in an IITA-sponsored cowpea workshop at Ibadan. His close relationship with IITA has facilitated CRSP project research, e.g., needed insecticides and other materials not otherwise available were obtained through the generosity and help of GLIP.

* Dr. Larry Murdock of the Cameroon/ Purdue University project served as a reviewer of IITA/GLIP as part of an internal review in late August/early September 1988. As a result, he was able to see many of GLIP's research sites in Niger and Nigeria and to meet many of the scientists and so become well-acquainted with IITA's activities in cowpea research.

* The RIISP (Research Initiative: Insects of Stored Pulses) group at Purdue University is the CRSP U.S. team for the Cameroon project. They are in the process of completing a collaborative agreement with IITA to undertake a substantial program of research to use biotechnology for cowpea improvement, with particular focus being post-flowering pests (cowpea pod borer, cowpea pod bug complex, and bruchids). Major approaches will include interspecific hybridization, specific gene transfer to confer resistance, and development of innovative screening methodologies.

* IITA/GLIP sent some of its scientists (Drs. H. Rossel, G. Thottappily and G. Hartmans) from Ibadan to IRA sites in Maroua and Garoua in the Cameroon to observe and characterize the cowpea virus problem there. Samples were taken back to IITA headquarters for analysis. While the full report was not yet available, the tentative view of the IITA team was that there may be a new strain of cowpea aphid-borne mosaic virus in the region. Their recommendation was that the CRSP project should use isolated farmers' fields for project seed multiplication since many IRA fields are already infected with the virus.

* One of the strengths of the Brazil/ University of Wisconsin project is the linkages that have been formed among individuals and institutions world-wide. The U.S. scientists, Bliss and Dazzo, are PIs on CSRS (Cooperative State Research Service)/A.I.D. BNF Special Grants with Honduras and Mexico, respectively. The H.C. institution (CNPAF) has funded projects through the International Atomic Energy Agency (IAEA) and NifTAL (Nitrogen Fixation by Tropical Agricultural Legumes) and works closely with the BNF project at the Center for Nuclear Energy in Agriculture (CENA), Piracicaba, Brazil. The project collaborates informally with CIAT scientists working on BNF in beans.

* Both CNPAF and the U.S. PIs have important domestic linkages in their respective countries. CNPAF is an active participant in the N_2 fixation network program in Brazil and collaborates with state institutions in testing both plant materials and inoculant. In the U.S., plant materials having improved N_2 fixation potential are made available to commercial breeders and other scientists. Rhizobial strains are exchanged and inoculant-producing companies (i.e., Nitragin Co.) are active supporters of research through provision of inoculant without charge.

* The University of Wisconsin CRSP scientists, with a high level of cooperation between Brazilian, CIAT and U.S. researchers, have initiated additional interactions with the CRSP personnel associated with

DR/UNL/UPR scientists. Also, contacts have been made with CIAT personnel in Costa Rica, Dr. J. M. Dessert and Ms. Maria Rojas. In Brazil, BGMV-tolerant breeding lines are tested by cooperating researchers at IAPAR (Parana State program) and at UEPAE/Dourados (Agriculture Research Experiment Station/Mato Grosso do Sul State program) where Dr. Fernando Paiva, research collaborator, is located. Dr. Maria Zimmermann, Acting H.C. PI, has initiated contact with IAC (Institute for Agronomy at Campinas) and CENA (San Paulo). Also, one breeding line, LM 30630, is being tested in all states in Brazil and in 39 institutions.

* Dr. Josias Faria, H.C. PI, on leave from CNPAF, has been in the University of Wisconsin laboratory since January 1988 and contributed to the sequencing of the Brazilian isolate of BGMV. Dr. Francisco Morales, virologist at CIAT, has been very helpful in the development of this project. He supplied isolates of bean geminiviruses and traveled to Madison in July to participate in discussions of research and preparation of a grant proposal on BGMV in Latin America. Dr. Morales discussed his observations on geminiviruses in Latin America and the association of a geminivirus on tomato and beans in Argentina. Ms. Maria Rojas also indicated the possible association of these geminiviruses.

* Scientists in Argentina and Peru have requested CRSP scientists' assistance in the identification of geminiviruses. There is a need for a diagnostic kit for the identification of the various geminiviruses in Latin America.

* From the work of the Guatemala/Cornell University project, the University of Idaho is using Performance Systems Analysis (PSA) to analyze its Cooperative Dry Bean Nursery which is annually grown at about 20 sites in 15 states, plus Alberta and Ontario. PSA procedures are being combined with those used by IBSNAT (International Benchmark Site Network for Agro-Technology Transfer) to model bean growth and development. These collaborations are fostered through Western Regional project W-150. Project PIs participated in a workshop on bean yield at CIAT.

* Representatives of the Cameroon/Purdue University and Senegal/UCR projects had a joint meeting in California in March 1988 to discuss collaboration. Subsequent to this, Dr. Moffi Ta'Ama from the Cameroon project visited UCR. The Nigeria/University of Georgia CRSP project is including cowpeas under sealed-drum storage conditions in their evaluation of the development of the hard-to-cook phenomenon. By maintaining low humidity, it is possible that sealed-drum storage slows down development of the hard-to-cook condition in cowpeas. The Senegal/UCR project is using cowpea accessions from the Botswana/Colorado State University and the Cameroon/University of Georgia projects in its search for resistance to the California biotype(s) of the cowpea aphid.

* The Cameroon/Purdue project has agreed to share germplasm, techniques and entomological know-how, as well as to test in Cameroon the barrel hermetic-sealing technique under development by the Senegal/UCR project. The Cameroon/Purdue project has had contacts with the Purdue INTSORMIL (Sorghum/Millet CRSP) project regarding possible future joint research activities where interests of the two CRSPs overlap. This way is open to further developments since Dr. Larry Butler, of the INTSORMIL group, recently joined the RIISP group, the U.S. team for the Bean/Cowpea CRSP/Cameroon project. Dr. Butler will be working with cowpea Striga.

MANAGEMENT SUPPORT GROUPS

Michigan State University (MSU) was awarded the Bean/Cowpea CRSP grant and became the Management Entity (ME) in September 1980. The University created the Management Office (MO) to carry out its responsibilities. Three groups--a Board of Directors (BOD), a Technical Committee (TC) and an External Evaluation Panel (EEP)--work closely with the University and MO to guide the CRSP through policy decisions, budget allocations, research strategy, review and evaluation. In addition, the CRSP enjoys important support both from an A.I.D. Program Officer, Dr. Harvey Hortik, and a liaison to the Board for International Food and Agricultural Development (BIFAD), Mr. W. Fred Johnson.

BOARD OF DIRECTORS

The BOD is the executive committee for CRSP policy and budget. It consists of five institutional representatives (IRs) from the U.S. lead institutions. Members serve for three years. IRs are designated by the chief executives of their institutions to represent them in CRSP policy and administrative matters. These IRs are typically administrators of international agriculture programs, deans of agriculture or experiment station directors. The BOD elects its own chairperson and secretary.

Members of the BOD for FY 88 were:

Dr. Richard L. Lower (Chair)
Associate Dean, College of
Agriculture and Life Sciences
University of Wisconsin

Dr. Lee Sommers (Secretary)
Chair, Agronomy Department
Colorado State University

Dr. E. Walter Coward, Jr.
Director, International
Agriculture Program
Cornell University

Dr. Dale Harpstead
Department of Crop and Soil Sciences
Michigan State University

Dr. Seymour Van Gundy
Associate Dean of Research
College of Natural and
Agriculture Sciences
University of California-Riverside

The BOD held three meetings during the year. Action taken at those meetings included:

1. Review of the EEP report and enactment of policy decisions as appropriate in response to the EEP findings.

2. Guidance in developing grant extension proposal.

3. Guidance and support in the organization and functioning of CRSP management.

4. Review and approval of project and MO budgets for FY 89.

Cumulative BOD actions on CRSP policy are as follows:

1. BEAN/COWPEA CRSP POLICY ON COLLABORATION

   Bean/Cowpea CRSP projects should be collaborative with U.S. and Host Country partners rather than free standing in any one country. The cross-national teams are to collaborate in the planning and implementation of the research and in budget decision-making.

2. BEAN/COWPEA CRSP MULTIDISCIPLINARY POLICY

Because of the complex nature of the food and agriculture issues addressed, the CRSP is encouraged to continue a multidisciplinary orientation in its projects and program-wide activities. Broadly, within the CRSP an integration of the production sciences (e.g., pathology, physiology, breeding) and the non-production sciences (e.g., food science, social science including economics) should be maintained through research and program management.

3. BEAN/COWPEA CRSP WOMEN IN DEVELOPMENT POLICY

In many parts of the world, the primary responsibility for bean and cowpea production rests with women. A major commitment is made by the Bean/Cowpea CRSP to the participation of women in its research projects and training opportunities. Attention to the effects of the program on family life is a major concern. A Women in Development Specialist is essential in the implementation of this policy.

4. BEAN/COWPEA CRSP POLICY ON PARTICIPATION OF NON-CRSP DEVELOPING COUNTRIES

Whereas the Bean/Cowpea CRSP has institution building and strengthening as a major goal, the BOD endorses the concept of CRSP Host Countries inviting scientists, representing limited-resource nations in CRSP regions of the world, to participate in Host Country collaborative research and training efforts which may provide mutual benefits.

5. BEAN/COWPEA CRSP POLICY ON INSTITUTIONAL INVOLVEMENT

The Bean/Cowpea CRSP Board of Directors is concerned about the degree to which institutional participation occurs in CRSP projects beyond activities associated with the individual PIs. Of special concern is the extent to which PIs interact with their Institutional Representatives and the extent to which the administration of each lead institution is aware of the progress. Every institution is strongly encouraged to take significant steps to strengthen institutional ownership through (a) internal project reviews with attention to greater institutional integration, (b) identification of project strengths and weaknesses with appropriate institutional response and (c) when relevant, institutional participation in on-site project evaluations.

6. BEAN/COWPEA CRSP POLICY ON U.S./H.C. DISTRIBUTION OF FUNDS

a. Based on each grant period, not less than 50 percent of A.I.D. funds for support of projects are to be spent in or directly on behalf of Host Countries in order:

   (1) To nourish a climate of collaboration and partnership between the U.S. and Host Country PIs and
   (2) To insure CRSP focus on the solution of H.C. problems rather than on the maintenance of existing research programs of U.S. institutions.

b. However, experience has demonstrated that the U.S. PI is uniquely restricted when institutional indirect costs

for project support are taken solely from the U.S. 50 percent of the total funds. Therefore, the 50/50 split is to be applied to the total project budget exclusive of all indirect costs.

c. Some projects have not settled into a spending pattern in the Host Country comparable to that in the U.S. Thus, in order to maintain a 50/50 split, more of each year's funds must be allotted to the half of the team spending less. Assuming that authorized project spending suggests the progress of approved research activity, it is appropriate to encourage Host Country utilization of project funds. Therefore, where Host Country spending patterns are seriously below the expected level, the Host Country and U.S. PIs will be requested to submit to the MO for TC discussion the reasons for the spending patterns and their suggestions for addressing the issue, including possible recognition of an unrealistic Host Country budget level.

7. BEAN/COWPEA CRSP PROJECT ALLOCATIONS POLICY

If there is an effective and consistent quarterly spending pattern of 80 percent (actual costs reimbursement not including encumbrances), subject to the availability of funds, projects may be considered for allocations up to 100 percent of project need as requested and demonstrated by the Principal Investigator. Maintenance of spending patterns less than 80 percent receive allocations commensurate with the prior spending pattern at a level which will discourage the accumulation of excess carry-forward funds.

8. BEAN/COWPEA CRSP POLICY ON CONTRIBUTIONS OF HOST COUNTRY INSTITUTIONS

While not specifically mandated as in the case of U.S. institutions, contributions from participating Host Country institutions are encouraged and are seen as strengthening the collaborative nature of the CRSP. In-kind contributions and indirect costs or overhead are among the contributions considered appropriate.

9. BEAN/COWPEA CRSP TRAINING POLICY

The Bean/Cowpea CRSP has as a major goal the strengthening of H.C. institutions through the training of H.C. nationals, a critical resource necessary for successful long-term research. To achieve this goal, CRSP projects are to give emphasis to the training of H.C. persons over the training of U.S. persons. This policy adopts a H.C. priority rather than U.S. exclusion and refers to both short-term training and graduate education.

10. BEAN/COWPEA CRSP POLICY ON LOCATION OF SPONSORED GRADUATE TRAINING

It is in the best long-term interest of each Host Country institution that its personnel achieve training from a diversity of institutions in an effort to avoid institutional "in-breeding." CRSP lead institutions and their Host Country collaborators are encouraged to consider using an assortment of different CRSP training sites for nationals from the same Host Country.

11. BEAN/COWPEA CRSP POLICY ON STUDENT SUPPORT

The Bean/Cowpea CRSP Board of Directors endorses the honoring of training commitments made to Host Country students associated with projects which are terminated prior to the completion of the students' programs. This policy is in effect only for the academic degree for which the students are studying at the time of their projects' termination. A total maximum commitment is not to exceed five years for the Ph.D., three years for the Masters, and five years for the Baccalaureate degree. This policy is contingent upon the continuation of the CRSP, the availability of funds and satisfactory academic progress by the trainee.

12. POLICY ON INSTITUTIONS FORMERLY ASSOCIATED WITH THE CRSP

Institution building, through (1) professional training and (2) financial investment in research infrastructure, is an important objective of the CRSP. As such, when a CRSP project comes to an end, a CRSP-generated institutional capacity, beyond that originally in place when the project began, should be evident.

To reinforce this increased capacity and its potential for on-going contributions to CRSP goals, the CRSP network is expanded to include former CRSP institutions as CRSP Alumni. The designation of institutions as CRSP Alumni shall be at the invitation of the Board of Directors and effective only upon the formal acceptance by the designated institution. Subject to the availability of funds, each year limited financial support for Host Country alumni institutions will be made available for specific, approved uses in order to reinforce the CRSP Alumni role.

TECHNICAL COMMITTEE

The TC advises the BOD, ME and MO in areas of project management and technical research strategy and technology. It has specific responsibility for technical monitoring of the CRSP projects, review/revision of the CRSP Global Plan, establishment of priorities for new research, evaluation of new proposals, reviewing budgets, and development of criteria for evaluation of existing projects. The TC consists of five investigators engaged in CRSP projects from U.S. institutions plus a scientist from a participating H.C. institution. TC members are appointed to three-year terms by the BOD. Representatives of the relevant international research centers (CIAT and IITA) also meet with the Technical Committee.

The members of the TC for FY 88 were:

Dr. A. E. Hall (Chair)
Department of Botany
and Plant Sciences
University of California-Riverside

Dr. James R. Steadman (Secretary)
Department of Plant Pathology
University of Nebraska-Lincoln

Dr. M. W. Adams
Department of Crop and Soil Sciences
Michigan State University

Dr. Larry R. Beuchat
Department of Food Science
and Technology
University of Georgia
Agricultural Experiment Station

Dr. Porfirio Masaya
Bean Program Leader
ICTA, Guatemala

Dr. Matt J. Silbernagel
USDA/SEA/AR
Washington State University

Dr. Douglas Pachico
Coordinator, Bean Program
CIAT, Colombia

Dr. Shiv R. Singh, Director
Grain Legume Improvement Program
IITA, Nigeria

The WID Specialist (Dr. Ferguson) is an ex-officio member of this committee. The Deputy Director (Dr. Freed) is the MO liaison with the Technical Committee. The A.I.D. Program Officer for the CRSP (Dr. Harvey Hortik) is the A.I.D. liaison.

The TC held three meetings during the year. Actions taken included:

1. Review of project annual report evaluations and follow-up of the EEP recommendations, with appropriate action taken, including recommendations for FY 89 workplans and budgets.

2. Approval of amended projects for Malawi/MSU, Mexico/MSU and BNF, due to Principal Investigator changes.

3. Review and recommendation of log frame modifications for extension grant proposal.

4. Review and recommendations of extension proposals for FY 89-92.

5. Initiation of CRSP-wide germplasm conservation activities for both beans and cowpeas.

EXTERNAL EVALUATION PANEL

The EEP is advisor to A.I.D./BIFAD, the ME and the CRSP as a whole. It is responsible for the review and evaluation of CRSP management and the progress of project research activities. A scope of work, developed by the Chair of the EEP and the CRSP Program Director, using the A.I.D. Guidelines and input from the BOD and the TC, guides the activities of the EEP throughout the year. Annual Reports of each project are used in the review. Each year the H.C. or U.S. components of some projects are reviewed in the field. For the FY 88 review, Senegal, Nigeria and Tanzania were visited by members of the EEP. A fiscal and administrative management evaluation is made from data provided by the MO. The report of the Panel is published by the MO following each review.

Panel members, nominated by the BOD and approved by the Joint Committee for Agricultural Research and Development of BIFAD, for 1988 were:

Dr. Clarence Gray, III (Chair)
Professor, International Extension
and International Studies
Virginia Polytechnic Institute
and State University

Dr. Edna McBreen
Associate Director
International Programs
State University of New York

Dr. Kenneth O. Rachie
Senior Associate
Winrock International

The review for the previous year, FY 87, concluded with the meeting in Costa Rica in February 1988. Also attending that meeting were the outgoing members of the EEP, Dr. Hugh Bunting of the University of Reading and Dr. Peter Hildebrand of the University of Florida.

THE MANAGEMENT OFFICE

The Bean/Cowpea CRSP Management Office is the operational component of the Management Entity, Michigan State University. The ME is represented by the MSU Vice-President for Finance, the official recipient of the prime grant from A.I.D., and the Dean of the College of Agriculture and Natural Resources, in whose unit the CRSP is organizationally located. The MO, on behalf of the ME, is the link between A.I.D. and thirteen CRSP projects organized through subcontracts to ten U.S. lead universities and one private research institute. These institutions in turn support twelve participating Host Country institutions in Africa and Latin America. The thirteenth project, Botswana/Colorado State University, was phased out in 1988. The MO encourages the development of active, well-coordinated research teams and is the prime support of the management support groups (e.g., Board of Directors) which undergird the overall administration of the CRSP. The major responsibilities of the MO are to:

1. Generate and maintain a Global Plan with U.S. and H.C. input to give direction and order to the conduct of the CRSP;

2. Receive and reallocate funds against that plan, documenting usage of all A.I.D. funds to the CRSP;

3. Establish a system for effective program management, fiscal accountability and the accounting of funds, including the required institutional match;

4. Monitor project fiscal, research and training activity in the U.S. and Host Countries;

5. Provide fiscal/administrative support (e.g., travel clearances, equipment purchase approvals from A.I.D.) and guidance to the lead institutions;

6. Coordinate and guide project work plans, research and training to keep them compatible with the goals of the prime grant and the Global Plan;

7. Keep the basic orientation of the CRSP (i.e., small-scale farmers and women) central in program operations;

8. Encourage project networking and complementarity;

9. Facilitate communications throughout the CRSP and with external groups;

10. Provide staff and administrative support to the Board of Directors, the Technical Committee and the External Evaluation Panel;

11. Enforce the policies and approved recommendations of these groups and A.I.D.;

12. Assist in developing and executing legal documents and agreements between CRSP institutions;

13. Organize and carry-out national and international meetings, conferences and workshops in support of CRSP goals;

14. Represent the CRSP throughout the national and international agriculture and development community;

15. Provide documentation as requested by A.I.D., BIFAD, special review teams and the offices of the Management Entity.

Although CRSP management is complex, this management arrangement makes it possible for a broad array of scientific and technological expertise and facilities to be engaged

in a coordinated way in addressing critical problems of world hunger. Smooth and efficient operation of the MO is essential to the functioning and success of the overall CRSP.

In 1988, the MO staff included:

Dr. Pat Barnes-McConnell, Director
Dr. Russell Freed, Deputy Director
Ms. Sue Bengry, Admin. Assistant
Ms. Annette McGarey, Program Secretary

MANAGEMENT OFFICE ACTIVITIES FOR 1988

Grant Extension. As the present grant extension for the CRSP expires May 6, 1989, much of the activity by the Management Office in 1988 was directed toward consolidation of program efforts (based on the EEP report) and preparation of the final grant extension proposal. Given the three-year span of extensions, proposal preparation events are cyclic in nature. Draft proposals from the projects are initiated at the end of the first year of this cycle. During the second year, these proposals are presented to the Technical Committee for review, to the EEP for comment and finally to the Board of Directors for approval. Documentation of these efforts, an appropriate overview and back-up financial statements prepared by the MO are included with the composite proposal and presented to A.I.D./BIFAD by the Management Office. The grant proposal then moves through U.S. Government-established policies and procedures in the third year.

As a part of the Triennial Review of 1988, the CRSP Guidelines require that an A.I.D. team evaluate the CRSP. This review began June 13-15, 1988 in East Lansing. The team reviewed the MO, the two CRSP projects at MSU (Malawi and Mexico) and the work of MSU researchers collaborating with other CRSP scientists (i.e., INCAP, Brazil). The team then visited CRSP projects at Cornell University and Boyce Thompson Institute. Arrangements and materials for this review were prepared by the MO. The review reported that the institutions visited were found to be very supportive of the CRSP concept. They concluded that the institutions are making contributions to the project beyond that required by agreements; significant scientific progress is being made; and important training is being conducted. This team strongly recommended a five-year extension for the Bean/Cowpea CRSP. In this review, the team noted that the CRSP ME/MO had been able to make substantial program changes and maintain a vigorous research program in spite of funding reductions. The ME/MO was found to be dedicated, efficient and effective. Recommendations made by this group supported training in the face of budget reductions, as training was felt to be vital to maintaining a vigorous and effective research program; development of mechanisms for systematic dissemination of the output from research which can be used by producers and other non-scientists; initiation of efforts to measure and report economic benefits of CRSP projects having reached a point where such analysis is possible; re-emphasis on the need for universities to adequately evaluate and reward good international development work by faculty members. The complete report of this A.I.D./BIFAD Administrative Management Review is available from the MO.

Regional Review. The highlight of the CRSP MO activity this year was the Regional Review, Evaluation and Planning meeting in Costa Rica hosted by the CRSP Board of Directors. This meeting provided important information for the extension request and focused on CRSP activities in all Central and Latin American projects. The Host Country Institutional Representatives of all the projects in this region were invited, as were representatives from A.I.D. offices in other non-CRSP countries in the region. This was the first meeting of the Board of

Directors, Institutional Representatives and the External Evaluation Panel to be held outside the United States. It provided a venue away from regular activities (and telephones) and a time frame for in-depth attention to the progress of the research and to the constraints, generic and particular, which affect the individual research efforts and the achievement of the Global Plan. Exchanges between the individuals and committees/boards who attended were of benefit to all. The H.C. IRs contributed to the BOD's understanding of the benefits and problems faced in each project. The H.C. IRs returned to their institutions with a greater appreciation of the place their research project holds in the Global Plan and of the value to them of the CRSP research being carried out elsewhere. The meetings were also instrumental in helping to facilitate more timely fiscal reporting from the projects. Overall, a more holistic sense of the importance of each scientist, research project and institution evolved from the days spent together.

Within the year, following a vote by the Board of Directors to repeat the initiative, the MO staff began identifying the venue and preparing materials for the 1989 Regional Review, Evaluation and Planning Meeting to be held in Africa.

Future Planning. In looking ahead to the ten-year mark of the Bean/Cowpea CRSP, a proposal was prepared and submitted to the Rockefeller Foundation to support a Bellagio Conference which would involve the PIs and other research scientists to (1) hold a senior seminar on the state-of-the-art of legume diversity research and identify appropriate research strategies for the future, (2) provide a forum for leaders in genetic diversity research and research management and (3) publish a set of seminar papers generated for wide distribution to legume improvement programs around the world. While this proposal was not funded by the Rockefeller Foundation, the need still exists and other options will be pursued.

Information Storage, Retrieval and Dissemination. Collection, storage, retrieval and, subsequently, dissemination of CRSP data are important responsibilities of the MO. The information is organized through a computerized system or in hard copy files and is available to give a comprehensive picture of the CRSP. Information dissemination is handled in response to individual requests; in the form of reports and other publications prepared and distributed; and frequently in response to inquiries from the A.I.D. Bureau of Science and Technology. MO publications for 1988 included the EEP Report of the 1987 Bean/Cowpea CRSP Review, the Bean/Cowpea CRSP Bibliography 1980-1987, the Bean/Cowpea CRSP Student Training Information 1980-1987 and the newsletter Pulsebeat. Also, the report of the Administrative/Management Review of the Bean/Cowpea CRSP was duplicated and distributed to project personnel.

BRAZIL - UNIVERSITY OF WISCONSIN

PLANT MICROBIAL INTERACTIONS IN BEANS:
IMPROVEMENT OF NITROGEN FIXATION AND DISEASE RESISTANCE

PART 1: BIOLOGICAL NITROGEN FIXATION

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Herb Hopen, U.S.	Horticulture	University of Wisconsin-Madison
Fred Bliss (thru Sept. 88), U.S.	Horticulture	University of Wisconsin-Madison
Pedro Antonio Arraes Pereira, H.C.	Soil Microbiology	EMBRAPA/CNPAF
Co-Investigators:		
Frank Dazzo	Microbiology and Public Health	Michigan State University
Robert A. Henson	Horticulture	University of Wisconsin-Madison

RESEARCH OBJECTIVES: To develop superior nitrogen (N_2) fixing cultivars that in association with superior strains of *Rhizobium phaseoli* produce high yields under bean-only and bean-maize cropping systems without supplemental nitrogen fertilizers. This research aims to produce improved adapted cultivars of Brazilian grain types; to develop generalized breeding strategies for increasing N_2 fixation and improving N response concurrently with selection for improvement of other traits in CRSP H.C. and U.S. breeding programs; identify and evaluate strains of *R. phaseoli* for effectiveness and competitive ability against native rhizobia for nodulation sites after inoculation; and define and study the factors in mixed cropping and monoculture bean production systems that either impede or enhance N_2 fixation by defined bean/rhizobia symbiotic combinations.

SUMMARY: Insufficient nitrogen is often a factor limiting the yields of common bean, since production may be relegated to N-poor soils, particularly on subsistence farms where fertilizer N is not used. Increasing the fixation of atmospheric N_2 by bean plants is a viable alternative to meet the large N demand imposed by the protein-rich seeds. The overall goal of this project is to improve the capability of the bean plant to fix N_2 in traditional cropping systems, either with native rhizobia or with the addition of inoculum.

Current research is focused on improvement of the host plant through breeding and selection, identification of superior rhizobial strains, and the optimization of N_2 fixation in prevailing cropping systems. Additional germplasm with superior fixation potential has been identified and is being tested at the Centro Nacional de Pesquisa de Arroz e Feijao (CNPAF--the National Center of Research for Rice and Beans) and in regional trials for other desirable traits. In this way the concept of selection for increased N_2

fixation has been institutionalized as a goal of the national program. Simplified criteria for estimating N_2 fixation are now used in selection instead of more complicated or more costly methods.

Five black bean breeding lines which have performed well in trials throughout Brazil will be released as germplasm jointly by CNPAF/EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria--the Brazilian Enterprise for Agricultural Research) and the University of Wisconsin-Madison. Seed of these lines, which have enhanced capability for N_2 fixation, will be available for development as new cultivars or for further research.

Plant x bacteria interactions for nodule initiation and factors related to nodule senescence are being studied. Possible benefits of corn/bean relay cropping to N_2 fixation are also being investigated. With the availability of improved bean lines and effective rhizobia, studies are being conducted to determine the optimum times and amounts of N application for better nitrogen management in bean production.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

The rich protein content of bean seeds, although a very desirable attribute, imposes a large demand for nitrogen, especially if seed yields are high enough to provide necessary food supplies and be economically attractive compared to other crops. It is estimated that a seed yield of 2000 kg/ha requires the accumulation of from 80 to 110 kg N/ha in the plants and seeds. Since beans are often grown on small farms with N-poor soils and by farmers with limited opportunity to obtain fertilizer N, increased ability of the bean plant to fix N_2 from the atmosphere is an important attribute that can contribute measurably to alleviation of low seed yields due to inadequate plant N.

Identification of Germplasm with Potential for Superior N_2 Fixation

The use of ^{15}N-isotope labelled fertilizers has been shown in several field studies to be the method of choice for estimating the amount of N_2 fixed by legumes. In research conducted at Wisconsin, it has been shown that when plants are grown on low-N soil, the total N accumulated by the plant and/or total seed N are highly positively correlated with N_2 fixed as estimated by ^{15}N-methods. Instead of screening plants for superior N_2 fixation potential based on nodule mass, acetylene reduction, etc., as was done previously, we now use total plant N at the R7 growth stage and seed dry matter and N yield at determining N_2 fixation by plants grown on low-N soils. Sometimes an additional comparison is made for these criteria between plants receiving added N and plants grown under low-N conditions.

Advanced Evaluations

From among the original entries in the 82/83 and 83/84 black bean preliminary yield trials (EPR) sent by CNPAF to locations throughout Brazil, twenty lines were chosen for a second N_2 fixation evaluation at CNPAF in 1986. Based upon the results of this trial, ten lines were entered in a third evaluation in 1988. This experiment has been harvested, but data analyses are not yet completed.

Promising materials from this evaluation will be candidates for use as parents in the breeding program.

This project routinely submits breeding lines and other genotypes selected for N_2 fixation as entries in the black EPR. In three Brazilian states, selections for N_2 fixation have advanced to the level of state trials, the last step before recommendation as varieties. WBR 22-50, WBR 22-14, WBR 22-27, WBR 22-52 and Honduras 35 have performed particularly well in these trials. The WBR lines were bred specifically for N_2 fixation under this CRSP project.

Early-Stage Evaluations

Dr. Pedro Pereira has reassumed responsibility for evaluation of germplasm for N_2 fixation at CNPAF. To facilitate this turnover, the forty most promising materials in the genotype evaluation pipeline were planted in 1988. Selections from this evaluation will form the basis of the next round of N_2 fixation maturity as criteria for entries for the Preliminary Line Trial (EPL) and of parents used in breeding for N_2 fixation. Analyses of these data have not been completed.

A program of evaluating wild (uncultivated) bean germplasm for N_2 fixation was begun at CNPAF in 1988. Since these materials are totally unknown, nodule mass and number are evaluated as well as shoot and root dry matter and shoot N accumulation. The results are not yet complete, but it is hoped that selections from these genotypes will be useful as parents in breeding for N_2 fixation and for other characteristics, e.g., disease resistance.

Until now, germplasm evaluation for N_2 fixation has concentrated on the principal seed types grown in Brazil: black, carioca, and mulatinho. The streamlined selection methodology developed by this project now has enabled the breeding and evaluation program to expand into other types. Populations of rosinha (pink) and short-season lines have been developed and will enter evaluation and selection in 1989.

Evaluation of germplasm for N_2 fixation has become an accepted procedure in the National Bean Improvement Program at CNPAF. Selected materials are tested in two stages: (1) promising high N_2 fixing lines identified by this project are submitted to the EPL to be evaluated for other traits and (2) promising lines from the EPRs and from other projects (e.g., disease resistance, yield breeding, etc.) are evaluated for N_2 fixation by this project. The results of these sequential field trials have provided promising black, mulatinho and carioca lines that can be used as parents for further breeding by this and other programs in Brazil, other CRSP projects and U.S. breeders.

Breeding for Improved Fixation Potential of the Bean Plant

The breeding activities of this project at CNPAF have increased following the return of Pedro Pereira, and results of previous studies provide a sound basis for increased emphasis on breeding. Further improvement for fixation can be accomplished by intercrossing outstanding selections, thus the superior lines identified in the screening trials are particularly important as new parents.

Influence of the Rhizobial Component on Symbiosis

Evaluation of Plant x Bacteria Interactions During Initial Growth and Nodulation. At MSU fourteen different

bean lines were evaluated in sand culture to measure growth of antibiotic-resistant strain CIAT 899 in the rhizosphere and non-rhizosphere and to assess early (10 DAE) root development and nodulation with CIAT 899 or CNPAF 150. CIAT 899 grew equally well in both rhizosphere and non-rhizosphere sand, with little plant genotypic influence on rhizobial growth. Bean root length (Figure 1) was stimulated more by CNPAF 150 than by CIAT 899 in all but one bean genotype, but approximately half the lines formed more secondary roots with CIAT 899 (Figure 2). Nodule formation, determined by root staining and light microscopy, showed high variability among genotypes in both the number of nodules formed by 10 DAE and the response to inoculation with a specific strain (Figure 3). These results suggest that rhizobium is a plant growth-promoting rhizobacterium which can benefit legume production in more ways than biological N_2 fixation alone and that a plant x bacteria interaction exists in early nodule formation.

Effect of Nodule Senescence on N_2 Fixation and Photosynthate Allocation. A flask culture assembly was used in a double-labelling study at MSU to determine N_2 fixation activity and photosynthate allocation in green (senescing) and red (active) nodules. As shown by a higher ^{15}N enrichment than the control, green nodules continued to fix N_2, although at a lower level of activity than red nodules. Results of the ^{14}C pulse-chase experiment indicated that photosynthate continued to be allocated to green as well as red nodules. This finding contradicts the hypothesis that blockage of photosynthate allocation to bean nodules triggers senescence, since it is clear that some green nodules accumulated ^{14}C and fixed N_2.

Inoculant Field Testing. Due to a lack of response to seed inoculation with rhizobium at CNPAF in previous years, field strain evaluations have been discontinued. In 1988, a field experiment was planted to study the effects of side-dressing inoculant on bean nodulation and yield. This trial has been harvested, but the data have not yet been analyzed.

This project participated in a CNPAF multidisciplinary program to develop a bean production management package for the Rio Formoso floodplain. Data from the N_2 fixation experiment are still being analyzed, but it was observed that the soil in this area does not contain indigenous *R. phaseoli*. This finding opens the door for a new generation of inoculant strain and methodology experiments.

Effects of Cropping Systems and Cultural Practices on N_2 Fixation and Productivity

Influence of Corn on Bean N_2 Fixation in Corn/Bean Relay Cropping. At MSU a controlled-environment, sand-culture experiment showed that water-soluble extracts from corn root and leaf residue can have an impact on bean (especially bean root) growth (Figure 4). Growth-promoting substances from these residues may contribute to the benefit of relay cropping on bean root growth and symbiosis with *R. phaseoli* observed in some years.

A 1987 field experiment at CNPAF tested the effects of relay cropping two bean genotypes after five corn cultivars. Preliminary analysis (data not shown) showed a slight stimulation of nodulation by corn cultivar AG 162, but no other differences in bean dry matter or N accumulation.

Figure 1

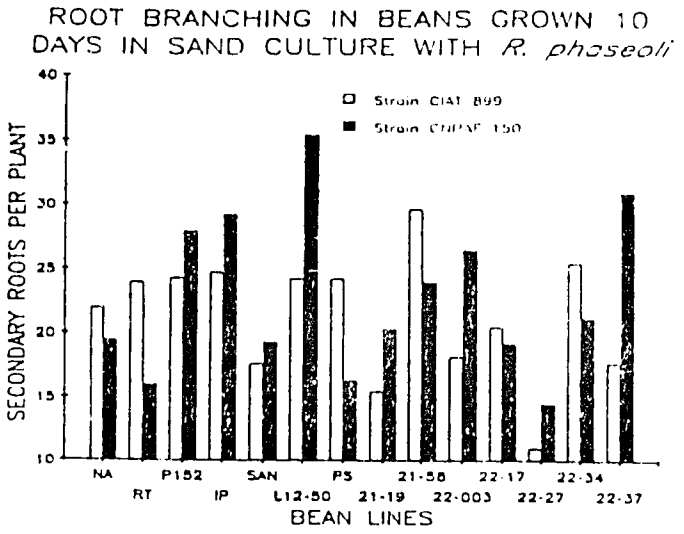


Figure 2

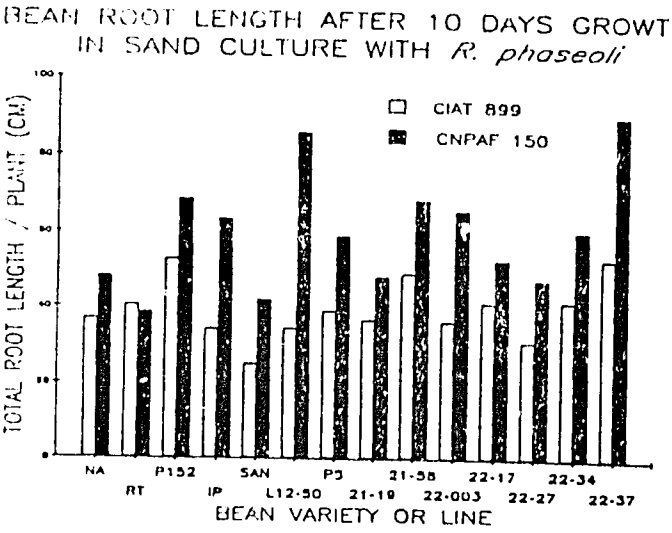
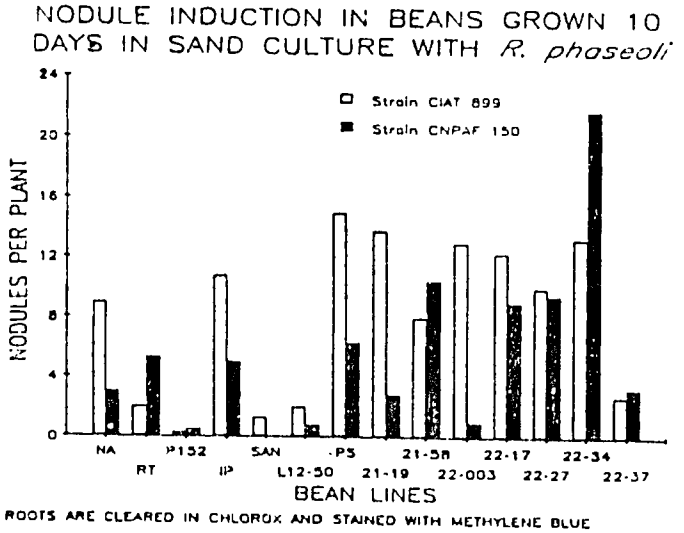
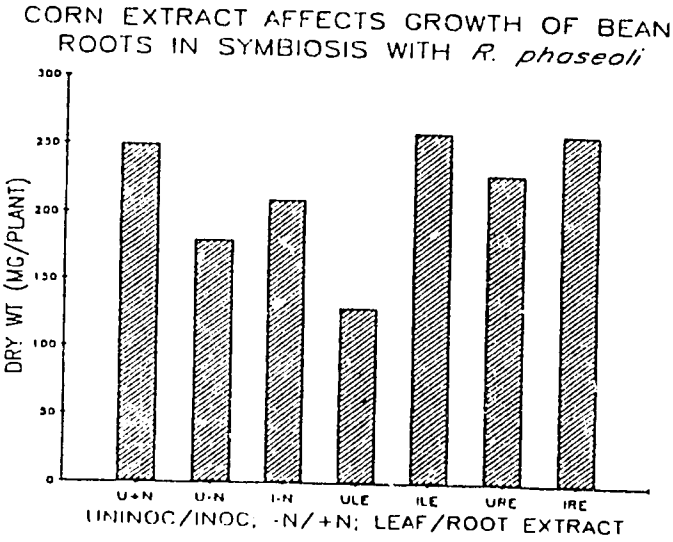


Figure 3



ROOTS ARE CLEARED IN CHLOROX AND STAINED WITH METHYLENE BLUE

Figure 4



Cultural Practices. Preliminary analysis of a 1988 field experiment at CNPAF (data not shown) showed improved bean nodulation and growth with deep plowing compared to conventional and reduced tillage prior to planting. The benefit of deep plowing was evident during periods of excess as well as insufficient rainfall.

Management of N Fertilizer Application to Maximize N_2 Fixation and Yield of Beans. The addition of fertilizer N at planting is usually recommended. In 1987, an experiment was planted for the second time to test the effects of four levels of N fertilizer (0, 5, 10, 20 kg/ha) added at planting to each of five black bean lines known to be good fixers. Although addition of N appears to affect different parameters at various growth stages, at maturity only the 20 kg/ha treatment resulted in a significant seed yield increase over the control. These data suggest that, for good fixers, applying up to 15 kg/ha of N fertilizer at planting will not significantly increase yields.

In 1984 and 1985, experiments with three bean genotypes showed that N fertilizer application during the vegetative stage produced higher yields than similar applications at planting, initial flowering and during pod fill. A repeat of this experiment in 1987 produced the same result, indicating that the vegetative growth stage is the most efficient for applying fertilizer N.

The availability of bean cultivars which are able to fix high levels of atmospheric N_2 and which can also respond to the addition of N fertilizer allows opportunity to improve the management of N fertility to obtain optimum yields under a range of cropping systems and management practices. Therefore complete understanding of rhizobial population dynamics, inoculation methodology, and factors governing initiation and loss of nodule function are important to maximizing N_2 fixation. The availability of bean line/rhizobial combinations that are not suppressed by high levels of fertilizer N would expand the flexibility of nitrogen management options even more.

RESEARCH RESULTS DISSEMINATED AND IN USE

Germplasm Development and Release

Five breeding lines of black bean germplasm (WBR 22-3, WBR 22-8, WBR 22-34, WBR 22-50 and WBR 22-55) have been tested extensively in Brazil for several years. These lines will now be released as germplasm through a "Registration of Germplasm" to be published in the journal Crop Science in early 1989. This will be a joint release by the College of Agricultural and Life Sciences of the University of Wisconsin-Madison and CNPAF, Brazil. Following publication of the registration, seed will be available for further use. Some or all of the lines may be released as named cultivars, particularly in Brazil. For example, WBR 22-50 is being considered for release in Minas Gerais state if it continues to perform well in state trials.

Sister lines of the five above-mentioned black bean lines (WBR 22-14, WBR 22-27 and WBR 22-52) and Honduras 35, selected for N_2 fixation as part of this project, have been included in Rio Grande do Sul and Goias state trials in Brazil and may be recommended as varieties within the next two years.

Rhizobial Inoculant

Bean rhizobial inoculant and strains were provided for studies at

CNPAF and to the USAID/Mexico BNF (Biological Nitrogen Fixation) Limiting Factors Project.

Value of Research to CRSP

This project plays a pivotal role in alleviating constraints to greater productivity due to plant response limitations. On many small and large farms in the tropics and sub-tropics, bean production is consigned to nutrient-poor soils, particularly deficient in N and P. Even on N-poor soils, addition of fertilizer is often not an economically attractive or culturally known practice to small farmers. Thus, improvement of the ability of plants to fix amounts of atmospheric N_2 adequate for moderate yields is an attractive--and perhaps the only--viable alternative for alleviating poor productivity due to inadequate N.

This project is the only one in the CRSP that is directed exclusively toward improving the N_2 fixation ability of beans. While the primary focus is on genetic improvement of the host plant, substantial emphasis is also placed on optimizing the contributions of the rhizobial component and the management of the symbiotic combination.

PUBLICATIONS AND PRESENTATIONS

Araujo, R. S., R. A. Henson, E. Lopes and F. B. Dazzo. 1987. Potential Role of Maize Genotype in Establishment of Rhizobial Populations in Maize/Bean Relay Cropping. Agronomy Abstracts :177.

Bliss, F. A. and J. C. Miller, Jr. 1988. Selecting and Breeding Grain Legumes for Enhanced Nitrogen Fixation. In R. J. Summerfield (ed.) World Crops: Cool Season Food Legumes. Dordrecht, The Netherlands: Klohier Acad. Publishers. pp. 1001-1012.

Bliss, F. A., P. A. A. Pereira, R. S. Araujo, R. A. Henson, K. A. Kmiecik, J. R. McFerson, M. G. Teixeira and C. C. da Silva. 1989. Registration of Five High Nitrogen Fixing Common Bean Germplasm Lines. Crop Science 29:240-241.

Henson, R. A., R. S. Araujo and C. C. da Silva. 1987. Host Plant Selection for N_2-fixation in Beans. Agronomy Abstracts :184.

St. Clair, D. A., D. J. Wolyn, J. DuBois, R. H. Burris and F. A. Bliss. 1988. A Field Comparison of N_2 Fixation Determined with ^{15}N-depleted and ^{15}N-enriched Ammonium Sulfate in Selected Inbred Backcross Lines of Common Bean. Crop Science 28:773-778.

BRAZIL - UNIVERSITY OF WISCONSIN

PLANT MICROBIAL INTERACTIONS IN BEANS:
IMPROVEMENT OF NITROGEN FIXATION AND DISEASE RESISTANCE

Part II: Disease Resistance

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Douglas P. Maxwell, U.S.	Plant Pathology	University of Wisconsin-Madison
Josias C. de Faria, H.C.	Plant Pathology	EMBRAPA/CNPAF/Brazil
Co-Investigators:		
Paul G. Ahlquist	Plant Pathology	University of Wisconsin-Madison
Robert L. Gilbertson	Plant Pathology	University of Wisconsin-Madison
Sally A. Leong	Plant Pathology	University of Wisconsin-Madison
Francisco J. Morales	Virology	CIAT/Colombia
Carlos J. Rava	Plant Pathology	EMBRAPA/CNPAF/Brazil
Maria J. Zimmermann	Bean Breeding	EMBRAPA/CNPAF/Brazil

RESEARCH OBJECTIVES: To characterize the viruses causing bean golden mosaic virus in tropical Americas. DNA probes will be developed to be used in the identification of geminiviruses. This research will include field evaluations of germplasm to identify cultivars resistant to bean golden mosaic virus.

SUMMARY: Diseases are a major factor reducing yields of beans in many areas of Brazil. Bean cultivars with multiple disease resistance are required to increase and stabilize bean production. The goal of this project has shifted from the development of methodologies for use by bean breeders in the development of multiple disease resistance in beans toward the characterization of viruses causing bean golden mosaic. In Brazil, previous research resulted in the development of a sequential inoculation procedure for four pathogens in a field nursery. This technology is routinely applied in the breeding program at CNPAF, Brazil. Resistance to anthracnose and bean common mosaic virus has been combined into breeding lines representing all the major seed color groups cultivated in Brazil. Current research continued on the field evaluation of germplasm for resistance to bean golden mosaic virus (BGMV) at CNPAF and Londrina. This evaluation involved the best material selected in 1987 and breeding lines developed from crosses of black-seeded, moderately BGMV-resistant parents by lines of different seed colors. The nonblack seed types had been evaluated in the greenhouse for resistance to BGMV. Several lines had very good pod formation in these tests. In the U.S., emphasis was on the molecular characterization of BGMV from Brazil and evaluating the variability of the common bacterial blight pathogen by studying restriction fragment length polymorphisms. Both DNAs (DNA A and DNA B) of a

Brazilian isolate of BGMV (BGMV-BZ) have been sequenced. Surprisingly, the sequence similarity between the open reading frames (genes) of BGMV-BZ and a Puerto Rican isolate of BGMV is between 71 and 82 percent, which is the percent sequence similarity between BGMV-BZ and tomato golden mosaic virus, another whitefly-transmitted geminivirus. This level of similarity between the BGMV isolates indicates that these two isolates are very different and might be considered separate viruses or at least distinct strains of BGMV. Efforts to clone the viral DNAs from isolates of BGMV from Guatemala and the Dominican Republic were initiated. An initial field evaluation of a nucleic acid spot hybridization test with BGMV-BZ DNA probes was very encouraging. Field samples were collected in the Dominican Republic and applied to DNA binding membranes. Geminivirus DNAs were detected in beans and several weeds which had symptoms typical of geminivirus. DNA:DNA hybridization techniques were used to examine relationships among *Xanthomonas* pathovars. Specific DNA probes were identified which could be used in the diagnosis of *X. campestris* pv. *phaseoli* and these probes clearly distinguished pathogenic *Xanthomonas* isolates from nonpathogenic *Xanthomonas* isolates which had been obtained from bean debris. A colony DNA:DNA hybridization procedure was used to detect *Xanthomonas campestris* pv. *phaseoli*.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Bean Golden Mosaic Virus (BGMV)

Bean golden mosaic is a serious constraint to bean production in a major agricultural region in Brazil, and its importance also extends beyond Brazil to Argentina, Central America and the Caribbean. This year, BGMV caused losses in northern Goias where normally it hasn't been a problem. Additionally, it was present on beans in the "wet season," and this is not the usual case. Dr. Zimmermann estimated that the total bean harvest in the State of Goias was reduced by 50 percent because of this disease. Because of the high incidence of BGMV at the National Rice and Bean Research Center (CNPAF), no beans were planted for the normal February/March planting as a means of reducing the disease severity in subsequent plantings. There is increased concern about potential losses from this disease, and a national workshop on BGMV will be held at Campinas, SP, Brazil in April 1989.

This disease has also been increasing in intensity in Argentina, and this year Dr. Morales noticed that tomatoes planted in areas with BGMV were also showing geminivirus symptoms. Ms. Maria Rojas from Costa Rica has also noticed the same thing. This raises important questions concerning the relationships between the geminiviruses in tomato and bean.

Development of BGMV Resistant Germplasm. Scientists at CNPAF have had an active program in BGMV control for several years. This has mainly involved the evaluation and development of germplasm with resistance to BGMV. One line, LM 30630, with tolerance to BGMV is in the final process of evaluation before it is released, and it is included in the Preliminary Yield Trials in all states in Brazil. Eleven other lines selected in the BGMV disease nursery are being field tested in all states and at 39 institutions. The evaluation and selection process has continued with the best material from 1987 in the BGMV nursery at CNPAF.

Most of the previous effort has been devoted to selection of black-seeded beans with resistance/tolerance to BGMV. In 1986, Dr. Faria made crosses of BGMV tolerant, black-seeded types with various nonblack-seeded

types that had been selected for BGMV resistance in greenhouse evaluations. F_4 and F_5 generation material was field evaluated, and some breeding lines with tolerance were detected. This effort will continue, since the bean golden mosaic project has been completely institutionalized.

Molecular Characterization of BGMV Isolates. Previous research by R. Goodman and associates (ARS, University of Illinois) has provided detailed descriptions of a particular geminivirus from *Macroptilium lathyroides* collected in Puerto Rico. This geminivirus is capable of causing bean golden mosaic syndrome and has become the "standard" BGMV isolate. Their work did not establish whether all or even any of the natural bean golden mosaic (BGM) infections were caused by this virus. This question is important because evidence indicates that genetic variation might exist in viruses causing BGM in different parts of Latin America and that this variation has caused major complications in ongoing attempts to control this disease by classical plant breeding methods. Thus, our major effort has been to characterize the molecular variation in BGMV isolates. This has involved the DNA sequencing of an isolate of BGMV from Brazil (BGMV-BZ) and initial work on the characterization of isolates from Guatemala (BGMV-GA) and the Dominican Republic (BGMV-DR). The BGMV-BZ isolates are not mechanically transmissible, whereas the BGMV-GA and -DR isolates are mechanically transmissible. The BGMV-DR isolate was selected because it appears to be more aggressive on BGMV-tolerant germplasm developed by CIAT, and it causes more severe symptoms than BGMV-GA. The BGMV-GA and -DR isolates were supplied by Dr. Francisco Morales, CIAT. This research was greatly aided by the arrival in Madison of Dr. Faria who has contributed significantly to the speed of our progress.

Computer-assisted analysis of the sequenced-DNA clones of BGMV-BZ (Figure 1) were performed to determine the similarity to other geminiviruses and the presence of open reading frames (genes). DNA A has four open reading frames (ORF), and it has a region of 181 nucleotides which is nearly identical to a similar region in DNA B. This latter region has been called the common region. So far, all bipartite geminiviruses have a region which is common between DNA A and DNA B, but the sequence in this region is different among the various geminiviruses (see Table 1).

The following characteristics of BGMV-BZ have been identified:

BGMV-BZ DNA A	
Bases 1-181	Common Region
Bases 358-1113	ORF AR1 (putative coat protein gene)
Bases 1508-1110	ORF AL3
Bases 1644-1255	ORF AL2
Bases 24-1556	ORF AL1 (putative polymerase gene)
BGMV-BZ DNA B	
Bases 1-181	Common Region
Bases 558-1317	BR1
Bases 2270-1391	BL1

The three characters in the name for each ORF denote the relevant DNA component, right or left direction of transcription, and the gene order, respectively. The gene organization of BGMV-BZ is similar to the other bicomponent geminiviruses (Lazarowitz, 1987, Pl. Mol. Biol. Reptr. 4:177-192). When BGMV-BZ was compared with the BGMV-PR isolate (PNAS 82:3572-3576), some regions showed clear sequence similarity; however, there were many regions of considerable divergence between the two viruses. The overall divergence of the DNA A's for BGMV-BZ and BGMV-PR is greater

Table 1. Nucleotide homologies at the common region between components DNA A and DNA B and among the common regions of four whitefly transmitted geminiviruses.[a/]

	BGMV.BZ		BGMV-PR		TGMV		CLV	
	A[b/]	B	A	B	A	B	A	B
BGMV.BZ	97.2							
BGMV-PR	58.6	58.6	100.0					
TGMV	68.3	66.7	47.6	46.1	90.4			
CLV	48.8	43.4	51.4	46.7	47.6	45.4	94.9	

a/ BGMV-BZ = bean golden mosaic virus isolate from Brazil; BGMV-PR = bean golden mosaic virus isolate from Puerto Rico; TGMV = tomato golden mosaic virus; CLV = cassava latent virus

b/ A = component DNA A; B = component DNA B

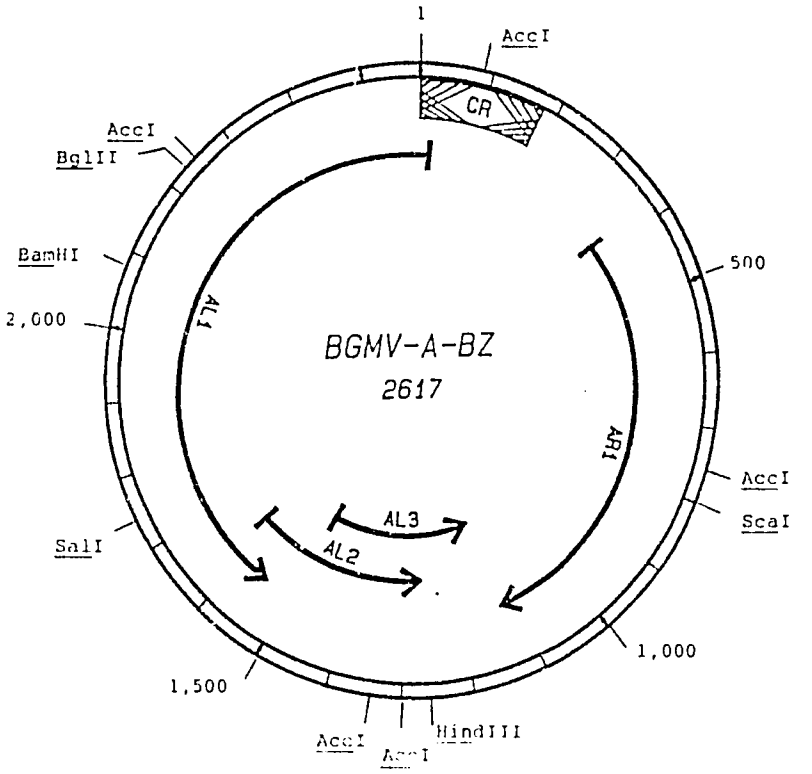


Figure 1. Schematic map showing common region (CR), open reading frames (genes), and selected endonuclease restriction sites for the replicative form of BGMV-BZ DNA A. This map is based on the computer assisted analysis of sequence data.

than 25 percent. This indicates that these two virus isolates should at least be considered different strains and may be different viruses. This latter point is strengthened by the comparison of the sequence similarities between BGMV-BZ and other geminiviruses. The sequence divergence between BGMV-BZ and BGMV-PR is as great as the divergence between BGMV-BZ and tomato golden mosaic virus. Additional observations indicated that the 15 nucleotide repeat found in the common region of BGMV-PR is not present in BGMV-BZ while a 14 nucleotide stem-loop is present in the common region of these isolates as well as in other bicomponent geminiviruses. The computer analysis of this data may indicate possible functions for the ORF's and other regulatory sequences. These sequences will be compared with all the gene sequences in the "Gene Bank."

The DNA B of BGMV-BZ has the common region and two ORF's designated BR1 (558 to 1317) and BL1 (2270 to 1391). The sequence divergence between BGMV-BZ and BGMV-PR is 34 percent which again indicates that these isolates are separate viruses.

Our analysis of BGMV-BZ indicate that this virus has the general gene order known for other geminiviruses and that BGMV-BZ and BGMV-PR are at least different strains and possibly should be designated as different viruses because of the divergence of their DNA's.

We have recently initiated studies on the DNA's from isolates of BGMV from Guatemala (BGMV-GA) and the Dominican Republic (BGMV-DR). These two isolates are mechanically transmitted so infected plants can be grown in plant growth rooms with restricted access. DNA extraction procedures similar to those developed for BGMV-BZ have been used and replicative forms of the viral DNA's isolated. Restriction enzymes have been evaluated for their use in cloning, and an intensive effort is devoted to obtaining full-length clones of these DNA's. A putative, full-length clone of DNA A and a 1 kb clone of DNA B of BGMV-GA have been obtained. No clones of BGMV-DR have been isolated. It is essential to obtain full-length clones of these isolates both for the DNA sequencing, but, more importantly, for the evaluation of the system for development of transgenic plants with viral-derived resistance factor(s).

Development of DNA Probes for Detection of BGMV. The molecular characterization of the BGMV isolates will allow the design of both universal and isolate-specific DNA probes which can be used for the detection and identification of BGMV isolates in beans and other plants. Our results comparing the BGMV-BZ and BGMV-PR DNA A sequences indicate that there will be no difficulty in identifying sequences suitable for use either as the universal or isolate-specific DNA probes.

Our initial effort has been to test the nucleic acid spot hybridization (NASH) method for detection of geminiviruses in leaf material using the BGMV-BZ cloned viral DNA as our DNA probes. This hybridization was done at low stringency so that the probe would detect geminiviruses which are not closely related, i.e., geminiviruses with DNA similarities of 70 percent or greater. This technique was evaluated in the summer of 1988 when Dr. Maxwell collected 58 field samples in the Dominican Republic and Puerto Rico. Geminiviruses were detected in all beans and weeds with typical gemini virus symptoms, whereas plants without symptoms gave negative results. In a bean breeding nursery in Puerto Rico, several bean breeding lines with atypical golden mosaic symptoms gave positive reactions with the probe. It is necessary to develop the BGMV-specific DNA probe before it is

possible to conclude if weeds harbor geminiviruses which will infect beans. This initial test was very encouraging and nylon membranes have been sent to various collaborators who will sample plants in Colombia, Dominican Republic and Costa Rica.

Multiple Disease Resistance

The sequential inoculation technique developed during this project was used routinely at CNPAF to evaluate germplasm for resistance to rust, common bacterial blight, angular leaf spot and anthracnose.

Additionally, resistance to anthracnose and bean common mosaic virus was combined into germplasm representing the major seed color groups grown in Brazil. Initially, the germplasm was evaluated for resistance to the predominant race of anthracnose and then crossed with beans which had the "I" gene (necrotic reaction) for resistance to bean common mosaic virus. Progeny were selected which had resistance to both pathogens and represented the different seed color groups.

Variability of *Colletotrichum Lindemuthianum*

Ms. Glaucia Figueiredo, a graduate student at the Universidade Federal de Vicosa, Minas Gerais, is completing her M.Sc. thesis on the variability of *C. lindemuthianum*. She has been studying isozyme patterns between races of this pathogen. Her results indicate that the growth medium influences the number of isozymes detected for esterase, lactate dehydrogenase and alcohol dehydrogenase, while peroxidase isozymes were the same on two media. Also, the two races studied, Brazilian 2 and Brazilian 5, could be distinguished by their isozyme patterns with esterase and lactate dehydrogenase.

Common Bacterial Blight

Research at UW-Madison has involved three aspects of common bacterial blight of bean: (1) evaluation of dry-leaf inoculum for evaluation of germplasm, (2) the overwintering survival of the bacterial pathogen, *Xanthomonas campestris* pv. *phaseoli* (*Xcp*), and (3) variability of *Xcp* and molecular epidemiology. The first two parts have been completed and limited effort has been devoted to the third objective because the main focus of this project is now BGMV.

Molecular Detection of *Xanthomonas Campestris* pv. *Phaseoli* Using a Plasmid DNA Probe. Identification of plant pathogenic bacteria is currently based on biochemical, physiological and pathogenicity tests that are time-consuming, laborious and often ambiguous and subjective. This can make evaluation of disease resistance to plant pathogenic bacteria difficult and/or time-consuming. We have taken a molecular approach to develop methods to identify this pathogen and, thus, to facilitate breeding for disease resistance to common bacterial blight of bean caused by *Xcp* and *Xcp* var. *fuscans*. A DNA probe from *Xcp* plasmid DNA was developed that can rapidly detect *Xcp*. Also, methodologies for the application of this probe were evaluated (see FY 87 Annual Report). A colony blot procedure has been successfully used for detection of *Xcp* colonies and this procedure allows for the differentiation of *Xcp* from nonpathogenic xanthomonads and other bacteria. Using this procedure, we confirmed that all xanthomonads recovered from primary leaves of bean were *Xcp* and that xanthomonads recovered from bean debris in the spring were nonpathogenic. These results confirmed that xanthomonads on bean primary leaves were *Xcp* and not the nonpathogenic xanthomonads and that these populations can be

used as a measure of the relative resistance of bean cultivars. Secondly, *Xcp* does not overwinter effectively in bean debris, and debris is not an important inoculum source in Wisconsin.

Squash and dot blot hybridization procedures (NASH) were also developed that allow for rapid detection of *Xcp* in bean leaves and provide a quantification of the *Xcp* population in bean leaves. These tests are rapid and precise and are useful diagnostic tools for common bacterial blight and provide a rapid indication of the relative resistance or susceptibility of a bean cultivar based on bacterial population densities in the leaves. We are presently successfully using these methods with viral DNA probes for the detection of bean golden mosaic virus in bean leaves.

These DNA probes from *Xcp* will allow the development of diagnostic kits which can be used for identification of the disease or monitoring the presence of the pathogen, e.g., scientists in the Dominican Republic are interested in the occurrence of *Xcp* on weeds, and these probes would be useful in these studies.

Use of Restriction Fragment Length Polymorphisms to Differentiate Xanthomonads. DNA:DNA hybridization procedures were used to examine the relationship among *Xcp* and nonpathogenic xanthomonads from bean debris, and other *X. campestris* pathovars. Nonpathogenic isolates were clearly different than *Xcp* and other *X. c.* pathovars based on restriction enzyme digestion patterns of total genomic DNA. Restriction fragment length polymorphisms (RFLPs) revealed that *Xcp* strains were clonal whereas nonpathogenic xanthomonad strains were related but a more heterogenous group. Furthermore, *Xcp*, *Xcp* var. *fuscans* and other *X. c.* pathovars were differentiated by total genomic DNA restriction enzyme digestion patterns and RFLPs. *Xcp* and *Xcp* var. *fuscans* were more closely related than were other *X. c.* pathovars. These procedures are useful for differentiating pathogenic and nonpathogenic xanthomonads.

RESEARCH RESULTS DISSEMINATED AND IN USE

Multiple Disease Resistance

Techniques developed by this project for inoculation of beans include the sequential inoculation technique for four pathogens and the use of dry inoculum. These methodologies continue to be used at CNPAF, and Dr. Zimmermann reports that the sequential inoculation techniques are used regularly in the final phases of their breeding program. In the breeding for disease resistance, lines are selected for each disease separately until F_5. In the F_5, all lines developed by the different programs (e.g., disease resistance, yield, architecture, N-fixation, etc.) are evaluated for multiple disease resistance using technology developed in the CRSP project. Between 500-3,000 accessions are evaluated each year in this multiple disease test.

Bean Golden Mosaic Resistance

Line LM30630 with bean golden mosaic tolerance is in the final stages of testing before release by the Agronomic Foundation and Institute of Parana (IAPAR) and is included in the Preliminary Yield Trials in all states of Brazil.

Control of Bean Golden Mosaic

CNPAF scientists evaluated various insecticides for use in controlling the whitefly vector of bean golden mosaic virus, and their findings are being used in Sao Paulo to control bean golden mosaic. Researchers at the Institute for Agronomy at Campinas, San Paulo, Brazil (IAC) report that without the use of

insecticides there would not be any bean production.

DNA Probes for Geminiviruses

Requests have been received from scientists in Argentina, Costa Rica and Peru for assistance in the identification of potential geminiviruses on beans, tomatoes and potatoes. Unfortunately, we are just in the process of developing the viral DNA probe technology, but it appears as if there is a need for this approach.

Germplasm Conservation and Use

Germplasm with tolerance to bean golden mosaic virus is being continually evaluated at CNPAF, and the best material is being tested in each state in Brazil. Germplasm with non-black seeds and some tolerance to bean golden mosaic virus was developed by crosses between bean golden mosaic tolerant black-seeded types and other colored beans. In addition, 158 germplasm lines of various seed colors with resistance to anthracnose and BGMV have been selected.

Impact on Production and Consumption of Beans

This project has had as its objective the development of methodologies for the evaluation of beans for disease resistance. These techniques have reduced the time needed to develop disease resistant cultivars by at least one growing season.

PUBLICATIONS AND PRESENTATIONS

Faria, J., C. 1988. In press. Sequential Inoculation of Common Beans (*Phaseolus vulgaris* L.) for Evaluation of Resistance to Four Diseases. Fitopatologia Brasileira.

Faria, J. C. 1987. Identificacao de germoplasma de feijoeiro (*Phaseolus vulgaris* L.) tolerante ao virus do mosaico dourado em casa de vegetacao. Fitopatologia Brasileira 12:148.

Faria, J. C. 1987. Metodologia para avaliacao do feijoeiro (*Phaseolus vulgaris* L.) quanto a resistencia multipla a doencas. Reuniao Nacional de Pesquisa de Feijao, Goiania, GO. 2.

Faria, J. C., R. L. Gilbertson, F. Morales, S. A. Leong, P. G. Ahlquist and D. P. Maxwell. 1988. Molecular Characterization of a Brazilian Isolate of Bean Golden Mosaic. Paper presented by Dr. Maxwell at the Caribbean Divisional Meeting of the American Phytopathological Society, San Andres, Colombia, September.

Faria, J. C. and M. J. O. Zimmermann. 1988. Control of Bean Golden Mosaic Virus in Common Bean (*Phaseolus vulgaris*) by Varietal Resistance and Insecticides. Fitopatologia Brasileira 13:32-35.

Gilbertson, R. L., J. C. Faria, E. Hiebert and D. P. Maxwell. 1988. Properties and Cytopathology of Bean Golden Mosaic from Brazil. Paper presented at American Phytopathological Society Annual Meeting, San Diego, CA, November.

Gilbertson, R. L., J. C. Faria, F. Morales, S. A. Leong, P. G. Ahlquist and D. P. Maxwell. 1987. Initial Molecular Characterization of Bean Golden Mosaic Virus from Brazil and Guatemala. Paper presented by R. L. Gilbertson at the Caribbean Division of the American Phytopathological Society, Guatemala City, Guatemala, October.

Gilbertson, R. L., J. C. Faria, F. Morales, S. A. Leong, D. P. Maxwell and P. G. Ahlquist. 1988. Molecular Characterization of Geminiviruses Causing Bean Golden Mosaic. Paper presented at the American Phytopathological Society Annual Meeting, San Diego, CA, November.

Gilbertson, R. L., D. J. Hagedorn, D. P. Maxwell and S. A. Leong. In press. Development and Application of DNA Probes for Detection of Bacteria Causing Common Bacterial Blight of Beans. Phytopathology.

Gilbertson, R. L., S. A. Leong, D. J. Hagedorn and D. P. Maxwell. 1987. Molecular Epidemiology of *Xanthomonas campestris* pv. *phaseoli* and *X. c. phaseoli* var. *fuscans*. Phytopathology 77:1718 (Abstract).

Gilbertson, R. L., R. E. Rand, E. Carlson and D. J. Hagedorn. 1988. The Use of Dry-Leaf Inoculum for Establishment of Common Bacterial Blight of Beans. Plant Disease 72:385-389.

Havey, M. J., J. C. de Faria, D. P. Maxwell and D. J. Hagedorn. 1988. Partial Resistance to Anthracnose in Brazilian Land Races of Dry Beans Shows Race Specificity. Euphytica 39:167-174.

Inglis, D. A. and D. J. Hagedorn. 1988. Use of Dry Inoculum to Evaluate Beans for Resistance to Anthracnose and Angular Leaf Spot. Plant Disease 72:771-774.

Inglis, D. A. and D. J. Hagedorn. 1989. Temperature Relations of *Phaeoisariopsis griseola* Cause of Angular Leafspot of Beans. Plant Disease (Information available from Dr. D. J. Hagedorn, University of Wisconsin).

BRAZIL - BOYCE THOMPSON INSTITUTE

INSECT PATHOGENS IN COWPEA PEST MANAGEMENT SYSTEMS FOR DEVELOPING NATIONS

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Donald W. Roberts, U.S.	Biological Control Program	Boyce Thompson Institute
Jose Emilson Cardoso, H.C.	Plant Pathology	EMBRAPA/CNPAF
Co-Investigators:		
Leslie L. Allee	Biological Control Program	Boyce Thompson Institute
Raymond Carruthers	Plant Protection Unit	USDA/ARS
Eliane Dias Quintela	Biological Control Program	EMBRAPA/CNPAF
Heidi Firstencel	Plant Protection Unit	USDA/ARS
Steven Kreuger	Biological Control Program	Boyce Thompson Institute
Stephen P. Wraight	Biological Control Program	Boyce Thompson Institute

RESEARCH OBJECTIVES: To develop insect pathogens as pest management tools compatible with other insect control practices for small farms. In the United States, research will emphasize two insect genera which are serious agricultural pests in both Brazil and the U.S., *viz Empoasca* leafhoppers and *Diabrotica* beetles. The research in Brazil will emphasize chrysomelid (*Diabrotica* and *Cerotoma*) and curculionid (*Chalcodermis*) beetles, as well as other insect species which are serious pests of both beans and cowpeas in Brazil. Research methodologies will include simulations of interactions, pathogen collection, identification, surveys and laboratory evaluation; production and formulation of fungi; field introduction of pathogens and characterization of agricultural patterns.

SUMMARY: Insect pests are major constraints to production of cowpeas and beans in many Latin American, African and Asian nations with large populations of subsistence farmers, including poverty-stricken northeastern and northern Brazil. Insect pathogens are being examined in Brazil and the U.S. as cowpea-pest-management tools compatible (integrated) with other insect control practices. They are particularly attractive for use in cowpea-insect-pest control because they are likely to be safer than most chemical insecticides and they can be produced within Brazil and other cowpea-producing nations without expenditure of hard currency. Both basic and applied studies are underway in Brazil and the United States. Survey for diseased insects in Brazil has provided more than 270 fungal isolates for further investigations. Collaborative research projects have been established with scientists at the Brazilian Research Center for Rice and Beans (CNPAF) and with several other groups within Brazil. These activities have generated data and concurrently increased the awareness of Brazilian scientists of insect diseases. Approximately 110 Brazilians have received training in Brazil in annual

week-long courses on microbial control and cowpea and bean entomology. Five Brazilian students have participated in Brazilian and U.S. university Masters degree programs in insect pathology. One U.S. student is conducting Ph.D. research on phenomena that will increase understanding of the epizootiology of insect diseases in Brazil and the U.S.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Constraint One: Insect Germplasm Pests Collection and Storage

During 1988, 30 fungal isolates were accessioned. Nineteen of these strains were isolated from cowpea insect pests by CRSP-project personnel working in north and central Brazil. The IPRC/Brazil (Insect Pathology Resource Center) collection of entomopathogenic fungi now contains approximately 270 strains.

Screening and Characterization of Fungal Isolates. Three isolates of *Zoophthora (Erynia) radicans* (Entomophthorales) are being characterized with respect to virulence and spore production capacity to define their epizootic potential against *Empoasca kraemeri*. The strain found most virulent against the local (CNPAF) leafhopper population (LC50 = 0.7 spores/mm^2) was a strain originally isolated from *E. kraemeri* collected at CNPAF in 1985. It is interesting, however, that a strain isolated from *Empoasca fabae* in the midwestern U.S., though less virulent (exhibited a higher LC50) than the CNPAF strain, actually killed the leafhopper hosts in a shorter time (Table 1). Also surprising was the extremely low virulence of the third strain examined, since it too originated from *E. kraemeri* in Brazil. The parent host of the strain, however, was collected from the southern state of Santa Catarina. This suggests that the *E. kraemeri* population in Santa Catarina may comprise a biotype physiologically distinct from the type that occurs at CNPAF in central Brazil.

A number of insect pathologists have reported that the time required by entomophthoralean fungi to kill their hosts is not dose dependent. Our results indicate, however, that there is in fact a significant direct relationship between dose and lethal time in the case of *Zoophthora (Erynia) radicans* infection of *Empoasca* leafhoppers (Table 2). This first documentation of such a relationship in an entomophthoralean pathogen-host system indicates that re-evaluation of other such systems may be warranted.

Improvement of Insect Rearing Methods. Procurement of larval and adult chrysomelid beetles for bioassays has been a persistent problem since the project's inception. Greatest difficulties have been encountered in rearing the soil-inhabiting larvae which feed on roots and lower stem of cowpeas and beans.

During 1988, work was conducted toward optimization of laboratory rearing conditions. A large factorial experiment was designed to test four soil types, two levels of soil moisture (percent saturation), and four insect:host-plant ratios. The percentage of beetles developing to maturity was highest in clay soil, and soil at 40 percent saturation supported a higher level of beetle development than soil at 60 percent saturation. The percentage of beetles that matured was directly related to the ratio of plants to larvae. However, the maximum number of beetles was produced at the low ratio of one

TABLE 1: VIRULENCE AND RESTING-SPORE PRODUCTION RATES OF THREE STRAINS OF ZOOPHTHORA RADICANS TESTED AGAINST EMPOASCA KRAEMERI

Strain ARSEF number[a]	Origin	LC50[b] (spores/mm^2)	Regression[c] coefficient	Survival time (hours)	Percentage of infected cadavers with resting spores
1590	E. kraemeri Goias, Brazil	0.7 (0.3-1.3)	1.2 ±0.12	81.9 ±1.19	2.0 (15/742)
1261	E. fabae Wisconsin, USA	1.4 (0.8-2.3)	1.4 ±0.16	72.4 ±1.42	10.8 (75/694)
1229	E. kraemeri Santa catarina	26.2 (8.3-82.8)	0.7 ±0.10	98.4 ±7.02	0.0 (0/334)

[a] U.S.D.A. Agricultural Research Service entomopathogenic fungus (ARSEF) collection.

[b] Mean (95% confidence interval) of LC50s determined in five bioassays against fifth-instar nymphs at 20°C.

[c] Mean probit regression slope ± standard error.

[d] Mean survival time (hours ± standard error) of leafhoppers after inoculation at a rate of ca. 0.6 spores/mm^2 (grand mean of survival times from five bioassays).

TABLE 2: DOSE-DEPENDENT SURVIVAL TIME OF EMPOASCA KRAEMERI INOCULATED WITH THREE STRAINS OF ZOOPHTHORA (ERYNIA) RADICANS

Dose in spores/mm^2	Survival time[a] (hours + SE) of leafhoppers inoculated with ARSEF strain 1590	1261	1229
0 - 1	82.0 ± 2.06	73.4 ± 2.84	95.3 ± 0.64
1.1 - 2	79.8 ± 2.25	71.7 ± 2.46	92.6 ± 0.25
2.1 - 3	74.9 ± 2.78	70.7 ± 2.89	91.0 ± 0.40
3.1 - 4	71.8 -	68.9 ± 3.83	85.9 ± 0.42
4.1 - 10	73.3 ± 4.85	67.0 ± 7.04	81.7 ± 2.03
10.1 - 20.0	71.5 ± 4.34	65.9 ± 6.34	79.5 ± 2.01
20.1 - 30.0	-	60.6 -	-

[a] Weighted mean survival time (hours ± standard error) of leafhoppers inoculated with E. radicans conidia at a dose within the specified range. Each tabulated survival time represents the weighted grand mean of survival times from three to five bioassays conducted at 20°C (values without standard errors based on a single assay).

[b] U.S.D.A. Agricultural Research Service entomopathogenic fungus (ARSEF) collection.

plant to two larvae. Rearing at this high, per plant larval density may be most efficient for production of large numbers of adult beetles, but tests are needed to insure that beetles grown under these conditions are of normal size and fecundity.

Improvement of Field Test Protocols. Assessment of *Beauveria* and *Metarhizium* persistence in the soil following field applications required development of selective media for reisolation of these fungi. Culture media selective for various entomopathogenic fungi are described in the literature, and during 1988 the applicability of several of these for isolation of *B. bassiana* and *M. anisopliae* from a tropical cerrado soil were examined. Tests involved four basal media supplemented with antibacterials. To these basal media were added various combinations and concentrations of four fungicidal agents. The medium most effective in inhibiting growth of contaminant microbes while producing highest counts of *Beauveria* colonies was potato dextrose agar supplemented with 650 ppm dodine, while the most efficient medium for selective isolation of *Metarhizium* was Sabouraud dextrose agar with 250 ppm cycloheximide and 1000 ppm morocide.

Control of the Cowpea Curculio (*Chalcodermus Bimaculatus*) with *Beauveria Bassiana* and *Metarhizium Anisopliae*. The cowpea curculio is generally considered the most important pest of cowpea in NE Brazil. A pathogen with high virulence against adult weevils has not yet been discovered, and thus our effort is currently focused on application of fungi against the susceptible larval and pupal stages in the soil. In addition to targeting a more susceptible pest stage, this control approach has other advantages, including: moderated temperature and solar radiation levels below the crop canopy; avoidance of infection of beneficial predatory insects; and contribution to control of other primary and secondary pests, including chrysomelid beetles, *Elasmopalpus* borers, and various cutworm species that live in close contact with soil.

Since cowpea is produced under a wide range of moisture conditions, laboratory investigations in 1988 included an assessment of fungal applications in soils of varying moisture content (percent saturation).

Field trials were initiated in 1987 at CNPAF. *Beauveria* and *Metarhizium* conidia were sprayed onto the soil in cowpea plots at rates of 250 and 1000 g/ha. Following application, small aluminum cylinders were forced into the soil to a depth of 8 cm and capped with screen. Field-collected, mature larvae of *C. bimaculatus* were then introduced into these cylinder cages 0, 3, 5, and 6 days post-application. The two doses applied did not produce markedly different results, and fungal efficacy did not diminish over the six-day post-application period. These results confirm that soil applications of entomopathogenic fungi have considerable potential for use in a control strategy aimed at reduction of local weevil populations over successive growing seasons.

Control of Chrysomelid Beetles with *Beauveria Bassiana* and *Metarhizium Anisopliae*. Adult chrysomelid beetles of the genera *Diabrotica* and *Cerotoma* are the most important defoliators of cowpeas in Brazil (especially in the Amazon basin). The larvae are also important pests in the soil where they feed on the plant roots and nitrogen-fixing nodules. Although we have isolated a number of fungi which show promise for control of adult chrysomelid beetles, we are currently investigating the effectiveness of fungal applications against the soil inhabiting larval and pupal stages.

Female *Cerotoma* and *Diabrotica* beetles deposit eggs on or slightly below the surface of the soil around the plant stem. The neonate larvae then enter the soil to feed on the plant roots. Treatment of the soil around the plant stems should thus provide excellent opportunity for fungal infection of beetle larvae. To test this, suspensions of *Beauveria* and *Metarhizium* conidia were sprayed onto the surface of soil and stems of cowpea seedling in small containers, after which, newly hatched larvae of *C. arcuata* were introduced. Consequent mortality of ca. 50 percent was obtained in both the *Beauveria* and *Metarhizium* treatments (Table 3), indicating that this control method warrants continued investigation.

Persistence and Vertical Movement of Fungal Conidia in a Tropical Soil. The control projects described above involve application of fungal conidia against immature stages of insects residing in the soil. Design of effective application strategies based on this approach presupposes a basic knowledge of fungal persistence and distribution in the soil following treatment.

Conidia of *B. bassiana* in aqueous suspension were sprayed onto the soil surface in two cowpea plots, one planted 20 days and the other 40 days prior to treatment. One day after fungus application and thereafter at weekly intervals, soil samples from five strata (0 to 6.5 cm depth) were collected from 10 x 10 cm areas in each plot. Of the total number of colony-forming units (CFU) recovered on day one post-application in the younger cowpea stand, 85 percent were located in the upper 2 cm of soil. The numbers of CFUs in the upper soil strata then declined rapidly: relative to the numbers recovered on day one, declines of 30, 54 and 68 percent were noted on days 7, 14 and 21, respectively (Figure 1). The numbers of CFUs in the deeper strata remained low and relatively constant over the course of the study, suggesting that the loss of CFUs from upper strata was not a result of downward movement. In the 40-day-old cowpea stand, the number and vertical distribution of CFUs the day after treatment was approximately equal to that in the younger stand. In contrast, however, a small increase in CFUs in the upper soil strata was noted on day 7 post-treatment, and subsequent samples showed declines of only 18 percent by day 14 and 37 percent by day 21. This slower rate of decline of CFUs is likely due to the more extensive plant canopy which blocked direct solar radiation and moderated soil temperature. CFU numbers in the deeper strata of the 40-day-old stand, as in the younger stand, remained low over time. These observations indicate that spray applications of fungal conidia against *Chalcodermus* and chrysomelid beetle larvae should be made prior to entry of the larvae into the soil, as the inoculum is not likely to reach insects already situated deep in the soil at the time of application.

Control of *Empoasca* Leafhoppers with *Zoophthora (Erynia) Radicans* and *Hirsutella* sp. *Empoasca* leafhoppers are primary pests of grain legumes throughout the tropics. In many areas subject to regular cycles of drought, these insects are considered among the most important pests of cowpeas.

To date, our investigations of *Empoasca* control agents have focused on the entomophthoralean pathogen *Zoophthora (Erynia) radicans*, an important natural control agent of *Empoasca* leafhoppers in central Brazil. Field applications of dry-formulated mycelium successfully initiated an epizootic in a population of *E. fabae* on a forage legume in New York State in 1986, and natural *Z. radicans* infection of *E. kraemeri* was augmented by similar applications to cowpea at CNPAF in 1987.

TABLE 3: PERCENT MORTALITY OF CEROTOMA ARCUATA LARVAE, PUPAE, AND ADULTS FOLLOWING INTRODUCTION OF FIRST-INSTAR LARVAE ONTO SOIL SPRAY-INOCULATED WITH BEAUVERIA BASSIANA AND METARHIZIUM ANISOPLIAE[a]

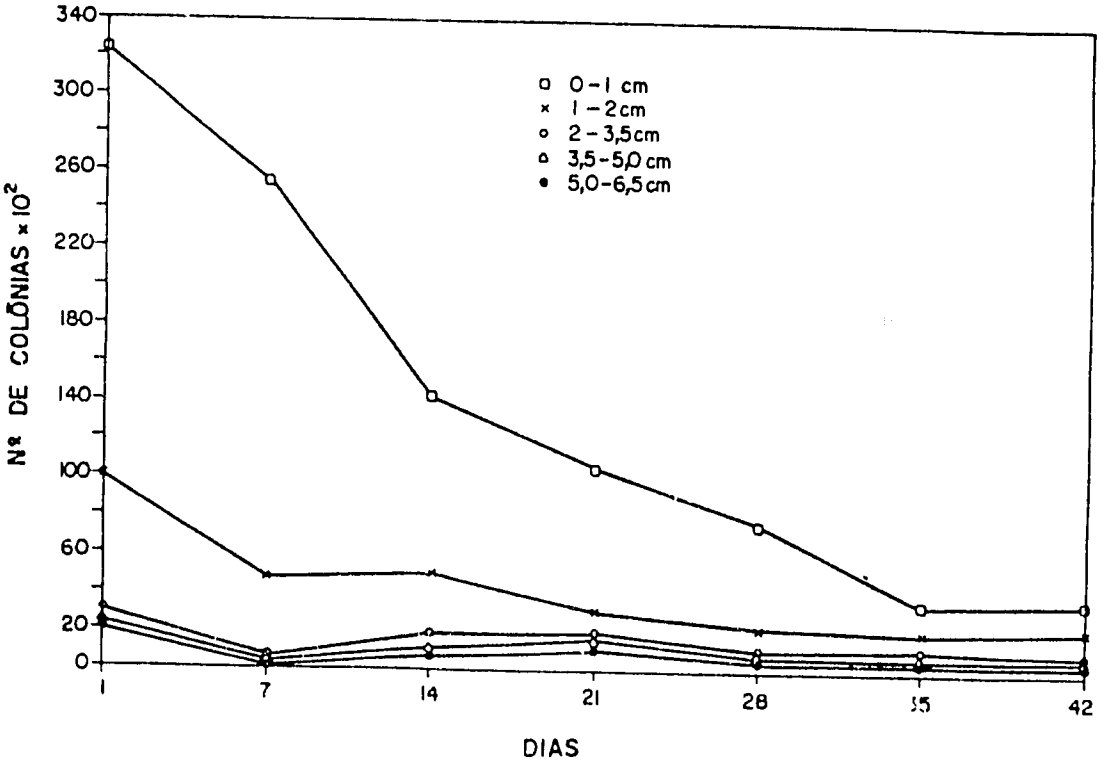
Fungus strain	Dose in grams of conidia/cm^2	Number of surviving insects[b]	Number of dead insects	Corrected[c] % Mortality
B. bassiana				
CP1	5.0×10^{-6}	17	43	57
	1.0×10^{-5}	18	42	54
CP7	5.0×10^{-6}	24	36	38
	1.0×10^{-5}	19	41	51
M. anisopliae				
E6	5.0×10^{-6}	28	32	28
	1.0×10^{-5}	17	43	57
Phil 7	5.0×10^{-6}	21	39	46
	1.0×10^{-5}	22	38	43

[a] Larvae introduced into 21 cm diam. containers containing treated soil and cowpea seedlings; 15 larvae per container, four containers per treatment.

[b] Adult beetles surviving after 30 day .

[c] Treatment mortalities corrected for 35% control mortality according to Abbott's formula.

FIGURE 1



Number of colony-forming units of Beauveria bassinana strain CP5 recovered per gram of soil sampled from five depths in a 20-day-old cowpea field following spray application at a rate of two kilograms per hectare.

During 1988, project scientists conducted the first trials of this fungus under actual producer-field conditions (in the state of Ceara in NE Brazil). Dry-formulated fungus was applied to cowpea foliage in 2 x 2 m treatment quadrants in four different corn-cowpea intercrops over a fifteen-day period (28 April--12 May). Results were initially encouraging in that up to 20 percent of the leafhoppers in the treatment quadrants were infected (determined by microscopic examination of squashed leafhoppers collected three days after application); however, subsequent samples from the quadrants revealed sharp declines in infection levels and leafhopper cadavers supporting fungal sporulation were not found attached to the cowpea foliage.

Virulence studies of three *Z. radicans* isolates described above (Screening and Characterization) also suggest the existence of *E. kraemeri* biotypes with varying susceptibilities to different *Z. radicans* strains. The optimum temperature for sporulation of our Goias strains of *Z. radicans* is ca. 20°C, and nighttime temperatures are low during early May when natural infection levels reach peak levels in Goias. Mean temperatures in the field in Ceara during the time field applications were made remained well above this optimum even throughout the night. Tests are in progress at CNPAF to examine effects of above-optimal temperatures on the development of *Z. radicans* in *E. kraemeri*, and experiments are being designed to test the other factors during the 1989 field season in Ceara.

The discouraging results of the *Z. radicans* trials were countered by an important discovery by project scientists working in Ceara two months after the *Zoophthora* field trials. High-level epizootics of a Hyphomycete fungus, *Hirsutella* sp. (probably *H. guyana*) were encountered in *E. kraemeri* populations in cowpea fields in the littoral near Fortaleza. The density of the *Empoasca* population in one field was only 0.51 leafhoppers per trifoliate, well below the economic threshold despite its occurrence during the early part of the dry season when leafhopper populations normally reach peak levels. Moreover, sampling revealed that the cowpea trifoliates had a mean of 0.93 attached leafhopper cadavers overgrown with fungus and that 30 percent of the living leafhoppers were infected.

This extremely interesting fungus was encountered and isolated by the project PI during initial survey trips to Rio Grande do Norte--also in NE Brazil--in April of both 1982 and 1983. These early season field incidence levels were low, however, and our research effort was subsequently directed toward *Z. radicans*, which appeared to have greater microbial control potential. It is now evident that this *Hirsutella* species replaces *Z. radicans* as the most important fungal pathogen of *Empoasca* leafhoppers in northern Brazil. The fact that this fungus has a higher temperature optimum for growth and sporulation than *Z. radicans* lends support to the hypothesis that the high temperatures of the region (ca. 2° from the equator) are inhibitory to *Z. radicans*.

Socioeconomic Study of Cowpea Preference and Marketing

A small socioeconomic study was done on the distribution system for cowpea and on market preferences for size and color for cowpea types at the consumer level in the city of Fortaleza. A survey with new varieties shown on a sample board was conducted at the markets. Consumer preferences were evaluated on the basis of price differentials indicated by consumers and merchants.

The studies were undertaken on cowpea marketing in Fortaleza, Ceara State at wholesale, retail, and consumer levels. A small amount of seed

money was provided to University of Ceara socioeconomists through our CRSP project to initiate the study. It is intended to visit rural markets and extension agencies to conclude the tasks, if EMBRAPA funds become available to extend the study into rural areas.

Findings from the socioeconomic study include:

Wholesale Level: Cowpea originate from interior of Ceara State, but also from the states of Bahia and Pernambuco.

Cowpea acquired from truck drivers (50 percent); other wholesalers (15 percent) and producers (15 percent) and cooperatives (20 percent) (Truck drivers in NE Brazil frequently purchase a few sacks of cowpea when passing through agricultural areas and sell them for personal profit in cities).

Products are sold to retailers (57 percent), other wholesalers (39 percent) and final consumers (9 percent).

Retailers Level: A total of twenty establishments were visited. These represented all of the major vegetable markets in Fortaleza. Most operated from stalls in "free markets" and most sold less than a ton of cowpea in 1987.

Final Consumers: Consumers in great part (57 percent) stated that prices are determinants of levels of demand. They will switch to flour, rice and vegetables if the price goes very high (double).

For cowpea there is a previously untapped (and unidentified) market for green beans year round. Development of methods for year-round production could provide an interesting move towards more consumption and providing higher value added for producers, as compared to dry cowpeas. Also, development of processing methods for green cowpea could assist farmers and consumers.

Research in the U.S.

Field Plot Tests for Control of *Diabrotica* Larvae with Fungus Dry Mycelium. In the U. S., the species complex of *Diabrotica* (Chrysomelidae) beetles are among the most important pests of corn in terms of damage and treatment costs. Suppression of rootworm larvae populations has traditionally been achieved through the application of chemical soil insecticides. However, recent documentation of rootworm resistance, ground water contamination and soil-microbe degradation of insecticides has fueled increased interest into research on the development of microbial control agents. Because of the prohibitive expense of chemical insecticides to Brazilian subsistence farmers and the close relatedness of the pest Chrysomelid species, information on the development of insect pathogens will be readily transferable to bean and cowpea cropping systems.

Considerable Bean/Cowpea CRSP research has been devoted to discovery of low cost methods for production of entomopathogenic fungi. The promising method used for these field trials involves production of dry mycelium in liquid air-lift culture. The fungus isolates chosen for study were *Beauveria bassiana*, ARSEF 731 (CP5), and *Metarhizium anisopliae*, ARSEF 925 (E9), both of which have been extensively studied in efficacy bioassays against a broad range of bean and cowpea pests.

Two rates of dry mycelium (9.0 and 90 kg/ha) of each fungus were broadcast onto the soil surface of replicate plots (3.7 x 6.1 m) on 6 June. Immediately following application, the mycelium was tilled into

the soil to a depth of 15 cm. Soil samples were taken to obtain baseline fungus inoculum levels, and a commercial field corn variety was planted on 8 June. One month later, on 5 July, when the corn plants were in the three-four leaf stage, the plots were artificially infested with eggs of *Diabrotica undecimpunctata*, the southern corn rootworm (SCR). Eggs were injected into the soil at the base of each plant in a dilute water-agar suspension at a rate of ca. 300 viable eggs per plant. Control plots, untreated with mycelium, were divided into two sets--one set infested with SCR eggs and the other left uninfested.

On 5 August, a census was taken of corn plants that exhibited abnormal goosenecked growth damage that is symptomatic of larval root feeding. At comparable application rates, a lower mean percent of goosenecked plants were observed in *M. anisopliae* treated plots than in those treated with *B. bassiana*. There was no significant difference between the percentage of damaged plants in plots treated with the high rate of *M. anisopliae* and plants in the control plots that did not receive SCR eggs.

On 26 August, random corn plants were dug from each plot, their root systems were washed and assigned a damage rating based on the evidence and extent of larval feeding. Again, at comparable rates, plants from plots treated with *M. anisopliae* had consistently less root damage than plants from *B. bassiana* treated plots. Thus, for these trials, there was a positive relationship between root system damage and above ground goosenecking of the plant stalk.

Emergence of adult rootworm beetles from plots was determined by trapping them in pyramid-shaped cages placed over individual corn stalks (cut to ca. 30 cm). Collections were made over the period 5-26 August. In addition to the artificially infested SCR, naturally occurring *D. virgifera*, western corn rootworm (WCR) and *D. barberi*, northern corn rootworm (NCR) were active in the field as evidenced by their presence in the emergence cages. Looking at the combined mean totals for the three species, the lowest emergence was seen in the *M. anisopliae* treated plots (even lower than control plots receiving no SCR eggs). These data, in general, support the apparently greater efficacy of *M. anisopliae* in suppressing rootworm induced plant damage. Interpretation of these data is difficult since the mean emergence per plant was low (the mean of 6.5 SCR adults obtained from control plots receiving eggs represents less than 3 percent of the viable eggs artificially introduced).

Yield data was not yet available at this writing, but plants typically having root damage ratings of 3 generally have a 10 percent reduction in yield (Sutter and Branson, 1986).

Soil samples from all plots were taken throughout the growing season to determine changes in *M. anisopliae* and *B. bassiana* titer resulting from the initial dry mycelium inoculum. The samples were plated onto a selective medium to detect changes in soil titer. On 8 July, one month following incorporation of the dry mycelium inoculum, mean soil titers increased, indicating conidia production from hydrated mycelium particles. The period between 8 July and 9 August was the time when the infested SCR larvae were active in the corn root system. Titers of *B. bassiana* from both the low and high treatments decreased sharply during this period while the low treatment rate of *M. anisopliae* showed only a moderate decline and the high rate continued to increase. We would normally expect regeneration of fungus propagules as colonized host cadavers release conidia into the soil. These data, along with the

plant damage and adult emergence data, suggest that the rootworm larval population complex present in the field was more susceptible to the *M. anisopliae* isolate than the *B. bassiana* isolate.

Insecticide application rates of 9.0 kg/ha are acceptable to U.S. growers. Relatively stable soil titers and moderate root damage were seen with this application rate of the *M. anisopliae* isolate. We will continue to screen other fungus isolates against corn rootworm larvae in laboratory bioassays. In addition, if resources are available, we will examine the potential for a build up of a pathogen reservoir in field soil through repeated yearly applications of fungus inoculum and measure the resulting suppression of damage and efficacy against rootworm populations.

Laboratory Bioassay of Dry Mycelium Against Pest Scarab Larvae. Management of root damaging Scarab grubs with biological control agents is receiving increased attention, since conventional soil insecticides do not provide reliable control of many pest species. Generally referred to as "white grubs" this group of insects causes severe crop loses in many third-world nations. A large number of entomopathogenic fungal isolates have been obtained from infected grubs. Bioassays of the efficacy of dry mycelium against selected pest species were conducted during the winter in collaboration with Dr. Michael Villani from the New York Agricultural Experiment Station, Geneva, New York.

Sporulation of dry mycelium inoculum and propagule longevity for *B. brongniartii* and *M. anisopliae* was determined from soil samples. Despite considerable differences, ample sporulation from both species of mycelium occurred after three-weeks incubation in soils held at all temperature and moisture treatment combinations (initial inoculum level was ca. 357 mycelium particles per gram of soil). Propagule longevity appears to be most adversely affected by the combination of high soil temperature and high moisture. Sterilized control soils indicate the potential fungus sporulation and longevity and demonstrate the need for increased research into formulation technology that will enhance protection of these entomopathogens from soil microbial degradation. The higher recovery rates of fungus from control soil containing no grub compared to recovery rates from soil containing a live grub indicates that viable propagules were removed from the soil, probably by adherence to the host cuticle and/or passage through the digestive tract.

These bioassays have yielded data on the efficacy of the dry mycelium of these fungal isolates against pest grub species and the effects of important soil abiotic and biotic factors on inoculum stability. This information will provide an excellent starting point for research into other fungal pathogen/host relationships in soil environments, including the Coleoptera being investigated by our CRSP team in Brazil.

Formation of Infection Structures of *Zoophthora Radicans in vitro*. Identification of factors which encourage formation of infection structures (appressoria and appressorium-like structures) by entomopathogenic fungi during invasion of insect cuticle enables us to enhance infection and epizootics of pests in the field by providing the fungi with appropriate stimuli. Appressoria and appressorium-like structures formed by *Zoophthora (Erynia) radicans* while invading exocuticule of *Empoasca fabae* were produced using an *in vitro* system. The morphology of these structures was similar to those produced *in vivo*. However, the time required for their formation was longer *in vitro* than on

5th-instar nymphs of *E. fabae*. Optimum induction of appressoria and appressorium-like structures was achieved by showering conidia onto 2 percent water agar and overlaying them with SDY (Sabouraud dextrose broth plus 1 percent yeast extract) liquid medium, then covering with a coverslip. Appressoria were also formed by capilli conidia on water agar overlaid with SDY diluted 50-fold under a coverslip 30-32 hours post inoculation at 23°C in the dark.

Literature Cited

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Ent. 18: 265-267.

Mayo, Z. B. 1986. Field evaluation of insecticides for control of larvae of corn rootworms. pp. 183-203. In: Krysan, J. L., and T. A. Miller (eds.). Methods for the study of pest *Diabrotica*. Springer-Verlag, NY.

Sutter, G. R. and T. F. Branson. 1986. Artificial infestation of field plots. pp. 147-158. In: Krysan, J. L., and T. A. Miller (eds.). Methods for the study of pest *Diabrotica*. Springer-Verlag, NY.

RESEARCH RESULTS DISSEMINATED AND IN USE

1. The project published or had in press nine research publications and reviews for FY 88. In addition, eight presentations were made at scientific meetings on the results of our work.

2. A very obvious product of our CRSP project in Brazil is the five students we have trained for Master's degrees and the approximately 110 agriculturalists who have participated in our annual one to two week long courses on insect pathology in Brazil. These people tend to be very enthusiastic about the topic and many are conducting research in a wide variety of locations in Brazil.

3. A long-term resource developed as an outgrowth of our CRSP project in Brazil is the large collection (270 isolates) of entomopathogenic microorganisms collected by project staff and by affiliates.

4. Methods developed in the course of our project for producing and formulating entomopathogenic fungi are expected to be utilized by both government and industrial organizations worldwide in developing this class of fungi as pest-control agents. In addition, these methods may be applicable by plant pathologists to control fungal plant diseases and weeds.

5. Some of our most serious insect pests in the U.S., because of pesticide tolerance and loss of registered insecticides, are soil insects such as the corn rootworm (*Diabrotica* spp.). *Diabrotica* is also a pest of beans and cowpeas in Brazil and therefore is under study by our project. Findings will be applicable to both nations.

PUBLICATIONS AND PRESENTATIONS

Butt, T. M., S. P. Wraight, S. Galaini-Wraight, R. A. Humber, D. W. Roberts and R. S. Soper. 1988. Humoral Encapsulation of the Fungus *Erynia radicans* (Entomophthorales) by the Potato Leafhopper, *Empoasca fabae* (Homoptera: Cicadellidae). Journal of Invertebrate Pathology 52:49-56.

Firstencel, H., T. M. Butt and R. I. Carruthers. A Flourescence Microscopy Method for Determining the Viability of Entomophthoralean Fungal Spores. Poster session at 21st Annual Meeting of Society for Invertebrate Pathology, San Diego, CA. August 14-18.

Krueger, S. R., G. Villani and D. W. Roberts. Bioassay of *Beauveria brongniartii* and *Metarhizium anisopliae* Dry Mycelium in Soil Against Scarab Larvae. 21st Annual Meeting of Society for Invertebrate Pathology, San Diego, CA, August 14-18.

Lord, J. C., B. P. Magalhaes and D.W. Roberts. 1988. Biological Control of Cowpea Pests in Brazil. In E. E. Watt and J. P. P. Araujo (eds.) Cowpea Research in Brazil. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, and Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), Brasilia, Brazil, pp. 301-313.

Magalhaes, B. P., J. C. Lord, S. P. Wraight and D. W. Roberts. 1988. Pathogenicity of *Beauveria bassiana* and *Erynia radicans* to the Conccinellid Predators *Coleomegilla Maculata* and *Eriopis connexa*. Journal of Invertebrate Pathology 52:471-473.

Magalhaes, B. P., E. D. Quintela, J. F. da S. Martins, S. P. Wraight and D. W. Roberts. 1987. Controle biologico de praga do feijao. Reuniao Nacional de Pesquisa de Feijao, 2, Goiania, Goias.

Magalhaes, B. P., M. Yokoyama and F. J. P. Zimmermann. 1988. Metodos de Amostragene Flutuagao Populacional de *Empoasca kraemeri* (Ross & Moore 1957) (Homoptera: Cicadellidac), Cerotoma arcuata (Olivier 1791) Diabrotica speciosa (Germar 1824) (*coleoptera: Chrysomelidae*) no feijoeiro, em Goias. Anais da Sociedade Entomologica do Brasil 17(1):81-95.

May, P. H., S. M. Teixeira and A. C. de Santana. 1988. Cowpea Production and Economic Imprtance in Brazil. In E. E. Watt and J. P. P. Araujo (eds.) Cowpea Research in Brazil. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), Brasilia, Brazil, pp. 31-62.

Wraight, S. P., T. M. Butt, S. Galaini-Wraight, L. L. Allee, R. S. Soper and D. W. Roberts. 1988. Investigation of the Germination and Infection Processes of the Entomphthoralean Fungus *Erynia radicans* on the Potato Leafhopper, *Empoasca fabae*. Poster session at 21st Annual Meeting of Society for Invertebrate Pathology, San Diego, CA, August 14-18.

Quintela, E. D., J. C. Lord and S. B. Alves. 1987. Pathogenicidade de Beauveria bassiana (*Hyphomycetes: Moniliales*) a larva e adulto de Chalcodermus bimaculatus (*coleoptera: Curculionidae*), praga de caupi. Reuniao Anual de Genetica de Microorganismo, 14, Goiania, Goias.

Quintela, E. D., S. P. Wraight, S. M. dos Santos and D. W. Roberts. 1988. Investigation of the Movement of *Beauveria bassiana* Through a Tropical Cerrado Soil Using a Selective Isolation Medium. Abstracts of 21st Annual Meeting of Society for Invertebrate Pathology, San Diego, CA, August 14-18.

CAMEROON - PURDUE UNIVERSITY

PRESERVATION OF POST HARVEST COWPEA BY SUBSISTENCE FARMERS IN CAMEROON

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Larry Murdock, U.S.	Entomology	Purdue University
Zachee Boli, H.C.	Experiment Station	Institut de la Recherche Agronomique
Co-Investigators:		
Chevalier Endondo	Agronomy	Institut de la Recherche Agronomique
Laurie W. Kitch	Entomology	Purdue University
Georges Ntoukam	Agronomy	Institut de la Recherche Agronomique
Richard E. Shade	Entomology	Purdue University
Moffi E. Ta'Ama	Agronomy	Institut de la Recherche Agronomique
Jane L. Wolfson	Entomology	Purdue University

RESEARCH OBJECTIVES: To improve cowpea storage technologies for subsistence farmers in the Cameroon to minimize losses caused by storage insects. Such technologies will be based upon an understanding of traditional storage systems and appropriate techniques for intervention. This will include surveys of cowpea storage methodologies used by low resource farmers in the Cameroon and assessment of insect infestations in stored cowpeas; evaluation of alternative cowpea storage technologies; development of improved screening methods to discover and evaluate resistance to storage insects; delineating mechanisms, nature and heritabilities of resistance in cowpeas to storage insects.

SUMMARY: The Cameroon/Purdue project was initiated March 1, 1987 to focus on the problems of insect-caused losses of cowpeas in storage--a national and global constraint to the availability of cowpeas as food in developing nations. Project strategy is to devise implementable storage technologies to reduce losses to insect pests and to enhance these technologies through short, mid- and long-term research. Project training strategy is to assist Institut de la Recherche Agronomique--Cameroon (IRA--the Institute of Agronomic Research) in building a research team capable of addressing storage and other problems of cowpea production and utilization over the long-term. Progress during the first full year of the project has included: (1) the invention at Purdue of a new and simple prototype technique to kill resident insect infestations in cowpeas with solar energy using cheap, widely available materials, and initiation of work toward testing and adapting this technique in Cameroon; (2) increased understanding of how low-resource farmers in northern Cameroon store and process cowpeas; (3) recognition that *Bruchidius atrolineatus* potentially causes serious losses to cowpeas in northern Cameroon around the time of harvest; (4) the tentative identification of *Vigna* types

with promising seed and/or pod resistance; (5) initiation of a small-farmer network to test project-recommended cultivars and technologies and to provide feedback about their performance and problems; (6) increased information about effective agronomic practices for cowpea production, including insecticide treatments; (7) preparations for establishing at the IRA/Maroua station connections to CGNET, expected to be completed in November 1988; (8) beginning of graduate study toward the M.S. degree in agronomy at Purdue of Mr. Chevalier Endondo; (9) the strengthening of ties, mutual understanding and commitment between the IRA leadership, both in Maroua and Yaounde, and Purdue CRSP scientists. One manifestation of this commitment is IRA's determination to hire a breeder to work in the context of the project; (10) increased understanding of the USAID/Yaounde Mission's needs and commitment to the project; (11) strengthened ties and cooperation of the CRSP project with the IITA Grain Legume Improvement Program (GLIP) and with the SAFGRAD (Semiarid Food Grain Research and Development Project) Cowpea Network.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Constraint 1--Inadequate Knowledge of Storage Methods and Insect Infestations in Northern Cameroon

Without baseline knowledge, it is not possible to assess changes in storage methods used and reductions in the degree of insect infestation resulting from dissemination and application of new, simple technologies developed in the project. Additionally, this knowledge is needed to identify which storage insect species are causing losses to permit addressing the most important insect constraints first.

Research in Process: In collaboration with IRA and NCRE (National Cereals Research and Extension Project) scientists, Dr. Jane Wolfson carried out a survey of cowpea storage methodologies and attendant insect infestations in stored cowpeas in four areas of northern Cameroon in November 1987. Interviews were conducted with 38 individual cowpea growers who identified themselves as belonging to 19 ethnic groups. Cowpea samples were collected at numerous sites and held until the insects infesting them emerged.

The results of the first survey are preliminary in the sense that a relatively small number of farmers in a limited number of areas could be interviewed, and a small number of cowpea samples taken and assessed. Further, the sample represents only a single year. With these caveats, the provisional picture of cowpea storage in northern Cameroon is as follows:

1. Storage is a process. Farmers do not, in general, harvest their cowpeas and then place them in one location where they remain until consumed, sold, used for seed or destroyed by insects. Rather, the cowpeas are placed in one location for a variable period of time and then moved to a second location;

2. Farmers store their cowpeas in different structures and the treatment (if any) that the cowpeas receive before they are placed into the structure appears related to (or limited by) the storage structure. For example, cowpeas stored in the farmers' houses were usually untreated against storage insects while most granary-stored cowpeas were treated in some way;

3. Cowpeas generally remain in the pod during the first phase of

storage and are threshed prior to the second phase of storage;

4. Cowpeas intended to be used as seed for next year's planting usually receive some special treatment intended to preserve them even if the rest of the harvested crop is not treated in any special way;

5. Most farmers use locally available materials, either ash from cooking fires or local botanicals to protect their cowpeas. These materials are combined with stored cowpeas according to detailed protocols;

6. Most farmers interviewed sell some of their cowpeas and do so when they need cash. Farmers are very aware of the seasonal market price fluctuations but often sell soon after harvest because of the need for cash rather than later when the prices are higher;

7. All farmers are familiar with signs of insect infestation and they are aware that the infestations they suffer can be influenced by their storage method. Farmers usually have some method for dealing with insect-infested grain; they will consume it quickly, feed it to animals, sell it, treat it with insecticides, etc., methods that help them salvage some of their investment.

Insects emerging from the cowpea samples obtained from farmers were sent on to the U.S. National Museum for identification. The predominant cowpea storage pest found during the immediate post-harvest period in northern Cameroon was *Bruchidius atrolineatus*, a peri-harvest pest which does not reproduce continually in storage but nevertheless does come in on the crop at harvest and completes its development and emerges while the cowpeas are in storage. The cowpea weevil (*C. maculatus*), which does reproduce continually in storage and which is the long-term storage pest, was present in Dr. Wolfson's samples, but in much lower numbers than *B. atrolineatus*. Among minor species were *C. chinensis*, as well as specimens of what may be a new species of bruchid.

It is important to know that *B. atrolineatus* may be a major pest of stored cowpeas during the early post-harvest period in northern Cameroon. It can be anticipated that farmers who may try growing cowpea cultivars with "storage weevil" resistance (i.e., IITA-developed resistance to *Callosobruchus maculatus*) may reject them as useless because, while they may indeed have resistance to *C. maculatus*, they may not be resistant to *B. atrolineatus*. The predominance of *B. atrolineatus* during the early post-harvest period may explain why many Cameroon farmers who use ash don't always have full confidence in it; while ash may (or may not) protect cowpeas against reinfestations by *C. maculatus* in storage, ash is probably valueless in preventing emergence when threshed seeds containing *B. atrolineatus* larvae are put into storage with ash. The insects living within the seed continue growing and emerge normally, causing the farmer--who doesn't know the seeds are already infested when they were put into storage and sees that holes have appeared in her/his cowpeas during storage--to conclude that ash storage doesn't work.

To expand on this initial survey, Dr. Wolfson will be returning to Cameroon in January 1989 to visit more villages and describe farmer storage practices in greater depth. The second survey will provide additional information on storage methods, including possibly important botanicals in use that can affect storage losses, on the insect pests present, as well as give a better sampling of farmer's methods and storage losses.

Based on the results of the first year's survey, experimental work will increasingly focus on techniques to control both *B. atrolineatus* and *C. maculatus*, give more attention to an experimental analysis of the value of ash storage for storage weevil control and pay particular attention to *B. atrolineatus* infestations and how they may begin in the field.

Constraint 2--Lack of Simple, Effective Technologies for Storing Cowpeas after Harvest to Minimize Losses to Storage Pests

This limits the availability of cowpeas as food in Cameroon.

Research in Process: A series of laboratory and field experiments were conducted at Purdue and in Maroua to determine the feasibility of using solar radiation to kill cowpea weevil infestations in storage. The rationale was that solar energy is abundantly available in the tropics and might be used to raise the temperatures of cowpeas to levels lethal to bruchids infesting them.

Laboratory studies at Purdue, West Lafayette, showed that brief exposure to temperatures of 65°C for as little as 5 minutes will kill 100 percent of all stages of *C. maculatus*. Accordingly, a simple solar heater was devised using two sheets of plastic sheeting, one black and one clear, by exposing them to direct sunlight. It was found that under full sun temperatures between the two plastic sheets of 60 to 65°C could be attained within minutes and maintained for three hours during the period around noon at the latitude of West Lafayette. Encouraged by these preliminary field results, additional laboratory tests were conducted to determine the lethal temperatures for all stages of the cowpea weevil when the insects were exposed for one full hour to elevated temperatures. Results showed that 100 percent mortality occurs when any stage of the cowpea weevil is exposed to 57°C for one hour.

Next, a series of solar heaters were constructed using different fabric types (plastic, cotton and burlap) and colors (white, beige, black, brown, and blue) that might be available to Cameroonian farmers. These materials were tested by placing them on the ground, spreading *C. maculatus*-infested cowpeas on them, and covering cowpeas and cloth with a clear plastic sheet whose edges were secured with small stones. The infested cowpeas were exposed to the sun for one hour. Three replicate tests were conducted on three clear to partly-cloudy days over a period of one week. Under these conditions, it was found that: (1) seed temperatures in all solar heaters, regardless of fabric type and color, were sufficiently high to kill all stages of the cowpea weevil; (2) the cooking time of heat-treated seeds was not significantly longer than untreated seeds; (3) there was at most a 10-15 percent reduction in seed germination in some treatments, and no reduction in others.

In September 1988, Laurie Kitch, Georges Ntoukam and Larry Murdock initiated experiments in Maroua, Cameroon, to verify that temperatures lethal to bruchids can be attained using the protocols and materials first worked out at Purdue. Although the experiments are still in progress, initial results suggest that the necessary temperatures can be attained and that the plastic materials needed for solar killing of bruchids are widely available in northern Cameroon at low cost. These experiments are being continued to determine if the technique can be used during the months of November-March, during the harmattan. Hazy skies may affect the efficacy of the technique during some of these months. In general, it is thought that the solar heating technique has substantial promise for

bruchid management in subsistence agriculture. The technique could be used by farmers at the time of harvest or threshing. It should work for *B. atrolineatus* as well as *C. maculatus*. It is very economical, the materials are widely available and reusable, and the technique could be used in conjunction with ash storage (if this proves effective) or some other storage technique that limits reinfestation, both to stop existing bruchid infestations and prevent their recurrence over long periods of time.

Constraint 3--Inadequate Availability of Cowpea Cultivars with Seed and Pod Resistance to Storage Insect Pests

Since initial infestation of the cowpea crop often takes place in the field on developing or mature pods and since harvested cowpeas are typically stored in the pod for considerable periods of time, pod resistance could play an important role in diminishing storage losses to bruchids, both *Callosobruchus maculatus* and *Bruchidius atrolineatus*. It may be possible to combine pod resistance factors with existing seed resistance factors and thereby create cowpea lines with greatly enhanced resistance to cowpea weevils. Such resistant lines would easily fit into the post-harvest processing systems currently in use by low-resource farmers in northern Cameroon.

Research in Process: **Pod Resistance Work in Cameroon.** One hundred local lines and ten different IITA seed-resistant lines were grown and harvested in Cameroon to screen for pod resistance. The actual screening experiments should begin by November when the recently initiated laboratory culture of *C. maculatus* begins yielding the required supply of insects. The lines from IITA will be screened to determine if any of these seed-resistant lines already possess pod resistance. All plots were sampled at intervals during the growing season and at harvest, counting the total number of *C. maculatus* and *B. atrolineatus* eggs present to determine when field infestation begins, if pods can be screened under conditions of natural infestation, and the relative proportion of this field infestation attributable to each bruchid species. The results of this sampling are presently being analyzed.

Seed and Pod Resistance Studies at Purdue. Three sources of seed resistance to *C. maculatus* have been identified at IITA; however, a biotype of *C. maculatus* has been developed in the laboratory at Purdue which completely overcomes the resistance of these three lines, suggesting that the resistance expressed by these cowpea types is genetically similar and may break down in the field as well. Accordingly, efforts have been initiated to discover alternative sources of resistance to *C. maculatus* among wild and weedy relatives of cowpea. Various *Vigna* species have been screened for both seed and pod resistance, sampling a number of accessions within several taxons (where possible) to better represent the variability present, and emphasizing species within the primary gene pool of cowpea, *Vigna unguiculata*. Through this initial screening, promising accessions for both seed and pod resistance have been identified. NI 147 (cv-gr.=cultigroup Biflora) exhibited the highest level of seed resistance among *V. unguiculata* accessions. This genotype readily crosses with cultivated *V. unguiculata* and several F_1 hybrids have been grown to initiate inheritance and allelism studies. In addition, an experiment is currently underway to determine if the *C. maculatus* biotype, capable of overcoming the TVu 2027 resistance, can complete development equally well on seeds of these two genotypes. TVnu 37 and TVnu 88 (both *V. oblongifolia*) and TVnu 72 (*V. vexillata*) possessed

high levels of seed resistance. Ovipositional nonpreference was highest among genotypes with pubescent pods (*V. vexillata, V. oblongifolia,* and *V. unguiculata* subsp. *pubescens*). In infested pods, pre-establishment larval mortality (mortality before larvae become established in seeds) varied among accessions, ranging from 19.3 percent in NI 778 (cv-gr. Biflora) to 91.3 percent in NI 816 (cv-gr. Textilis). The total percentage larval mortality in infested pods ranged from 34.6 percent in TN 88-63 (*V. unguiculata*) to 100 percent in TVnu 72 (*V. vexillata*) and NI 816 (cv-gr. Textilis) with the majority of accessions producing over 80 percent mortality. A manuscript describing these results and screening methodologies is near completion. In addition, it has been found that TARS 36, an accession provided by the USDA station in Puerto Rico, has a high degree of pod resistance, which seems to reside in the inability of the young larvae to become established in the seeds of this cultivar. Approximately 132 accessions of *V. unguiculata,* believed to be weedy, introgression types have been collected in the Mandara Mountain region of Cameroon. These are being routinely screened for seed resistance. No useful seed resistance has been found to date.

Earlier studies by the RIISP (Research Initiative: Insects of Stored Pulses) group at Purdue of the basis of resistance in the IITA-developed seed-resistant cowpeas suggested that lines TVu 2027, KNS, and KNW owe their resistance to their hardness or toughness. In continuing studies of the basis of resistance of these types we have observed that resistance to *C. maculatus* decreases as level of seed moisture increases. This observation suggests that resistant cowpeas stored under the higher humidities experienced at certain seasons and places in West Africa may have less resistance than expected. Conversely, resistant cowpeas stored in lower humidities may be more resistant than expected.

Constraint 4--Need by the Project for A Small-Scale On-Farm Testing Network Involving Low-Resource Farmers Who Can Test Recommended Cultivars and Other Technologies for Storage Insect Management and Give Feedback to the CRSP/IRA Team

Technologies developed in this project should be identified, designed and evaluated within the context of the farming systems practiced by farmers themselves. To better understand these systems, an on-going relationship with representative farmers needs to be established. This should improve the planning, conduct and evaluation of research and ensure that it is relevant to the needs of low-resource farmers.

During the past year, Kitch, Ntoukam and Ta'Ama conducted interviews with low-resource farmers in four important cowpea-growing areas near Maroua, namely, Dogba, Boga, Mourtourwa and Pourtamai. At least three farmers were contacted in each area. Interviews and field observations of the crop were designed to give specific information regarding agronomic practices, variety preferences, specific local problems and storage methods. All the farmers contacted agreed to cooperate with this project on an on-going basis and provide feedback regarding the value or problems with recommended technologies. Initial sampling for preharvest infestation by *C. maculatus* and *B. atrolineatus* has been made and sampling will continue at bi-monthly intervals throughout the storage period. Some of these same farmers will be interviewed by Dr. Wolfson during her survey in January 1989.

Constraint 5--Need for General Information on Cowpea Agronomy and Pest Management in Northern Cameroon

Although this project has mitigation of cowpea storage losses as its main focus, the CRSP project in Maroua has historically been the source of information about varietal types, cultural practices, and pest management recommendations. Since there will be continuing need for up-to-date information, the project will seek to supply needed baseline information in conjunction with its main storage thrust.

1. Insecticide trials at two locations were conducted by Mr. Georges Ntoukam using nine materials at two dosages. While some difficulties were encountered in accomplishing these tests, preliminary results indicate that field infestations of cowpeas by bruchids may be reduced by insecticide treatment.

2. Agrononic trials conducted by Mr. Chevalier Endondo indicated that tied-ridges spaced at two and four meters increased cowpea yields by about 50 percent compared to controls planted without ridges. Longer spacings of ridges have less or no yield advantage.

3. International, regional and local varietal trials were continued by Dr. Ta'Ama and Mr. Chevalier with the aim of identifying cowpea types with good agronomic properties and suited to northern Cameroon. The ten IITA bruchid-resistant lines, grown under multiple insecticide sprays, averaged yields of 1800 kg/ha. Two hundred local lines of cowpeas were grown on the station with and without insecticide sprays. Nearly all these varieties suffered from a yet-unidentified virus.

RESEARCH RESULTS DISSEMINATED AND IN USE

NOTE: This project has been in formal existence for one year and therefore has disseminated very few research results thus far.

1. The report of Dr. Wolfson's survey of cowpea storage and insect infestations in northern Cameroon has been completed and is undergoing final review by the IRA leadership.

2. Detailed, simple, illustrated protocols for establishing and maintaining research colonies of *Callosobruchus maculatus* have been prepared by laboratory technician Margaret Pomeroy and are available for distribution.

3. Germplasm conservation and use.

   a. Accessions acquired: samples of the Mandara Mountain collection of wild cowpea types have been incorporated into the RIISP *Vigna* germplasm collection. In addition to these local accessions, the RIISP germplasm collection now includes about 40 various *Vigna* species from the IBPGR (International Board of Plant Genetic Resources) seed bank at Gembloux, Belgium, in addition to over 100 species from the IITA germplasm storage unit. Several wild species in our collection were provided to Dr. Ivan Buddenhagen, cowpea breeder at the University of California at Davis.

   b. Samples of the Mandara Mountain collection of wild cowpea types have been sent to the IITA germplasm unit for identification and conservation.

4. Currently, three different cultivars have been released through IRA. Demand for improved cowpea seed over the last five years has grown steadily. Overall requests for improved seed submitted to the IRA seed production unit Projet Semencier was 57 tons in 1986 (enough to plant 19,000 ha.); three years earlier, demand was only about 5 tons. Since most farmers produce their own seed for planting, it is clear that farmers in the region are becoming aware of the value of improved cultivars and are actively seeking a source of seeds. In addition, on a small scale, the CRSP project has helped make available small amounts of cowpeas as seed to farmers. As an example, 200 kg of seed cowpeas were made available to growers in Adamawa Province this year, where interest in cowpea is growing.

5. Impact of CRSP-produced technology. The CRSP project has tested numerous insecticides available in the northern region of the country distributed by the cotton parastatal Societe de Developement du Coton (SODECOTON--Cotton production cooperative in Cameroon) and available to SODECOTON farmers who grow cowpeas. The insecticides distributed change from year to year and it is necessary to continue testing annually to keep the information base up-to-date. Information on treatment schedules, application rates and methods are made available to SODECOTON.

6. Other project impact. At the IRA Agro-Pastoral Show held in Maroua in December 1987, the project's cowpea plots were visited by President Paul Biya and received attention in the public press. A report is being prepared by Drs. Richard Chalfant and Moffi Ta'Ama on the contributions and accomplishments of the five years of the CRSP Cameroon pest management project. The current Purdue storage project is actively supporting and encouraging the preparation of this document.

PUBLICATIONS AND PRESENTATIONS

Kitch, L. W. and R. E. Shade. 1988. Seed and Pod Resistance to Callosobruchus maculatus Among Various Vigna Species. Entomologia Experimentalis et Applicata. In process.

Pomeroy, M. 1988. Protocols for Establishing and Maintaining Research Colonies of *Callosobruchus maculatus*. (Available from L. L. Murdock, Department of Entomology, Purdue University).

Shade, R. E., L. L. Murdock and M. A. Pomeroy. 1988. Loss of Cowpea Weevil (Bruchidae: Coleoptera) Resistance in Artificial TVu 2027 Cowpea Seeds. Submitted to Entomologia Experimentalis et Applicata.

Wolfson, Jane. In review by IRA. Survey of Cowpea Storage and Insect Infestations in Northern Cameroon. In process.

DOMINICAN REPUBLIC - UNIVERSITY OF NEBRASKA

BIOLOGY, EPIDEMIOLOGY, GENETICS, AND BREEDING FOR RESISTANCE TO PATHOGENS OF BEANS WITH EMPHASIS ON THOSE CAUSING BACTERIAL AND RUST DISEASES

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Dermot P. Coyne, U.S.	Horticulture	University of Nebraska
Freddy Saladin Garcia, H.C.	CESDA	Secretaria de Estado de Agric.
Co-Principal Investigators:		
James S. Beaver	Agronomy and Soil Science	University of Puerto Rico
James R. Steadman	Plant Pathology	University of Nebraska
Investigators:		
Cristobal Adames	EEAL	SEA
Rosendo Angeles	CESDA	SEA
Rodrigo Echavez-Badel	Crop Protection	University of Puerto Rico
Oviedo Fernawdo	EEAL (now at UPR)	SEA
Graciea Goddy	CESDA	SEA
Rosarid Maritza	CESDA (UNL)	SEA
Monte Miles	Plant Pathology	University of Nebraska
Julio Cesar Nin	EEAL	SEA
Alberto Pantojas	Crop Protection	University of Puerto Rico
Estela C. Pena Matos	EEAL	SEA
Mercedes Rodriguez	EEAL	SEA
Alfonsina Sanchez de Mora	EEAL	SEA
Eladio Arnaud Santana	EEAL (Head)	SEA
Anne K. Vidaver	Plant Pathology	University of Nebraska
Haytham Zaiter	Horticulture	University of Nebraska
Mildred Zapata	Crop Protection	University of Puerto Rico

RESEARCH OBJECTIVES: To develop biological, epidemiological, genetic and breeding information on rust and bacterial pathogens, primarily rust and common blight of beans. To produce a multiple disease resistant bean germplasm base in order to provide cropping security over time, to preserve or improve the agronomic characteristics, yield and quality of the preferred Dominican cultivars to assure economic and efficient production that will be accepted and fulfill nutritional requirements of the population. In the U.S., this will include determination of inheritance of bean rust resistance and identification of studies of rust resistance variation; determination of usefulness of tissue culture techniques; development of a semi-selective medium for common blight bacterium in the U.S.; and determination of the nature and number of virulence

genes in the common blight bacterium. In the H.C., research will include determination of the epidemiology of the common blight bacterium; evaluation of field performance of breeding lines possessing resistance to rust and common blight; collection and identification of rust strains; expansion of the genetic and breeding program; and development of international rust nurseries in the Dominican Republic (DR), Puerto Rico and Nebraska.

SUMMARY: Diseases of beans, particularly common blight (CB), rust (RU), web blight (WB) and bean golden mosaic virus (BGMV) are major constraints to bean yields and seed quality in the DR. The objectives were to identify resistant (R) germplasm and determine pathogenic variation, to conduct epidemiological and genetic studies, to develop resistant cultivars, to improve research facilities and capabilities, to train personnel and educate graduate students. The expected impact is (1) the improvement of breeding programs in the DR, U.S. and other CRSPs (now realized); (2) improvement of yields and income to small farmers in DR (in progress); (3) returning specialists will permit improved research in the DR (now realized); and (4) institutionalization of the project (now realized). The most significant advances in the past year were as follows: (1) additional evidence for the association for low rust intensity and leaf pubescence was accumulated and the later trait was inherited qualitatively. Slow rusting, due to increased latent period or reduced pustule density was identified. Cluster analysis was useful to group rust isolates according to virulence patterns. (2) Developments in breeding included red seeded bean lines (University of Puerto Rico--UPR) with heat tolerance, red mottled lines with resistance to WB or CB, and BGMV (UPR and DR), advanced Pinto and GN lines (University of Nebraska--UNL) with resistance to CB, RU, White Mold and BCMV, and a rust resistant white line (DR-UPR). Also new sources of resistance to BGMV were identified. (3) Coinoculation tests of pathogens on bean leaves showed that there was no interaction between *Xcp* and BCMV but RU interacted with *Xcp* and BCMV so separate leaves should be inoculated. (4) Survival of *Xcp* in infested bean debris was limited to two months when incorporated in soil but survived five months when left on the soil surface.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Constraint--Rust Disease

Leaf Pubescence and Race Nonspecific Resistance. The methodology for quantitative inoculation of bean leaves with rust was developed. A collection of 28 dry bean accessions from the Pompadour germplasm collection was inoculated on primary leaves (nonpubescent) with six single pustule rust isolates known to have different virulence patterns. The majority of the accessions were susceptible. Slow rusting was observed on seven host/pathogen combinations. Partial resistance, identified as increased latent period and reduced infection frequency, was found in PC 83-30 and PI 171772.

The few exceptions to the positive relationship between abaxial leaf pubescence (straight nonglandular hairs) and low rust intensity will be investigated. The recent development of glabrous and hairy sister lines at UPR and UNL will allow studies on linkages with other adaptive characteristics and mechanisms of action. Straight hair and hook hair (insect

resistance) densities will be studied for possible associations.

The dense abaxial pubescence of the rust resistant Pompadour or Jamaica Red was found to be controlled by one or two dominant genes (field UPR and UNL greenhouse studies). The expression of dense pubescence on the leaves appears not to be greatly affected by the environment. Correlations of pubescence density scores between environments were about +0.9. A rating scale of 1 (little or no pubescence) to 9 (very dense pubescence) was used to evaluate beans for leaf pubescence density. Bean genotypes with pubescence scores of 1, 3, 5, 7 and 9 were identified.

Virulence/Epidemiology. Virulence data of 58 Nebraska and 70 DR rust isolates collected from 1979 through 1986 were compared with previously published bean rust virulence patterns through the use of cluster analysis. With few exceptions all isolates were found to differ in virulence patterns. Virulence to all 19 differential genotypes was found in both populations. When the populations from the two geographic locations were compared there appeared to be greater virulence in the DR population. Cluster patterns indicate similarily of DR and Florida isolates, also similarity of midwest U.S. isolates. This is evidence for long range (>1000 miles) dispersal of spores.

Methods to purify DNA from rust spores have been evaluated. Purification of mitochondrial (mt) DNA from bean rust uredospores has been inconsistent. Most purification methods for mtDNA require a greater weight of spores than is currently available in our lab, thus uredospores of selected rust isolates are being increased in the greenhouse.

Constraint--Common Bacterial Blight

Use of Tepary to Identify Races. Strains of *Xanthomonas campestris* pv. *phaseoli* (*Xcp*) were differentiated into pathogenic races by using cotyledons and pod tissues of the host, *Phaseolus acutifolius*. A cotyledon bioassay was developed, which seems to be useful for the screening of segregating populations for resistance to the pathogen. It also provides a new means to identify resistance at the level of cotyledons (resistance to seed infection) and it permits the generation of plants which can be screened for resistance on foliage and pod tissues. Some tepary accessions were incompatible to strains of *Xcp* and others were highly resistant at the compatibility level.

Coinoculation experiments on *P. vulgaris* cultivars showed that screening for *Xcp* and BCMV can be done at the same time during early vegetative stage. Rust, however, interacted with *Xcp* and BCMV and thus, should be tested on separate leaves from *Xcp* and BCMV.

Gene Transfer. One of the greatest barriers preventing genetic analysis of many bacterial plant pathogens is the inability to develop efficient mechanisms for gene transfer. For the bacterial plant pathogens, the most successfully used mechanism of gene transfer is through the use of conjugation. Triparental matings are the basis of systems involving nonenteric bacteria. Work is proceeding on isolation of genomic *Xcp* DNA and purification of cosmid vectors to build genomic libraries of *Xcp*. In addition, 16 strains have been altered to carry an antibiotic marker, rifampin-resistance (100 ug/ml), for *in vitro* studies.

Xcp Population Studies. Survival of *Xcp* in soil incorporated infected bean debris was limited to less than two months in San Juan de la Maguana, DR. Surface debris yielded active *Xcp* for up to five months. Thus, bean debris should be incorporated into the soil after harvest.

The *Xcp* epiphyte study on *P. vulgaris* lines was repeated with similar results in the DR. Either none or very few populations of *Xcp* developed on the leaves of the resistant PI 207262 while high populations developed on leaves of the susceptible varieties. This has implications in breeding beans for resistance to *Xcp* and to reduce levels of inoculum on the debris which can infect a subsequent crop.

Field tests in North Platte, NE indicate little if any control of *Xcp* by application of copper compounds. Neither disease severity nor epiphytic populations of *Xcp* were significantly different in treated vs. untreated plots. Bioassays indicate that non-pathogenic xanthomonads are five times more resistant than the pathogenic xanthomonads to copper sulfate; but this does not explain lack of efficacy. Droplet tests conducted with copper compounds (Kocide 101, Bravo C/M, Dithane M-45 plus Kocide 101 and copper sulfate) have shown that Dithane M-45 plus Kocide 101 is the most effective bactericide *in vitro*. There is not a good explanation for lack of field efficacy.

Breeding. Advanced (F_6--F_7) red mottled Pompadour lines with resistance to bacterial blight have been selected for testing in advanced nurseries along with BAT-1274, BAC-42, L100846, 78631 and Xan-6. Further tests of lines for BGMV resistance and for low intensity of rust infection due are needed.

Resistance Associations. Near isolines of Great Northern and Pinto dry beans developed by back crossing to a CB resistant recurrent parent GN Nebr. #1 sel 27 and varying in maturity (early vs late) and plant habit (determinate vs indeterminate) were grown again in an inoculated common blight nursery. Earliness and determinate growth habit were associated with common blight susceptibility but recombination was also identified in some lines.

Constraint--Web Blight Control

Experiments on the chemical control of web blight were continued. Three applications of Brestan (0.8 g/ha) to PC-50 resulted in a seed yield of 1590 kg/ha for comparison with a yield of 716 kg/ha in unsprayed control plots. A tenfold return from the investment of applying Brestan to control web blight was realized, and its use was considered economic for smallholder farmers growing beans in web blight infested locations. Less chemical (or none) will be needed with the possible introduction of disease resistant varieties in the future.

Constraint--Improved Disease Resistant Cultivars/Lines

Ashy Stem Blight. Isolates of *Macrophomina phaseolina* causing ashy stem blight in the DR and PR varied in virulence. Sources of resistance were identified for each isolate. The inheritance of resistance to specific isolates of *M. phaseolina* appears to be fairly simple.

General Breeding--DR. Red seeded bean lines have been identified which can tolerate the high summer temperatures in PR. These lines will be used as parents in crosses for developing red mottled bean lines with greater heat tolerance.

A group of white-seeded lines developed in PR were tested on small farms and experiment stations in the DR. Line L86001 has resistance to rust and produced average yields of 1879, 1918 and 2146 kg/ha at San Cristobal, Moca and San Juan de la Maguana (DR), respectively.

Crossing blocks were established to develop Pompadour type lines with tolerance to bacterial blight and

BGMV diseases. This is now part of the DR breeding program.

Web Blight. Red mottled bean lines were selected with low incidence (5-11 percent) of web blight (*Thanetephorus cucumeris*) infection. The fungus causing web blight was also found to be transmitted through seed of Pompadour Checa and BAT-1297. Percentage seed transmission in these entries ranged from 1.0-28.3 percent, depending on severity of field infection. Multiplication of basic bean seed should be done in areas where web blight (also common blight) is not present to avoid transmitting this disease to additional areas of the country.

Bean Golden Mosaic Virus. New sources of dry bean resistance to BGMV (DR) were identified and, along with previously known G-14376, G-Murasakisaya, DOR-303 and A-429, will be used in the multiple disease resistance breeding program. About 600 lines were evaluated in separate adaptation, yield, BGMV, web blight and rust nurseries in ten production zones (DR).

General Breeding--UNL. The Nebraska breeding program with the objective to develop multiple disease resistance to common blight (CB), rust (RU) white mold (WM) and bean common mosaic diseases (BCMV) in Great Northern (GN) and Pinto beans was continued. Since CB was found to interact with RU and WM, separate inoculated nurseries (replicated) were used to evaluate resistance of advanced and early generation progenies to those pathogens. The lines were also evaluated in a non-disease nursery to determine yield in the absence of disease. Overall, 6000 plots were grown in 1988. Several levels of CB, RU and BCMV developed in the nurseries permitting effective selection of resistant lines. A number of lines with combined resistance to CB, WM and RU, good seed type, earliness and yield were selected for further testing and possible release.

RESEARCH RESULTS DISSEMINATED AND IN USE

1. The seed of the black line H-270 is currently being multiplied for release by the DR Ministry of Agriculture (Black beans constitute 20 percent of DR production). This erect, rust resistant line has proven to be particularly well adapted to environments which are prone to stress. None of the other black bean cultivars grown in the DR have rust resistance.

2. The red mottled PC-50 bean cultivar has been introduced; seed has been increased; and it is being grown throughout the DR. In 1988 over 40 percent of the basic (equivalent to certified) seed needed for red mottled (Pompadour and PC-50) bean production nationally was produced by government contracts (91 percent) and by a private seed company (9 percent).

3. Great Northern Belneb-1 and -2 advanced breeding lines were released jointly by the USDA and Nebraska. These lines combine superior specific rust resistance with the CB and BCMV resistance of the popular Great Northern (GN) 'Harris'. A cultivar derived from these lines will expand the production area in the high plains where this white seeded type can be grown successfully.

4. Management of BGMV and CB diseases by date of planting, incorporation of plant debris and controlling weeds within and near production fields in the DR was demonstrated for farmers and extension agents.

PUBLICATIONS AND PRESENTATIONS

Aggour, A. R. 1987. Genetics of and Breeding for Resistance to *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye in Beans (*Phaseolus vulgaris* L.). Ph.D. Thesis, University of Nebraska-Lincoln.

Aggour, A. R., D. P. Coyne and A. K. Vidaver. In press. Comparison of Leaf and Pod Disease Reactions of Beans (*Phaseolus vulgaris* L.) Inoculated by Different Methods with Strains of *Xanthomonas campestris* pv. *phaseoli* (Smith) Dye. Euphytica.

Aggour, A. R., D. P. Coyne and A.K. Vidaver. In press. Transmission of the Common Blight Pathogen in Bean Seed. Journal of the American Society for Horticultural Science.

Aggour, A., D. P. Coyne and A. K. Vidaver. 1988. Testing Methods, Resistance to Seed Transmission, and Genetics of the Reaction to *Xanthomonas campestris* pv. *phaseoli* in *Phaseolus vulgaris*. Annual Report of the Bean Improvement Cooperative 31:75-76.

Aggour, A. R., D. P. Coyne and A. K. Vidaver. 1988. Potential of Seed Inoculation to Select for Resistance to Common Blight of Beans (*Phaseolus vulgaris* L.). Annual Report of the Bean Improvement Cooperative 31:136-137.

Aggour, A., D. P. Coyne and A. K. Vidaver. 1988. A New Technique for Detecting Internal Infection of Bean (*Phaseolus vulgaris* L.) Seed by *Xanthomonas campestris* pv. *phaseoli*. Annual Report of the Bean Improvement Cooperative 31:132-133.

Coyne, D. P. 1988. Research and Extension's Role in the Future of Dry Bean Production. Annual Report of the Bean Improvement Cooperative 31:5-11.

Coyne, D. P. In press. Research and Extension's Role in the Future of Dry Bean Production in the U.S. HortScience.

Coyne, D. P., J. R. Steadman, D. Lindgren, D. Nuland and H. Z. Zaiter. 1988. Breeding for Multiple Resistance to Common Blight, Rust, White Mold, and Bean Common Mosaic Diseases in Common Beans. HortScience 23:771 (Abstract).

Coyne, D. P., J. R. Steadman, D. Nuland and D. T. Lindgren. 1988. Evaluation of Dry Beans for Reaction to Common Blight, Rust and White Mold, 1987. Biological and Cultural Tests for Control of Plant Diseases 3:8.

Echavez Badel, R. and J. S. Beaver. 1987. Testing Resistance and Susceptibility of Beans (*Phaseolus vulgaris*) to Ashy Stem Blight [*Macrophomina phaseolina* (Tassi) Goid]. Journal of Agriculture of the University of Puerto Rico 71(4):403-406.

Echavez Badel, R. and J. S. Beaver. 1987. Dry Bean Genotypes and *Macrophomina phaseolina* (Tassi) Goid in Inoculated and Uninoculated Field Plots. Journal of Agriculture of the University of Puerto Rico 71(4):385-390.

Echavez Badel, R., F. Perdomo and J. S. Beaver. 1988. Pathogenicity of Two *Macrophomina* Isolates from Bean Plants with Ashy Stem Blight. Paper presented at Annual Meeting of the Caribbean Division of the American Phytopathological Society, San Andres, Colombia, September 14-17.

Jimenez, J. A. 1987. Evaluation of Growing and Storage Conditions on Imbibition, Germination and Cooking Times of Dry Bean Seeds. M.S. Thesis, University of Nebraska, Lincoln, NE.

Jimenez, J A., D. P. Coyne and F. Saladin. 1988. Imbibition, Germination and Cooking Time of Seeds of Dry Beans (*Phaseolus vulgaris* L.) Stored in Different Containers. Annual Report of the Bean Improvement Cooperative 31:152.

Jimenez, J. A., D. P. Coyne and F. Saladin. 1988. Effect of Type of Storage Container on Imbibition, Germination, and Cooking Time of Seeds of Different Dry Bean Varieties. Paper presented at XXXIV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25. (Abstract). (Translation from Spanish).

Lazu Laboy, J. 1987. Efecto del genotipo de *Phaseolus vulgaris* L. en la fijacion biologica de nitrogeno por *Rhizobium phaseoli*. M.S. Thesis, University of Puerto Rico, Mayaguez.

Lindgren, D. T., D. P. Coyne, J. R. Steadman and D. Nuland. 1988. Evaluation of Small and Large Seeded Dry Beans for Reactions to Common Blight, Rust, White Mold, 1986. Biological and Cultural Tests for Control of Plant Diseases 3:10.

Lindgren, D. T., D. Nuland, J. R. Steadman and D. P. Coyne. 1988. Evaluation of Selected Dry Bean Cultivars Within Ten Market Classes for Multiple Disease Reaction to Common Blight, Rust and White Mold--1986 and 1987. Annual Report of the Bean Improvement Cooperative 31:138-139.

Lindgren, D. T., J. R. Steadman and D. M. Schaaf. 1988. Measuring the Effect of Rust on Pinto Beans. Annual Report of the Bean Improvement Cooperative 31:62-63.

Mateo Solano, M., J. S. Beaver and F. Saladin. 1988. Heritabilities and Phenotypic Correlations for Seed Yield and Seed Yield Components of Beans. Journal of Agriculture of the University of Puerto Rico 72(2):301-308.

Miles, M. R. and J. R. Steadman. 1988. Cluster Analysis of Bean Rust (*Uromyces appendiculatus*) Isolates Collected in Nebraska and Colorado, 1979-1986. Abstract Phytopathology 78:1604.

Miles, M. R. and J. R. Steadman. 1988. Cluster Analysis of Bean Rust (*Uromyces appendiculatus*) Isolates Collected in the Dominican Republic, 1982-1985. Abstract Phytopathology 78:1604.

Miles, M. R. and J. R. Steadman. 1988. Comparison of Virulence Frequency and Diversity of Bean Rust (*Uromyces appendiculatus*) Isolates from Dominican Republic and Nebraska. Abstract presented at Annual Meeting of American Phytopathological Society, San Diego, CA, November 13-17.

Nuland, D., D. T. Lindgren, D. Coyne and J. R. Steadman. 1988. Evaluation of Medium Seeded Dry Beans for Reactions to Common Blight, Rust, White Mold, 1986. Biological and Cultural Tests for Control of Plant Diseases 3:9.

Rodriquez, Merceles. 1988. Transmission de Mustia hilachosa (Thanatephorus cucumeris (Frank) Donk) a traves de la semilla de habichuela (Phaseolus vulgaris L.) en San Juan de la Maguana. B. S. Thesis, Universidad de Santo Domingo, Dominican Republic.

Saladin, F. G., Maritza Rosario V., J. C. Nin and M. Herrara. 1988. Ensayo comparativo de rendomiento de la lineas de frijol blanco (*Phaseolus vulgaris*) en cuarto zonas productores de Republica Dominicana. XXXIV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25.

Shaik, M. and J. R. Steadman. 1988. Nonspecific Resistance to Bean Rust and Its Association with Leaf Pubescence. Annual Report of the Bean Improvement Cooperative 31:62-63.

Stavely, J. R., J. R. Steadman, D. P. Coyne and D. T. Lindgren. 1988. In press. Belneb Rust Resistant -1 and -2 Great Northern Dry Bean Germplasm. HortScience.

Weiss, A., D. L. Lukens and J. R. Steadman. 1988. In press. A Sensor for the Direct Measurement of Leaf Wetness: Construction Techniques and Testing Under Controlled Conditions. Agricultural and Forest Meteorology.

Weiss, A., D. L. Lukens and J. R. Steadman. 1988. In press. Leaf Wetness in Dry Beans Under Semi Arid Conditions. Agricultural and Forest Meteorology.

Zaiter, H. Z., D. P. Coyne and J. R. Steadman. 1988. Coinoculation Effects of the Pathogens Causing Common Bacterial Blight, Rust, and Bean Common Mosaic in *Phaseolus vulgaris* L. HortScience 23:792 (Abstract).

Zaiter, H. Z., D. P. Coyne, A. K. Vidaver and J. R. Steadman. 1988. Differential Reaction of Tepary Bean Lines to *Xanthomonas campestris* pv. *phaseoli*. HortScience 24:134-136.

Zaiter, H. Z., D. P. Coyne, A. K. Vidaver and J. R. Steadman. 1988. Differential Reaction of Tepary (*Phaseolus acutifolius* L.) Bean Lines to *Xanthomonas campestris* pv. *phaseoli*. HortScience 23:766 (Abstract).

Zapata, M. and A. Vidaver. 1987. Differentiation of *Xanthomonas campestris* pv. *phaseoli* into Pathogenic Races Based on the Tepary Bean Reactions. Phytopathology 77:1709 (Abstract).

Zapata, M. and A. Vidaver. 1987. Tepary Bean Cotyledon Bioassay for the Differentiation of Races in *Xanthomonas campestris* pv. *phaseoli*. Phytopathology 77:1746 (Abstract).

GUATEMALA - CORNELL UNIVERSITY

AGRONOMIC, SOCIOLOGICAL AND GENETIC ASPECTS OF BEAN YIELD AND ADAPTATION

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Donald Wallace, U.S.	Plant Breeding	Cornell University
Porfirio Masaya, H.C.	Bean Program	ICTA
Co-Investigators:		
Samuel Ajquejay	Bean Program	ICTA
Armando Monterroso	Bean Program	ICTA
Rafael Rodriguez	Bean Program	ICTA

RESEARCH OBJECTIVES: To improve the production of beans by small subsistence farmers through agronomic investigations. To conduct research aimed at understanding the daylength, temperature and genetic bases for variations in days to maturity and adaptation of bean cultivars. This will include research to breed higher yielding bean cultivars using physiological-genetic information derived from simplified growth analysis of yield trials; to determine how the several variables of climate affect the adaptation, growth and yield of beans; to identify genes that facilitate adaptation, growth and higher yield in different environments; and to explore the merits of new combinations of these genes for maximizing adaptation, growth and yield; to conduct research on management practices that maximize expression of higher yield in improved genotypes.

SUMMARY: This research aims to increase knowledge about the biology of yield, while simultaneously developing ways of improving efficiency of breeding higher yielding genotypes plus breeding higher yielding cultivars. We have summarized the complex biology of yield accumulation into three components: the rate of vegetative growth; the partitioning rate of part of the vegetatively accumulated biomass to the yield; and control over the partitioning rate to the yield. The project has shown the partitioning to be strongly controlled by photoperiod gene activity, including changes of this activity by both the daylength and the mean temperature of the growing site. The time each cultivar needs to develop, i.e., to grow to the stage of flowering or maturity, depends strongly upon the rate of yield accumulation.

A yield system analysis (YSA) was developed. A complete YSA measures the biomass, yield, time to flowering and time to maturity. The two measures of biomass plus the two measures of time used allow each yield trial site to quantify the different physiological processes and the different time durations and rates through which the different cultivars achieve their yield. By adopting statistical analysis newly developed by others, the project has shown that the genotype (G) x environment (E) interactions of these yield accumulating processes caused by the different cultivars (genotypes) and those caused by

the different sites (environments) can be quantified. This too is applied to improving the efficiency of breeding for adaptation and yield.

Higher yielding genotypes are being developed in both Guatemala and New York. Contrary to general belief, we have shown that early generation selection for yield or for some of its components can improve the efficiency of selecting for and breeding better-adapted, higher-yielding cultivars. Improved understanding of the biology of adaptation has enabled breeding for specific environment in the tropics, so we use the plant response rather than struggle against it.

Homozygous genotypes are being developed to continue elucidating the major genes and gene activities that control adaptation and yield of bean cultivars.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Basis for Applied Progress

Ten concepts summarize the biology of yield. Yield integrates the following:

1. The rate and duration of vegetative growth, i.e., the total biomass accumulation by photosynthesis.

2. The rate and duration of partitioning of part of the accumulated biomass to the reproductive growth, which is also the rate and duration of actual yield accumulation.

3. Regulation of the partitioning of the accumulated biomass between vegetative and reproductive growth, which this project has shown to result from simultaneous controls by the three-factor complex consisting of (a) the photoperiod gene activity as it is (b) controlled by the site daylength and further controlled by (c) the site temperature.

4. The rate of partitioning to the yield, which is the rate of yield-organ growth, strongly controls the duration and rate of vegetative growth. That is, if the vegetatively accumulated biomass is not partitioned to the reproductive growth, then this biomass will support continued and thereby prolonged and enlarged vegetative growth and total biomass accumulation. Stated alternatively, the higher the proportion of partitioning to the growth of the yield organs of a cultivar, the shorter the time required for these organs to develop to harvest maturity.

5. This time requirement is the genotype's time-related adaptation to the site of growth, and yield will be maximized if it matches the site-provided growing season duration.

6. From items 2, 3, 4 and 5, cultivar adaptation is strongly influenced by its genotype for sensitivity to photoperiod interacting with the site daylength plus with the site temperature.

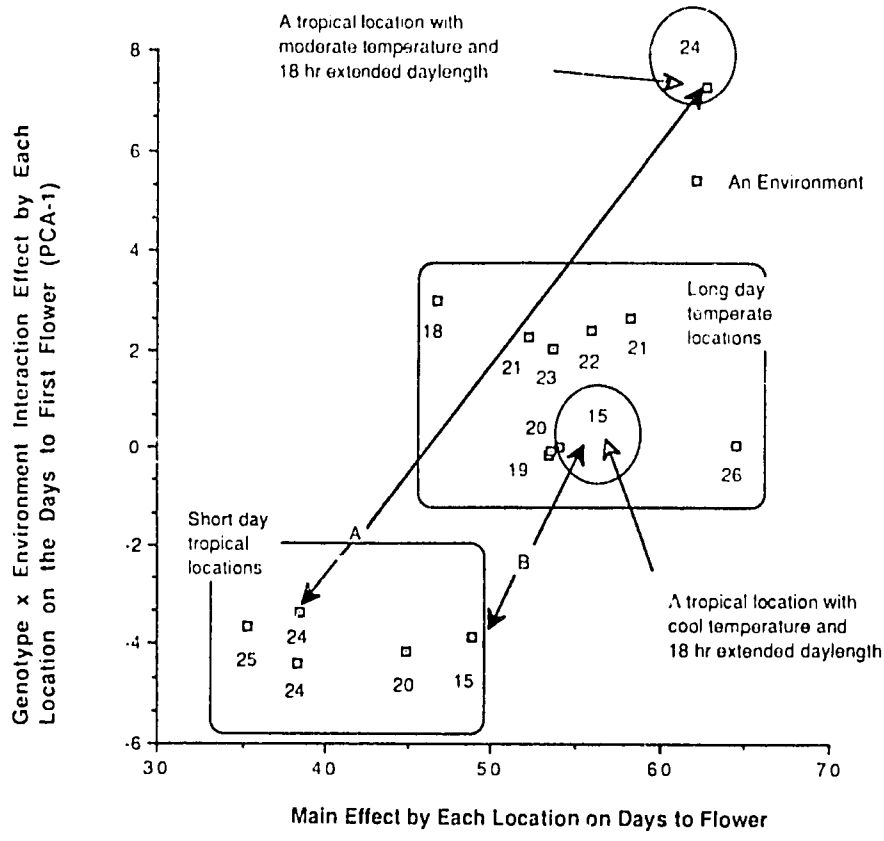
7. Highest yield for a short growing season requires rapid partitioning of assimilates to the earliest initiated reproductive organs of yield, while highest yield for a long growing season requires non-partitioning to these first available reproductive organs but partitioning to continued vegetative growth in order to maximize the total biomass accumulation.

8. Both extending daylength and raising the temperature will increase the activity of photoperiod genes, thereby delaying the node and therefore the days to flowering.

9. Any rise of temperature will, simultaneously with enhancing photoperiod gene activity, increase activity of the genes that control the rate of node development. Therefore, each temperature rise will simultaneously: (a) tend to reduce the days to flowering (by decreasing the time needed to develop a node; (b) tend to increase the days (by increasing the node to flower through enhanced photoperiod gene activity). Therefore, whenever days to flowering is measured without also measuring both the days to develop a node plus the node to flower, only the larger (predominant) of the opposing acceleration and delaying of the days to flowering by temperature will be detected.

10. Concept 10 is illustrated in Figure 1; it is that Yield System Analysis followed by Additive Main effects and Multiplicable Interaction effects analysis (AMMI) will assign positive G x E to the predominant temperature-caused increases in days to flowering (to temperature enhancement of the photoperiod responses) and will assign negative G x E to the predominant temperature-caused decreases in days to flowering (that result from the reduced days to develop a node). In addition to indicating via plus or minus sign whether the predominant change in days is through the photoperiod response or through

Figure 1: The main effect on days to flowering caused by each of 15 tropical to temperate locations plotted against the genotype x environment interaction effect on the days to flowering caused by that same location (environment, i.e., daylength plus temperature). Data from Yourstone, 1988.



the days to develop a node, AMMI will more precisely quantify each by giving numerically larger G x E scores to the larger changes in days to flowering.

YSA was developed to improve efficiency of breeding for better adaptation and higher yield within any single environment. YSA uses ongoing yield trials to quantify and compare yield-tested cultivars for contributions to their yield by each of the first seven biological processes or characteristics listed above. YSA measures: (1) yield; (2) days to flowering; (3) days to maturity; (4) the aerial biomass. Calculated from these are: (5) the biomass accumulated per day of plant growth; (6) the yield accumulated per day of plant growth; (7) the yield accumulated per day of actual biomass accumulation by the organs of yield; (8) the duration of yield accumulation (seed fill); (9) the harvest index.

Merit of Early Generation Selection

In Guatemala thirteen progenies from F_2 plants having high and seven with low yield per day were tested at advanced generations in 1988. Respectively they averaged 1461 and 1135 kg/ha, compared to checks with 1477, indicating effectiveness of the early generation selection. Progeny 12362-7-1-cm-cm yielded 1781 kg/ha, being the top yielder for both yield trials. It outyielded recently released golden mosaic resistant Ostua by 9 percent. 12362-7-1-cm-cm has exceptionally high golden mosaic resistance, plus exceptionally high yields in the absence of this virus.

F_8 Progenies from Each of Six Possible Crosses among Four Guatemalan Cultivars of Differing Adaptation

One parental cultivar is highly and one is moderately photoperiod sensitive. Two are insensitive with their adaptation controlled predominantly by the temperature effect on days needed to develop a node. Genetic dominance for early vs. late maturity reverses between high and low temperature sites (elevations). Gene activities are most difficult to differentiate at intermediate temperature. Advancement of segregates to the F_8 was completed in 1988. Activities of homozygous photoperiod and other maturity genes of the parents will be compared at field sites of different mean temperature (elevation) in Guatemala, and under different daylengths-temperatures in Cornell fields, greenhouse and growth chambers. Segregation of photoperiod gene control over maturity will be revealed at the high temperature tropical sites and in the long daylength temperature zone. Segregation of genes that control the rate of node development will be revealed in the cool highland tropics.

Cultivar Development for Hillside (Ladera) Farms

Harvest index is being evaluated as a selection criterion to assist selection for yield on the shallow soils of steep hillside farms. Harvest index might be of assistance because the ladera soils are shallow, so water retention is limited, and early maturity is needed. A high partitioning rate to the reproductive organs (and accumulation of yield) results in both high harvest index and early maturity. Analysis is not completed, but preliminary results are encouraging. Surprisingly high yields resulted during two years for lines selected for high harvest index.

F_8 Lines of Redkloud x Redkote

Under high lowland field temperature and 13-hour daylength, half of the F_8 progenies flowered early, and half were delayed. This verifies New York's field, greenhouse and growth chamber demonstrated control by a single photoperiod gene. Indication that another single gene determines

location on the plant of the first flower merits further study.

Yield System Analysis Is Being Applied to All Bean Breeding in Guatemala

Parents are being selected on the basis of the yield system output traits. The most recent crosses emphasized selection on the basis of yield arising predominantly via extra high rate of pod fill or the alternative of long duration of pod fill.

Role of Photoperiodism

Traditional highland varieties climb and are extremely photoperiod sensitive. Farmers are changing from climbing late maturing cultivars to early bush cultivars adapted to intensive agricultural systems that are spreading through the highlands. Early maturing cultivars allow sequential crops (beans followed by beans or by other crops). The early maturing cultivars for the highlands must be photoperiod sensitive. Without photoperiod delay of the flowering the low-temperature would retard vegetative growth more than development toward reproductive growth. This would allow flowering before achieving a vegetative structure adequate for reasonable yield.

Yield Gains

At Cornell, line 4109 yielded 20 percent more than cultivars Redkloud and Redkote. Canning splits seedcoats of 4109 to limit its use, but excellent precanning color and shape favor packaging. In 1984 line 10758 yielded more than 4109. Scully compared 10758 with the above lines plus 108 others from the U.S., Latin America, Africa and Europe. Across five site-years (15 replications) 4109 yielded 10 percent more than Redkloud and Redkote, and 10758 yielded 33 percent more. These respective lines matured in 96, 98, 114 and 106 days. Redkloud, 4109 and 10758 had 11, 19 and 22 percent larger yield per day than the original standard Redkote.

Physiological Ideotype for Maximized Yield

Using YSA, 112 lines originating in many countries with reasonable adaptation to New York were compared (Scully, 1989). The level for each YSA trait that will maximize bean yield in New York was estimated. The data indicate that yield can be maximized at 112 days to maturity and harvest index of 57 percent. Days to flowering would be about 50, and days of seedfill near 60, both longer durations than the 38 and 50 for the currently important variety Redkloud. Each enlargement of the other five yield-system traits increased yield.

Isolation of Genotypes Homozygous for Different Sensitivities to Daylength

1. <u>Homozygous F_8 generation segregates from the Redkloud x Redkote cross showed</u>: An insensitive and a sensitive allele of one photoperiod gene controlled the three-week earlier maturity and simultaneously controlled the higher harvest index of Redkloud compared to Redkote.

2. <u>From Redkloud x the indeterminate very highly photoperiod sensitive tropical cultivar Rojo 70</u>, the following four genotypes with determinate bush habit have been identified: (a) progenies with early flowering and maturity like Redkloud; (b) a homozygous progeny with its delay of flowering by long daylength being the same as for Redkote; (c) a progeny with much longer delay than Redkote for which homozygosity is tentatively identified; (d) a homozygous progeny with longer delay under long daylength in the field and greenhouse than for Redkote, but lacking delay in the growth chamber. Selection with deter-

minate habit is to facilitate comparisons of the different photoperiod gene actions. About ten times as many determinate than indeterminate plants can be studied in a chamber. Climbing beans with delay by long daylength require longer to flower, since more nodes must develop before flowering. Also, climbing habit requires constant manual separation to prevent intertwining of plants.

3. The late maturing 30 percent higher yielding 10758 has high harvest index and higher yield per day than photoperiod insensitive Redkloud and 4109. 10758 was environmentally made earlier while Redkote was made later by 1988's highest field temperature in over 50 years. A growth chamber test demonstrated that 10758 is photoperiod sensitive. Thus, it has gene action affecting partitioning, maturity and yield that merits comparison with the photoperiod gene activities of Redkote, Redkloud and Rojo 70.

RESEARCH RESULTS DISSEMINATED AND IN USE

Cultivars for Trellising with Papaya in the Hot Lowlands

Cultivar Ostua, released by ICTA, yields acceptably in Guatemala's Pacific lowlands, as does CIAT's DOR 364. On-farm trials of bean trellised on papaya will begin in 1989. These lowlands could not previously grow beans. Our research on adaptation and yield required a high temperature site. Development of papaya trellising accompanied this basic research. Erect cultivars are being sought to grow after a maize crop. Erectness and the crop succession could bypass destruction of the bean crop by web blight, a soil fungus splashed onto leaves by heavy rains.

Earlier Maturing Bush Cultivars for the Highlands

Highland farmers want earlier maturing bush cultivars to replace climbing beans that require nine months trellised on maize. The bush cultivars are grown in monoculture and mature in three months. Photoperiod sensitive line Ch 86-30 is such a cultivar. Its early maturity, compared with the climbing beans, accompanied by good yield allows options of successive bean plantings or of wheat or potatoes after beans.

Application of Performance Systems Analysis

In 1988 the Central American bean yield trials were analyzed using AMMI analysis by S. Orozco of CIAT, who is housed at the Instituto de Ciencias y Techologia Agricola (Institute of Agricultural Science and Technology--ICTA), assisted by Juan Herrera of ICTA. For red and black beans, respectively, 41 and 34 percent of the total Genotype x Environment interaction effect on yield was accounted for by the first principal component of the G x E interaction. For red beans most yield variation was due to G x E interaction. For black beans the G x E effect on yield was similarly large, but the main effect was also large. Main effects seem to reflect differences in number of nodes on the plant shoots.

Performance Systems Analysis

We described last year the benefit from analyzing yield, days to maturity, harvest index, etc. using Yield Systems Analysis (YSA) combined with Additive Main effects and Multiplicative Interaction analysis (AMMI). Assistance to breeding for better adaptation and higher yield was further described in: "Using yield trial data to analyze the physiological genetics of yield accumulation and the genotype x

environment interaction effects on yield" (Wallace, D. H. and P. N. Masaya. 1988. Bean Improvement Cooperative Annual Report 31:vi-xxiv). Wallace has joined with the developer of AMMI to describe collection of YSA data plus its analysis using Analysis of Variance (ANOVA) followed by AMMI analysis. These collective procedures are termed Performance Systems Analysis (PSA)(Wallace and Zobel, 1989).

1. A first assistance by PSA toward breeding for better adaptation and higher yield is quantification of the contribution made by each individual genotype (cultivar) and by each individual environment (site-year) to the total Genotype x Environment interaction effect. G x E interaction is very strongly influenced by the three-factor complex consisting of cultivar (genotype), plus the growing-site's daylength, plus that site's temperature. Therefore, the PSA-identified first principal component of the G x E often (always if the phenological development is the largest cause of G x E) quantifies the genotype x daylength x temperature interaction effect on adaptation and yield. PSA assigns a plus sign to the first G x E effect it detects. It assigns negative sign to any oppositely acting G x E effect. With standardization (multiplying by -1 if necessary), a plus G x E score indicates that the cultivar is photoperiod sensitive, because longer daylength and higher temperature enhance the photoperiod gene activity to delay maturity and alter adaptation. An insensitive genotype has no or only weakly acting photoperiod genes. Therefore the predominant effect on adaptation by a rise of temperature will be reduction of the days required to develop a node and consequent earlier flowering and maturity. The cultivar will have negative G x E interaction. Site-years with a mean temperature below the optimum for flowering of the tested cultivar will extend days to flowering and will likewise have a negative G x E interaction effect. The optimum temperature for flowering of a cultivar is that temperature which gives the fewest days along the U-shaped response to temperature of its days to flowering.

2. The second contribution to improved efficiency of breeding for better adaptation and higher yield is realized by using the quantified G x E effects to improve prediction of the adaptation and yield for each specific genotype-environment combination. Duplicating the improved predictability requires at least twice as many replicates in yield trials analyzed using only ANOVA.

3. Other contributions by the quantified G x E effects are separation of traits and unknown factors that alter development. Demonstrated is differentiation of an apparent third allele of the single photoperiod gene that differentiates Redkloud and Redkote. Accession 274 is slightly later flowering than Redkote. In agreement, photoperiod sensitive homozygous F_8 progenies from the Redkloud x Acc. 274 cross are usually later. This information is derivable from analysis with ANOVA. Less evident would be that variation in G x E for sensitive F_8 progenies from 274 seems to be smaller than the G x E of the F_8 from Redkote. The biplot distributions will often separate such effects, even if the researcher cannot specify the causal factor. This will indicate there is more to be learned about genetic control over development of the compared germplasms.

PUBLICATIONS AND PRESENTATIONS

Aqjuejay, S. 1988. Choosing Parents for the Highlands Using the Rate and Duration of Podfilling. Paper presented at the XXIV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25.

Monterosso, A. 1988. Use of Harvest Index as a Selection Criterion for Ladera Conditions. Paper presented at the XXIV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25.

Rodriguez, R. 1988. Choosing Parents for Middle Elevations Using the Rate and Duration of Podfilling. Paper presented at the XXIV Annual Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25.

Scully, B. T. In process. The Adaptation and Yield of Common Beans. Ph.D. Thesis, Cornell University.

Wallace, D. H. 1988. Using Yield Trial Data to Analyze the Physiological Genetics of Yield Accumulation and the Genotype x Environment Interaction Effects on Yield. Oral presentation at the 1988 Biennial Meeting of the Bean Improvement Cooperative and Western Region W-150 Meetings, Denver, CO, October 27-29.

Wallace, D. H. and P. N. Masaya. 1988. Using Yield Trial Data to Analyze the Physiological Genetics of Yield Accumulation and the Genotype x Environment Interaction Effects on Yield. Invited paper in the Bean Improvement Cooperative Annual Report 31:vii-xxiv.

Wallace. D. H., K. S. Yourstone and P. N. Masaya. 1988. Effect on Days to Flowering and Maturity and on Harvest Index by Photoperiod Gene Control Over Partitioning. Submitted to Crop Science.

Wallace, D. H., P. Gniffke and P. N. Masaya. 1988. Photoperiod, Temperature and Genotype Interaction Effects on Days and Node to Flowering, Maturity and Yield of Bean (*Phaseolus vulgaris* L.). Submitted to Journal of the American Society for Horticultural Science.

Wallace. D. H. and R. W. Zobel. In preparation. Improving Crop Adaptation and Yield Through Performance Systems Analysis.

Yourstone, K. S. 1988. Photoperiod and Temperature Interaction Effects on Time to Flower and Its Components in Bean (*Phaseolus vulgaris* L). Ph.D. Thesis, Cornell University.

In preparation:

Yourstone, K. S. and D. H. Wallace. The Application of Plastochron Index to Common Bean (*Phaseolus vulgaris* L.) Grown Under Growth Chamber Conditions.

Yourstone, K. S. and D. H. Wallace. Effects of Photoperiod and Temperature on Rate of Node Development in Indeterminate Bean (*Phaseolus vulgaris* L.).

Yourstone, K. S., D. H. Wallace and R. W. Zobel. Genetic, Environmental and G x E Effects on Time to Flower in Common Bean (*Phaseolus vulgaris* L.).

HONDURAS - UNIVERSITY OF PUERTO RICO

IMPROVEMENT OF BEAN PRODUCTION IN HONDURAS THROUGH BREEDING FOR MULTIPLE DISEASE RESISTANCE

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
James S. Beaver, U.S.	Agronomy and Soils	University of Puerto Rico
Juan Carlos Rosas, H.C.	Agronomy	Escuela Agricola Panamericana
Co-Investigators:		
Rodrigo Echavez-Badel	Crop Protection	University of Puerto Rico
Jacobo Caceres	Plant Pathology	Escuela Agricola Panamericana
Monty Miles	Plant Pathology	University of Nebraska
Luis Ernesto Rivera	Agronomy and Soils	University of Puerto Rico
James R. Steadman	Plant Pathology	University of Nebraska
Roberto Young	Agronomy	Escuela Agricola Panamericana

RESEARCH OBJECTIVES: To increase the production of beans through improved varieties resistant to major diseases and pests. Research in the U.S. will include identification of additional sources of resistance to the most important diseases in Honduras and development of red-seeded bean populations with a greater frequency of major and minor genes for disease resistance. In the H.C., research will aim to develop the local breeding program; to measure effectivness of different sources of disease resistance and monitor the frequency and severity of bean diseases; to screen promising germplasm for resistance and to determine how multiple disease resistant germplasm can be most effectively utilized by small farmers.

SUMMARY: Several diseases limit bean yield in Honduras. Smallholder farmers need bean varieties with enhanced levels of disease resistance in order to insure a greater, more predictable level of production in the wide range of environmental conditions in which beans are grown in Honduras. Therefore, the principal objective of the project is to identify and incorporate genes for disease resistance into adapted bean genotypes having seed types which are acceptable to the Honduran consumer. The project also strives to strengthen the bean research programs at the Escuela Agricola Panamericana (EAP) and the Ministry of Natural Resources (MNR).

Promising small-red breeding lines developed by the project are currently being tested in Honduras and in regional performance trials. Preliminary results indicate that dense leaf pubescence (abaxial tall non-glandular hairs) may contribute to race non-specific resistance to rust. Small-red lines with dense pubescence have been developed by the project. All of the sources of specific resistance to bean rust that were tested in Honduras during the past year were found to be susceptible. Forty-four isolates tested on the bean

rust differential genotypes resulted in the identification of at least 40 different races of rust. In Honduras anthracnose reduced the yield of a susceptible variety by more than 50 percent. Narrow sense heritabilities for early maturity found in Honduran bean varieties ranged from 0.40 to 0.63. Breeding lines which combine disease resistance with earlier maturity are currently being developed. Heat tolerant lines and genotypes with longer seed-filling periods have been identified. Results from a preliminary evaluation of the EAP Bean Germplasm Collection indicate that there is considerable variability among genotypes for agronomic traits, biological nitrogen fixation capability and disease resistance.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Inheritance of Early Maturity

Narrow sense heritability estimates for early maturity found in Honduran bean varieties "Cuarenteno" and "Cincuenteno" ranged from 0.40 to 0.63. The expression of number of days to physiological maturity of these varieties has been found to be fairly stable across environments. On the other hand, the days to maturity of the recently released variety "Catrachita" varied depending on the planting date. A series of crosses have been conducted to incorporate early maturity into later-maturity small-red breeding lines which have desirable agronomic traits and/or improved levels of disease resistance.

Heat Tolerance

Several small-red lines were identified which tolerate the high temperatures which prevail during the summer months in Puerto Rico. Greater tolerance to heat may permit the expansion of the range of adaptation of beans in Honduras. Yields of the most promising lines ranged from 2000 to 2500 kg/ha. A few of these genotypes will be used to study the inheritance of heat tolerance in dry beans.

Leaf Pubescence and Resistance to Rust

All of the sources of specific resistance to bean rust tested in Honduras during the past year were found to be susceptible. Preliminary results from field trials indicate that dense leaf pubescence (abaxial tall non-glandular hairs) may contribute to race non-specific resistance to rust on leaves from the third node on the main stem to the top of the canopy. Near glabrous leaves from the cotyledonary and second nodes on the main stem develop susceptible reactions when inoculated with certain rust races. A group of 29 red mottled genotypes with pubescence scores of 3.5 or greater (1 to 9 scale with 1 = glabrous and 9 = very hairy) had less than 5 percent of their leaf area infected with rust. In contrast, three lines with very little pubescence (score = 1) had an average of 28 percent of their leaf area infected with rust. However the relationship between dense leaf pubescence and rust resistance appears not to be absolute. A few dense pubescence breeding lines derived from pedigrees containing "Jose Beta" were found to be susceptible to rust. Further studies are planned to determine if additional factors contribute to race non-specific rust resistance.

Results from research conducted in collaboration with the University

of Nebraska indicate that the dense pubescence trait is controlled by a single dominant gene. A group of small-red sister lines which vary in leaf pubescence density have been developed by the project. These lines will be used in additional field experiments which will study the effect of leaf pubescence on bean rust infection. The expression of leaf pubescence density has been found to be stable over environments. The correlation for leaf pubescence density scores for a group of bean genotypes grown in Puerto Rico and Honduras was near 0.9.

Virulence of Honduran Rust Isolates

During the past year nineteen field collections of bean rust were taken from three different regions in Honduras. At present, a total of 150 single pustule isolates have been obtained at the University of Nebraska. The variability in the virulence in the Honduran bean rust races appears to be great. Forty-four isolates have been tested on the bean rust differential genotypes and at least forty different races have been identified. The sources of resistance found in the rust differential genotypes were not effective for all Honduran isolates of bean rust. These results help to explain why the deployment of sources of specific resistance has not proved to be effective in Honduras.

The Honduran isolates of bean rust appear to have a great potential for genetic recombination. Bean rust must first produce teliaspores in order to sexually reproduce. A total of 94 percent of 114 isolates of bean rust tested in growth chambers at the University of Nebraska developed telia within 22 to 62 days after inoculation. Studies will be conducted to determine which isolates of rust produce the sexual stage. If the sexual stage of rust is found in the field in Honduras, more variability in virulence would be predicted. This information will help to design more effective strategies for the deployment of resistance genes.

Breeding for Disease Resistance

Crossing blocks were conducted in Puerto Rico between promising small-red bean genotypes and sources of disease resistance. Small-red lines with dense leaf pubescence have been developed. This should be a first step toward the development of small-red beans with race non-specific resistance to rust. Results from research conducted at the University of Nebraska has identified a bean genotype with little or no seed transmission of common blight. This trait would be of particular value to smallholder farmers in Honduras who grow their own seed. This source of common blight resistance was crossed with several different small-red bean genotypes. Crosses were also conducted to combine the dominant "I" gene and the recessive bc_3 resistances to the necrotic strain of bean common mosaic. In addition, promising small-red lines were crossed with lines which have been found to have field resistance to bean golden mosaic in the Dominican Republic.

Crossing blocks were also conducted in Honduras. Breeding lines selected from the Central American Adaptation Nursery were used as sources of resistance to bean common mosaic, common blight and anthracnose. Several hundred breeding lines developed from crossing blocks conducted in Honduras and Puerto Rico in previous years were evaluated at the Escuela Agricola Panamericana (EAP) for adaptation and disease resistance.

Yield Loss Due to Anthracnose

During the "primera" planting season field trials were conducted to determine the effect of anthracnose infection on bean yield in Honduras.

Anthracnose was found to reduce the yield of the susceptible variety "Desarrural" by more than 50 percent. On the other hand, yield reduction of the tolerant variety "Catrachita" was less than 10 percent. Yield loss can be reduced with fungicide application. This practice, however, is considered uneconomical and unpractible for smallholder farmers. In order to be more effective in breeding for resistance to anthracnose, pods having anthracnose infection were sent to Dr. Pastor Corrales at CIAT to identify the anthracnose races that are present in Honduras.

Evaluation of Bean Germplasm

The results from the evaluation of the first group of genotypes from the EAP Bean Germplasm Collection indicate that there is considerable variability among genotypes for agronomic traits, and biological nitrogen fixation capability. Particular emphasis will be placed on screening the bean germplasm collection for resistance to rust, anthracnose, common blight and other diseases of economic importance in Honduras. Other bean genotypes which had been collected in Honduras but are missing from the EAP collection have been requested from the CIAT Bean Germplasm Collection. A complete evaluation of the EAP Bean Germplasm Collection should permit a greater use of native bean germplasm in the Honduran bean breeding program.

Outcrossing of Common Beans

The outcrossing of beans in Puerto Rico was estimated as part of the M.S. thesis research of Mr. Bryan Brunner. The outcrossing rate for most traits was very low indicating that conventional breeding techniques used for self-pollinated crops are appropriate for beans grown in Puerto Rico. However, the dwarf outcrossing trait was found to have outcrossing rates of 16 and 39 percent in two planting dates in Puerto Rico. Since dwarf outcrossing is a recessive trait that can be easily identified before flowering, this trait may be useful in a recurrent selection program. The first backcross has been completed to incorporate the dwarf outcrossing trait into small-red beans.

Physiological Maturity

Dry matter accumulation patterns of L-227 and Catrachita were conducted at two dates in Puerto Rico to identify a morphological trait which coincided with physiological maturity. Results from these experiments indicate that physiological maturity occurs when one/two green pods remain on the top of each plant. This criterion has proved useful in studying the seed-filling period of beans.

Seed-Filling Period

Significant negative genetic correlations between days to physiological maturity and seed-filling period were found for certain bean crosses. This genetic relationship may permit the development of early maturity bean genotypes with longer seed-filling periods. Several F_3 plants having early maturity and a long seed-filling period were selected for further study.

RESEARCH RESULTS DISSEMINATED AND IN USE

Breeding Lines

Twelve promising small-red breeding lines developed by the project were included as entries in a regional performance nursery, Vivero de Adaptacion Centroamericano (VIDAC) which is coordinated by CIAT. This nursery will be conducted in several Central American countries. In Honduras sixteen breeding lines are currently in the final stage of testing at the EAP. During the upcoming year the project expects to release two to

three of the most promising lines to the Minsitry of Natural Resources for on-farm trials. Since the project has had sufficient time to help develop a mature bean breeding program at the EAP, it expects to continue to produce promising breeding lines for regional and local testing.

Conservation and Exchange of Germplasm

The existence of other bean research projects at the EAP creates an environment which favors the exchange of germplasm. The efforts of the Bean/Cowpea CRSP project to improve the adaptation and disease resistance of small-red beans complement on-going efforts at the EAP to develop bean germplasm with improved BNF capacity and drought tolerance.

Seed Production

The project continues to provide support for the multiplication of seed of small-red bean varieties. Due to a severe drought during the 1987 "postrera" planting season, there was an estimated 30 percent deficit in the supply of seed. This deficit contributed to a 400 to 500 percent increase in the price of seed. In order to provide some short-term relief to the seed shortage, the EAP produced five tons of the recently released variety "Cathrachita." In an effort to develop a more reliable long-term supply of seed, the EAP is collaborating with the Ministry of Natural Resources (MNR) to develop a seed certification program for beans in Honduras. At present the EAP produces basic seed of "Catrachita," "Desarrural 1R" and "Zamorano." The role the EAP will play in a bean certification program has yet to be defined. However, the establishment of such a program should prove to be of great value to small-scale farmers and their families. The bean breeding program at the EAP should also benefit from the existence of a bean seed certification program since it will provide a mechanism for the multiplication and distribution of varieties developed by the project. Since bean yields in 1987 were greatly reduced due to the severe drought, shortage of seed is expected to reduce the hectarage planted in beans during the 1988 "postrera" planting.

A bean breeding program has been established in Honduras which has begun to produce breeding lines with improved agronomic traits and greater levels of disease resistance. During the next few years breeding lines developed by the project will be tested by the MNR on small farms. Results from these trials will provide valuable information concerning the strengths and weaknesses of the lines produced by the project. During the three-year extension period, it is likely that a line developed by the project will be released as a variety. The release of a small-red bean variety with more disease resistance or better agronomic traits should have a direct beneficial impact on smallholder farmers and their families. The project will continue to exchange germplasm with bean breeding projects in other Central American countries through participation in the regional nurseries such as the VIDAC trials. The development of bean germplasm with non-specific resistance to rust, earlier maturity and greater tolerance to heat should be of interest to the entire bean research community.

PUBLICATIONS AND PRESENTATIONS

Brunner, B. 1988. Estimation of Outcrossing of the Common Bean in Puerto Rico. M.S. Thesis, University of Puerto Rico-Mayaguez.

Castano, J., J. Zepeda, and S. Zuluaga. 1988. Epidemiologia y control de roya de frijol [*Uromyces appendiculatus* (Pers.) Ung. mediante mezclas de Cuarenteno, variedad endemica de Honduras]. Submitted to CIEBA.

Erazo, J., S. Zuluaga and J. C. Rosas. 1988. Evaluacion de genotipos de *Phaseolus* bajo condiciones de deficit hidrico en diferentes epocas de siembra. Submitted to CIEBA.

Steadman, J. R. and M. Shaik. 1988. Leaf Pubescence Confers Apparent Race Non-Specific Resistance in Beans (*Phaseolus vulgaris*). Abstract presented at the Annual Meeting of the American Phytopathological Society, San Diego, CA, November 13-19.

Unander, D. W., R. Diaz Donaire, J. S. Beaver, J. Cerna and Dinne Rueda. 1988. Yield Stability of Dry Bean Genotypes in Honduras. Submitted to Journal of Agriculture of the University of Puerto Rico.

Young, R., R. Monchada, and J. C. Rosas. 1988. Cuantificacion del efecto de danos por anthracnosis [*Colletotrichum lindemuthianim* (Sacc. y Magn) Scribner]. Submitted to CIEBA.

INSTITUTO DE NUTRICION DE CENTRO AMERICA Y PANAMA
WASHINGTON STATE UNIVERSITY

IMPROVEMENT OF DRY BEAN NUTRITIONAL QUALITY AND ACCEPTABILITY

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
B. G. Swanson, U.S.	Food Science/Human Nutrition	Washington State University
R. Bressani, H.C.	Agriculture and Food Science	INCAP
Co-Investigators:		
E. Acevedo	Nutrition Science	INCAP
M. R. Beninк	Food Science/Human Nutrition	Michigan State University
L. Elias	Nutrition Science	INCAP
A. Garcia-Sota	Nutrition Science	INCAP
L. Garcia-Vela	Nutrition Science	INCAP
C. de Godinez	Nutrition Science	INCAP
J. M. Gonzalez	Nutrition Science	INCAP
R. C. Hoseney	Grain Science	Kansas State University
G. Hosfield	USDA	Michigan State University
L. de Leon	Nutrition Science	INCAP
P. Seib	Grain Science	Kansas State University
J. Sosa	Nutrition Science	INCAP
M. Uebersax	Food Science/Human Nutrition	Michigan State University

RESEARCH OBJECTIVES: To improve the utilization, availability and nutrient quality of dry beans. To integrate post-harvest physiology, food technology and nutritional research with genetic and breeding programs for dry beans. This research aims to improve production, storage, nutrient and cooking quality of dry beans on small farms in Guatemala. Improvements in utilization and acceptability of dry beans, as well as growth and health, are expected when more beans are incorporated into the diets of rural populations. In the U.S., this research will assess relationships among dry bean harvest maturity, microstructure, phytate, pectin, mineral composition and the hard-to-cook phenomenon; study nutritional significance of chemical interactions; evaluate tissue culture as a research method for assessment of chemotaxonomy in dry beans; and isolate, characterize and assess concentrations and cooking stabilities in dry beans. In the H.C., research will study the role of pre- and post-harvest technology and storage on cooking time and nutritive value; establish the significance of antiphysiological substances on dry bean insect and fungi resistance and nutritive value during production, storage and preparation of dry beans for human consumption; determine the biological utilization of carbohydrates in dry beans and diversify the utilization of dry beans in food product development.

SUMMARY: The utility of beans (*Phaseolus vulgaris*) as a food for humans is largely determined by perceived convenience and food quality. Consumers of

beans in developing countries are conscious of the time and fuel required to cook beans to an acceptable softness. Genetic effects on cooking time overshadow growing conditions and post-harvest storage for studied tropical bean cultivars. Onset of hard-to-cook phenomenon has been related to phytase activity, pectinesterase activity, loss of phosphorous, magnesium and potassium, and free concentrations of hydroxycinnamic acids in the stored seed. High temperature processing of beans prior to storage inhibits development of hard-cooking beans. Genetic selection for quick-cooking beans significantly reduces both the cooking time and fuel requirement. The hard-to-cook defect apparently has a minimal effect on the protein digestibility of beans. Beans are an excellent source of soluble and insoluble dietary fiber. Insoluble fiber has a greater effect on reducing protein digestibility than tannins. Dry matter and apparent protein digestibility in bean and cereal diets increase in relation to the quantity of beans added to the diet. Farmers' perceptions of quality beans are often related to production rather than consumption characteristics. A food product derived from young black beans, rice, young amaranth leaves and carrots has been developed as a significant source of vitamin A and iron. Hard-cooking or insect-damaged beans can be extruded and used as chicken feed.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

The constraints addressed by the WSU/INCAP research project in 1988 were:

1. The hard-to-cook phenomenon in dry beans;

2. Poor dry bean digestibility and quality;

3. Small farmers' and womens' perspectives and attitudes that hinder production, storage, preparation or consumption of beans; and

4. Limited availability of food products containing beans.

Understanding and Preventing Development of Hard-Cooking Beans

Kansas State University reports that loss of phosphorus, magnesium and potassium coincide with the development of bean hardness for Great Northern, pinto and red kidney beans stored under accelerated conditions (100 percent RH and 46°C). Phytase activity was also observed to be greatest in bean cultivars that hardened most rapidly. Phytase concentration and activity were directly correlated to rate of hardening during accelerated storage.

Kansas State University suggests the action of phytase on phytate is the principal mechanism responsible for hardening of beans. Fluoride, a phosphatase inhibitor, is a reversible inhibitor of the development of hard-to-cook beans. Beans soaked in sodium fluoride, dried and stored under humid, warm conditions remained cookable. The color of beans soaked in sodium fluoride was darker toward brown than the color of control beans.

Michigan State University stored Navy beans for nine months under three conditions to produce different degrees of the hard-to-cook defect. Storage-induced hard-to-cook beans contained greater concentrations of hydroxycinnamic acids, especially ferulic acid, than control beans, suggesting an association between free hydroxycinnamic acid concentrations and increased bean hardening. Washington State University also observed the increase in ferulic acid

concentrations in stored beans using MSU procedures.

Pectin extracted from beans stored under high RH high temperature conditions was more viscous than pectin extracted from beans stored at ambient temperatures. Pectinesterase activity was significantly greater in beans stored under adverse conditions than pectinestrase activity for freshly harvested beans.

Michigan State University, in attempting to ascertain the range of cooking time variability in diverse bean populations, tilized remnant C_1 S_1 seed selfed to form C_1 S_2 populations. The additional generation of selfing was required to provide ample seed for conducting cooking-time studies.

Recurrent selection continues for plants with suitable seed characteristics, good architecture with Type II (CIAT classification) growth habit, and rapid and uniform cooking time for release as germplasm in Central America. Sixteen plants of exceptional architecture and red-seededness were selected from the C_1 S_1 cycle growing in the nursery at Saginaw, Michigan in 1987 and crossed in diallel in the greenhouse during the winter of 1987-88 to generate the C_2 cycle of recurrent selection. Seed from 178 C_2 cycle plants was harvested and sent to Puerto Rico in September 1988 to be increased by selfing in a winter nursery. Since the goal of combining good red seed color with architype architecture has been successful, selection for rapid cooking time will commence with seed harvested from plants of the C_2 S_1 generation to be grown in Saginaw in 1989.

INCAP directed three projects toward understanding the physical and chemical changes taking place during the storage of beans that may result in long cooking times. The cooking time of whole beans increased fivefold (99 to 480 minutes) during six weeks of accelerated storage. A smaller increase in cooking time (45 to 111 minutes) was observed for beans stored as cotyledons without the seed coat. The seed coat accounted for 54 to 77 percent of the cooking time by this method. The data suggest that the seed coat contributed significantly to the cooking time of the whole bean as determined with the Mattson bean cooker. Beans stored without the seed coat absorbed 35 percent less water after 6 weeks of accelerated storage than whole beans in accelerated storage.

Vine-type beans had a greater initial cooking time than bush-type beans. The quantity of solids in the soaking waters increased and water absorption decreased with storage time for both vine and bush type bean cultivars. Total dietary fiber, acid detergent fiber, cellulose and lignin decreased for both cultivars as storage time increased. These results do not support the hypotheses that dietary fiber and components increase as storage time increases and result in hard-cooking beans.

INCAP also continued to study the effect of heating high moisture beans 10, 20 or 30 minutes at 204, 234 or 254° F to inhibit development of hard-to-cook beans. A heat treatment of 254° F for 20-30 minutes on beans adjusted to 35 percent moisture effectively reduced the development of hardness for beans stored for 8 weeks under high RH, high temperature conditions. Beans with the shortest cooking time did not have a good appearance, darkening significantly and exhibiting 8 percent seed coat checks during storage. Water absorption by the beans remained about the same; however, total solids in the cooking broth were greater. Trypsin inhibitor and tannin concentrations decreased with thermal treatment and storage. The heat treatment shows some promise in the control of the hard-to-cook condition.

Farmers in rural Rwanda were asked to cook, eat and evaluate the cooking time of beans from ten cultivars including variable seed types. There was good correlation between cooking time as determined with the Mattson bean cooker and cooking time as perceived by farmers. The genotypic effect on cooking time was highly significant and overshadowed interactions with growing locations and season. Selection for short cooking time in this population of beans can be accomplished by testing in few environments and conserving resources. Rapid cooking 'Calima' cooked 12 percent faster and required 19 percent less firewood than the slower cooking 'Rabana-S'.

Dry Bean Protein Digestibility and Quality

Michigan State University reports that preliminary results from both *in vivo* and *in vitro* studies indicate the protein of hard-to-cook beans is similar in digestibility to control beans. Apparently, the hardening defect has minimal effect on protein digestibility. However, preparation of hard-to-cook beans for *in vitro* assays and feeding *in vivo* to laboratory animals also requires grinding, a procedure that may alter cell walls and protein availability that could relate directly to protein digestibility of hard-cooking beans.

Scanning electron microscopy was used at Washington State University to examine soluble, insoluble and total dietary fibers of uncooked and cooked bean flours prepared in laboratories at INCAP. Cooking beans reduces soluble fiber and results in an increase in insoluble fiber. Insoluble fiber appears to have a greater effect on lowering protein digestibility than tannins, though neither factor appears to be significant. The protein digestibility of white beans is not significantly less than casein digestibility. The protein digestibility of black beans is significantly less than the protein digestibility of white beans.

INCAP studied the protein digestibility of diets containing beans and maize or rice. Beans contain greater concentrations of total dietary fiber than maize or rice. Addition of beans to maize or rice based diets increases soluble and total dietary fiber simultaneously with protein. The addition of beans to maize or rice diets increases weight gain and net protein ratio (NPR) directly proportional to the quantity of beans added. Enhancement of NPR in bean/maize or bean/rice diets reflects the lysine contribution of beans to the diet. Dried matter digestibility decreased in both maize and rice based diets as greater amounts of beans were included in the mixtures. Dried matter digestibility correlated well with total dietary fiber. Apparent protein digestibility decreased as the quantity of beans increased in cereal-based diets. INCAP and WSU collaborative studies report a reduction in protein digestibility with an increase in total dietary fiber.

Neutral detergent fiber and lignin content apparently increase with prolonged storage of beans. Increasing cooking time of beans reduces protein quality, suggesting that for hard-to-cook beans it is best to heat them under pressure, at greater temperatures for shorter times to recover optimum protein quality.

A comparison of vine-type and bush-type beans indicated that vine-type beans are larger, heavier and contain a greater percentage of seed coat than bush-type beans. Solids in the cooking liquid were greater for bush-type beans than for vine-type beans. Proximate and mineral composition of the beans were similar. Farmers perceive that vine-type beans are larger, softer and better tasting than bush-type beans. Vine-type beans

often are reported to cook "better," give a thicker cooking broth and cook more quickly after storage than bush-type beans. Experimental results do not indicate large differences between vine-type and bush-type beans and do not appear to support perceptions of farmers.

Small Farmers' and Women's Perceptions and Attitudes about Beans

Washington State University has collected local agronomic, cultural and economic data in Guatemala between 1986 and 1988. Bean descriptions and consumption preferences for the village of Nahuala are presented in Table 1. Several of the Quiche names represent more than one cultivar of beans. Small black beans, for example, are recognized as two groups--dull or shiny seed coats--though both are called *eka kinak'*. Consumption preferences were most often referred to as thickness of broth or distinctive flavor.

The most important aspects of growth habit involve the costs and intensity of production. Beans must function within the perceived farming system. The information gathered suggests that while most beans grown in Nahuala function well. a handful of cultivars locally lumped together as *nimak' kinak* are not adapted to current production systems and appear to be disappearing due to community change.

The hardening of beans affects the rural poor by reducing available nutrients. Hard beans require a long cooking time, wasting womens' time and fuel. Hard beans bring lower prices for farmers. Consumer awareness of bean hardness was much greater in circumstances where women work outside of the home and in regions with depleted forest resources.

Rural communities in Guatemala have extensive cooperative systems, formal systems with directors and

TABLE 1

BEAN DESCRIPTION AND CONSUMPTION PREFERENCE IN NAHUALA, GUATEMALA, 1986-88

1	2	3	4	5	6
SCIENTIFIC NAME	DESCRIPTION	QUICHE NAME	CONSUMPTION PREFERENCE	GROWTH HABIT	MARKET AVAILABILITY
Phaseolus vulgaris	small black	*eka kinak'*	high	small corn climber	42.2%
Phaseolus coccineus	large red	*piley*	moderate	medium corn climber	22.2%
Phaseolus vulgaris	small red	*kaka kinak'*	moderate	small corn climber	15.5%
Vicia faba	large flat light green	*kax lan'*	high	free standing	11.1%
Phaseolus vulgaris; coccineus; lunatus	large multi-colored	*nimak' kinak'*	low	large corn climber	4.4%

informal systems formed seasonally to overcome collective problems. Inter-farmer cooperation plays an active role in bean production by influencing land use rights, credit, soil preparation, harvesting, drying, separating, sorting, transporting and marketing.

To identify community populations nutritionally at risk, the nutritional status of 753 children in Patzicia, Guatemala was assessed with anthropometric measures and correlated to social strata and the general farming system employed by the family. Two problems encountered were community distrust and the local approach to calculating age. Patzicia children's height and weight were significantly below previously identified socio-economic urban barrio groups.

To determine anthropometric data, size of farm, cropping pattern and some indication of household sanitation, 386 Patzicia households were interviewed. Family distrust and previous dependency on explicit financial support from foreign agencies in exchange for cooperation with household interviews were experienced in this research.

A dominant trend in Guatemalan subsistence agriculture has been the elaboration of the labor inputs in the undercapitalized basic grains sector. Undercapitalization has led to higher real costs for foods and impoverishment of the rural masses. Crop diversification promoted by government agencies results in increased production of high value export crops and decreased production of subsistence crops such as beans. As bean production is concentrated on fewer farms and distribution is controlled by market forces, bean prices have undergone dramatic realignments influencing bean purchasing and consumption.

Innovative Bean-Related Food Products

INCAP successfully developed a high quality food product that is easily prepared and well accepted from locally available raw materials. Precooked black beans and rice form the basis for a food product also containing young amaranth leaves and carrots, which contribute significant quantities of vitamin A and iron. Flavoring agents include onion, garlic, tomatoes, bacon and salt. The nutritional quality of the mixture is better than a bean/rice diet or a bean/rice/carrot diet. Attempts are being made to improve nutritional quality to about 80 percent of the quality of casein. Acceptability studies for the innovative food as a soup or hydrated dish are in progress.

Hard-cooking, insect-damaged beans were toasted or extruded and fed to chickens. The weight gain and feed efficiency for chickens on toasted or extruded beans were satisfactory. Addition of 12-14 percent beans to a normal chick diet was more acceptable than addition of beans at 6 or 18 percent of the diet. Damaged hard-to-cook beans can be successfully heat processed and used as feed for chickens.

RESEARCH RESULTS DISSEMINATED AND IN USE

1. Accelerated storage environments and procedures (KSU and INCAP) utilized in research laboratories.

2. Mattson bean cookers (WSU) fabricated and purchased by U.S. universities and developing country research laboratories.

3. Scanning electron microscopy preparations and procedures (WSU and MSU).

4. Nutrient composition and nutritional quality of beans (WSU, MSU and INCAP).

5. Plants from recurrent selection cycles have good architecture and red-seededness. The materials are adapted to Central American

and Caribbean production sites (MSU and [illegible]) and have been shared with CRSP and other research institutions.

6. Objective screening methods for cooking time correlate with perceived cooking times determined subjectively (MSU and WSU).

7. Methodology developed permitting *in vitro* evaluation of protein digestibility of beans.

8. Assay methodology for assessing free hydroxycinnamic acids in beans (MSU and WSU).

9. Fast-cooking and slow-cooking bean cultivars (MSU) distributed and collected among INCAP, CIAT, KSU and WSU.

10. Alternative legumes of interest . . . adzuki and anasazi beans, peas and lentils (WSU).

11. Recurrent selection of bean plants with good architecture and Type II (CIAT) growth habit, suitable seed characteristics and rapid and uniform cooking time.

12. Impact related to collection of cooking time and protein digestibility research information, combined with rural H.C. family perspectives on beans and health status will help CRSP investigators understand constraints that affect bean production, storage, marketing and consumption.

13. Impact of providing alternative bean foods and uses for hard-cooking or insect damaged beans will be helpful to rural populations and bean producers in U.S. and developing countries.

14. Project objectives and socio-cultural initiatives have enhanced consumer appreciation for the nutrient contribution of beans to the diet.

15. Research information on dietary fiber will improve consumer acceptance of beans.

PUBLICATIONS AND PRESENTATIONS

Bressani, R. 1988. Overview on Bean Quality. Paper presented to CIAT at the First International Workshop on Nutrition and Acceptability Parameters of Common Beans. Cali, Colombia, October 10-11.

Bressani, R. 1988. Calidad de Grano de Frijol Comun. Paper presented at Seminario del ICTA Sobre Frijol Comun, Solola, Guatemala, October 21.

Bressani, R., A. Garcia-Soto and E. Acevedo. 1988. Valor nutritivo del Caldo de Coccion del Frijol Comun, Solo y Como Suplemento a Cereales. Paper presented at VIII Congreso Latinoamericano de Nutricion. Vina del Mar, Chile, November 8-11.

Bressani, R., E. Hernandez and J. E. Braham. 1988. Relationship between content and intake of bean polyphenolics and protein digestibility in humans. Plant Foods Human Nutrition 38:5-21.

Bressani, R., A. Garcia and L. Estrada L. 1988. Preliminary study of factors that determine bean cooking broth nutrient composition. Plant Foods Human Nutrition 38:297-308.

Carpenter, J. W., G. L. Hosfield and M. A. Uebersax. 1988. Difference in Seed Physical and Chemical Characteristics of Two Dry Bean Isolines. Proceedings of the 1988 Biennial meeting of the Bean Improvement Cooperative and National Dry Bean Council, Denver, CO, October 27-29, p. 30-31.

Hogg, J. and B. G. Swanson. 1987. Providing Biochemistry with a Mayan Cultural Context. Paper presented at the 86th Annual Meeting of the American Anthropological Association, Chicago, IL, November.

Hosfield, G. L., T. G. Isleib and M. A. Uebersax. 1988. Genetic Analysis of F_2, F_3, and F_4 Dry Bean Populations for Yield and Culinary Quality. Proceedings of the 1988 Biennial meeting of the Bean Improvement Cooperative and National Dry Bean Council, Denver, CO. October 27-29, p. 34-35.

Hosfield, G. L., T. G. Isleib and M. A. Uebersax. 1988. Gene Effects for Yield and Processing Quality in Three Successive Inbred Populations of Dry Beans. HortScience 23:768 (Abstract).

Hughes, J. S. and B. G. Swanson. 1988. Effect of Cooking on Common Bean (*Phaseolus vulgaris*) Insoluble and Soluble Dietary Fiber. Paper presented at the International Conference on Food Microstructure, Scanning Electron Microscopy, Inc., Reading, England, September.

Joseph, E. 1988. Protein Quality of Idli Prepared from Beans (*Phaseolus vulgaris*) and Rice. Ph.D. Thesis, Washington State University.

Ott, D. B., M. E. Zabik, M. A. Uebersax and J. A. Machiorlatti. 1988. Thiamine Content in Air-Classified *Phaseolus vulgaris* (Pinto bean) Flour Fractions. Journal of Food Composition Analysis I(3).

Silverstein, L., D. Moffett and B. G. Swanson. 1988. Procyanidin Inhibits Glucose-Induced Increase in Short Circuit Current in Rat Ileum. Paper presented at Federation Meetings, Las Vegas, NV (Abstract 2540).

Swanson, B. G. 1988. Beans Are Good Food. Michigan Bean Digest XII 3:14-15.

Swanson, B. G. 1988. Beans Are Good Food. Paper presented to the Industry Committee for Dry Bean Research at the National Food Processors Association Meeting, Orlando, FL, February.

Swanson, B. G. and W. E. Artz. 1988. Protein Interactions with Procyanidius. Invited presentation at 3rd Symposium on Food Proteins--Interactions in Protein Systems, Reinhardsbrunn, Friedrickroda, German Democratic Republic, May.

Wassimi, N. N., G. L. Hosfield and M. A. Uebersax. 1988. Combining Ability of Tannin Content and Protein Characteristics of Raw and Cooked Dry Beans (*Phaseolus vulgaris* L.). Crop and Soil Science 28:452-458.

MALAWI - MICHIGAN STATE UNIVERSITY

GENETIC, AGRONOMIC, AND SOCIO-CULTURAL ANALYSIS OF DIVERSITY AMONG BEAN LANDRACES IN MALAWI

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
M. Wayne Adams, U.S. 7/88	Crop and Soil Sciences	Michigan State University
Thomas Isleib, U.S. 8/88	Crop and Soil Sciences	Michigan State University
Wilson Msuku, H.C.	Crop Production	Bunda College of Agriculture
Co-Investigators:		
Henry Mloza-Banda	Crop Production	Bunda College of Agriculture
James Bokosi	Crop Production	Bunda College of Agriculture
Alex Mkandawire	Crop Production	Bunda College of Agriculture
Anne Ferguson	Bean/Cowpea CRSP/WID	Michigan State University
Susan Sprecher	Crop and Soil Sciences	Michigan State University

RESEARCH OBJECTIVES: To build on the understanding of the genetic and socio-cultural factors underlying the diversity present in Malawian beans by quantifying and describing the variability found within major preferred seed classes. Germplasm accessions will be collected and sorted on the basis of seed type and screened for agronomic characteristics. Research will include socio-cultural investigations of small-scale farmers' cultivation practices and preferences. A second major focus will be on screening for differential disease reaction within the major seed classes; identification of disease resistant genotypes in several preferred seed types that are also acceptable on agronomic and culinary grounds; collection of information on small farmer bean cultivation, use practices and methods of disease control.

SUMMARY: An enormous range of genetic diversity exists in the form of variation among and within farmer-grown mixtures of beans in Malawi. Components of mixtures include beans from the Andean and Mesoamerican gene pools. Within the Andean pool, both determinate (bush) and indeterminate (vine) growth habits are commonly found on the same farm. A similar range of diversity is found in other East African countries. Much genetic variation is deliberately maintained by growers who, according to socio-cultural surveys, determine the composition of their mixtures by deliberate selection of plant and seed types to be grown. Growers know the beneficial and deleterious characteristics of numerous seed and plant types within their local areas and attempt to compose their mixtures to meet their specific needs. Information gathered during FY 88 and now being analyzed should shed light on differences in mixtures maintained by women in the various smallholder strata.

Studies of changes in component frequency in mixtures protected from the human component of selection indicate that natural forces rapidly select the

components with superior local adaptation, eliminating lines with poor competitive ability. Favored lines in some environments may be at a disadvantage in others, leading to local differentiation in composition of mixtures. On the other hand, some aspects of the selective environment can change from year to year, causing oscillation of component frequencies from year to year but maintaining several components at appreciable levels.

Within many mixtures, natural hybridization occurs between components, leading to recombinant types. As long as the outcrossing is between members of the same gene pool, recombinant types are readily produced and subjected to the selective pressures of the environment and of the grower. Data from isozyme analysis indicates that although the occurrence of hybridization between gene pools is relatively common, persistence of inter-pool recombinants is rare. It appears that post-zygotic mechanisms, e.g., lethality/subvitality of the F_1 or some form of hybrid breakdown, suppress the exchange of genes between pools. A set of restriction fragment length polymorphisms in mitochondrial DNA is under development. Preliminary results indicate that the differentiation of gene pools may extend to the cytoplasmic genome. If so, it will be possible to determine the direction of inter-pool hybridization by examination of the mitochondrial genotype in lines with recombinant nuclear genotypes.

Additional data on socioeconomic and cultural influences on diversity were obtained from the Central Region of Malawi. This data is currently under analysis.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Agronomic Influences on Diversity

Experimentation on the effect of natural selection in varietal mixtures was completed in 1987. Nine pure lines were compared with five two-component, two four-component and one nine-component mixtures of those lines as well as a ninth contrived mixture, four mixtures obtained from farmers, and a segregating population. These entries were grown in replicated plots for two seasons at Dowa and Dedza in the Central Region and for four seasons at Bunda in the Central Region and Thyolo in the Southern Region. Seed for successive seasons at a location was randomly sampled from that harvested in the previous season. In each test, mixtures were monitored for their composition with respect to the nine pure line components.

Some components fluctuated alternatively upward or downward in frequency in successive seasons at a given location, implying genotypic responsiveness to specific seasonal factors. Frequencies of other genotypes increased or decreased steadily over four seasons at Bunda and Thyolo. One entry decreased steadily and quickly at all locations except Dedza (high elevation, cool conditions) where it became the dominant component in a four-component mixture, again implying specific fitness of particular genotypes to specific environments. The competitive ability of genotypes in a mixture varied depending on the other components and on the location in which they were grown. One genotype, a large-seeded Andean vine type, held its own across locations and seasons.

These results illustrate the strength of natural selection in changing the genotypic composition of mixtures over time. In the absence

of human intervention in maintaining frequencies through selection of seed, components with specific adaptation to a particular site quickly come to dominate the mixture. That some components exhibited fluctuating frequency shows that the selective environment changes from year to year, probably as a result of variation in rainfall, temperature, and pathogen/pest populations.

Genetic Influences on Diversity

Evidence from Studies of Allozyme Distribution. Dr. Susan Sprecher completed her doctoral dissertation entitled "Allozyme differentiation between gene pools in common bean (*Phaseolus vulgaris* L.), with special reference to Malawian germplasm." Six enzymes assayed using starch gel electrophoresis exhibited two patterns that characterized Malawian bean lines from the Andean (large-seeded) and Mesoamerican (small-seeded) gene pools. The allozyme evidence suggests that divergence between the gene pools occurred before domestication. Subsequent recombination has been restricted not by geographical separation but by post-zygotic incompatibility mechanisms as shown in Malawian lines which lack significant numbers of gene pool recombinants in spite of the interplanting of both types over several centuries. Although selection by local growers has maintained desirable phenotypes, it has not produced recombinations of the gene pool-specific traits of seed size and growth habit. Allozyme data from the Malawian material indicate that a previously known syndrome producing male sterility is a result of hybridization between gene pools. This and other genetic incompatibilities suggest that incipient speciation is occurring between the gene pools.

Evidence from Studies of Restriction Fragment Length Polymorphism. The mitochondrial genome of twenty-three bean lines and two *Phaseolus* species is being examined for diversity. Twenty of the lines are a sample of the 375 collected in Malawi and measured for morphological and agronomic characters by Greg Martin and for allozyme pattern by Susan Sprecher. The three other lines are pure-line cultivars, "Mecosta," "Sanilac" and "Tendergreen." One accession each of *P. coccineus* and *P. acutifolius* are included to compare inter- with intra-specific variation. Mitochondrial DNA is isolated, digested with eight different restriction endonucleases that recognize different palindromic sequences of nucleotide bases, and the resulting fragments separated by agarose gel electrophoresis. Genetic polymorphism is expressed as a differential rate of migration of bands of digested DNA bearing particular base sequences or as the absence/presence of particular bands. Bands are identified by homology with radioactively labelled probes, i.e., segments of DNA. In this study, the probes are 34-48 kb segments (C2-C10) of the bean mitochondrial genome, provided by Dr. C. Chase of the University of Florida.

Three combinations of endonuclease and probe (EcoRI with C2, DraI with C3 or C6, and EcoRI with C4) were identified that divide the sample of Malawian lines into Andean and Mesoamerican gene pools. The pure-line cultivars examined had patterns characteristic of the Mesoamerican pool although Mecosta and Tendergreen are Andean types. Two other RFLPs were identified that differentiated Mecosta from all other *P. vulgaris* lines. Restriction patterns of *P. coccineus* and *P. acutifolius* were quite different from those found within *P. vulgaris*.

Genetic Variation in Cooking Time. This, the doctoral research of Mercy Mafuleka, is in the initial stages. The research proposal has been approved by the graduate advisory committee. Thirty pounds of seed of each of two Malawian lines to be

studied was produced on the Bunda College farm in the 1987 growing season and was brought to MSU in June. Mercy will complete her comprehensive examinations in November 1988 and will then devote more time to the research project.

Socioeconomic and Cultural Variables Affecting Diversity. Twenty smallholders in the Dedza Hills Agricultural Development District (ADD) and fifty in the Lilongwe ADD were interviewed. The newly appointed social science Co-Principal Investigator at Bunda College, Dr. Richard Mkandawire (Department of Rural Development), and his assistant, Mr. Willie Chimombo, participated in this research.

Dedza Hills is one of the major bean production areas in the Central Region. Almost all farmers in the area grow beans for household consumption and many produce for the market. Return visits were made to seventeen farmers interviewed during May 1987 to examine changes in bean seed inventories over the period and to collect information on planting practices. Three additional farmers were added to the sample, bringing the total to twenty. This data is currently being analyzed. These households will be followed over a period of three years to monitor changes in seed stock. They may also form the core for future intensive studies on small-scale farmers' pest and disease management strategies in beans.

Lying at a lower altitude than Dedza, the Lilongwe ADD is less suited to bean production but may be more representative of the conditions under which beans are grown on small farms in Malawi. Interviews were conducted with fifty bean-growing farmers from five villages. Discussions with extension agents indicated that approximately 40-60 percent of the families in these villages grew beans, almost all produced by women for household consumption. Information on types of crops grown, number and uses of bean varieties, and bean planting practices was gathered from each household. General demographic and socioeconomic information was also collected. This data is currently being analyzed.

The information from these two surveys should permit examination of the relationship between stratification within the smallholder sector and bean and other crop diversity. Specifically, we will be able to determine if amount of bean diversity present varies by stratum or type of farming household and, if so, we can begin to examine the implications for food security. Of special concern are the effects on diversity, and ultimately on household well-being, of the declining size of landholdings in the Central Region, a pattern that is more pronounced in the Lilongwe than in the Dedza area.

The information generated from these studies will also allow us to better define and delineate bean landraces in the Central Region and to begin to generate recommendations regarding which lines, from farmers' perspectives, may be most appropriate for initial breeding and improvement efforts.

Towards this end, a photographic record of bean landraces in the Central Region is being compiled. This includes photographs of the inventory of bean landraces maintained on individual farms as well as of landraces common to the Central Region. These materials have been used during presentations at professional meetings in the U.S. and Africa and for various CRSP publications. In addition to these immediate uses, this record provides baseline documentation of the nature and extent of bean diversity on small farms. It will facilitate study of the impact of the bean improvement program and other

changes in social and economic organization on bean diversity in the future.

RESEARCH RESULTS DISSEMINATED AND IN USE

Four breeding lines are in the initial stages of increase on the Bunda College farm. They include three lines intended for grain production: a white-seeded short upright vine (F50001), a red-seeded short upright vine (F50002), and a large white-seeded bush (F50003). The fourth line is a determinate white-seeded one intended for use as a snap bean. These lines were produced by hybridizing parents selected from CRSP collections made in Malawi.

PUBLICATIONS AND PRESENTATIONS

Adams, M. W. 1987. Genetic Diversity in the Common Bean. Diversity 12:24-25.

Ayeh, E. 1988. Bean/Cowpea CRSP Project Activities in Malawi (1982-88): Progress Report on Research at Bunda College of Agriculture. Report submitted to Malawi Ministry of Agriculture, Research Unit, Lilongwe, Malawi.

Ayeh, E. 1988. Changes in *Phaseolus vulgaris* Seedcoat Phenotypes in Mixture Populations over Three Generations of Selfing Without Selection. Document presented to Malawi Ministry of Agriculture, Research Unit, Lilongwe, Malawi.

Ayeh, E. In press. Evidence for Yield Stability in Selected Landraces of Beans (*Phaseolus vulgaris* L.). Experimental Agriculture 24.

Ayeh, E. 1988. Sixteen Hundred Accessions of Germplasm Materials. Document presented to Malawi Ministry of Agriculture, Research Unit, Lilongwe, Malawi.

Ayeh, E. 1988. Some Advantages of Intraspecific Mixtures of Cultivated Beans. Submitted to Tropical Agriculture.

Barnes-McConnell, P. 1987. Keepers of the Trust. Diversity 12:22-24.

Ferguson, A. E. and S. Sprecher. 1987. Women and Plant Genetic Diversity: the Case of Beans in the Central Region of Malawi. Paper presented at the American Anthropological Association Meetings, Chicago, IL, November 18-22.

Ferguson, A. E. and S. Sprecher. 1988. The Maintenance and Use of Plant Genetic Diversity: Perspectives from the Agricultural and Social Sciences. Paper presented at the meeting of the Society for Applied Anthropology, Tampa, FL, April 20-23.

Sprecher, S. L. 1988. Allozyme Differentiation Between Gene Pools in Common Bean (*Phaseolus vulgaris* L.) with Special Reference to Malawian Germplasm. Ph.D. Dissertation, Michigan State University.

Mloza-Banda, H. and E. Ayeh. 1988. Collection, Characterization, and Conservation of Malawi *Phaseolus vulgaris* Germplasm. IBPGR Newsletter.

MEXICO - MICHIGAN STATE UNIVERSITY

IMPROVING RESISTANCE TO ENVIRONMENTAL STRESS IN BEANS THROUGH GENETIC SELECTION FOR CARBOHYDRATE PARTITIONING AND EFFICIENCY OF BIOLOGICAL NITROGEN FIXATION

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
M. Wayne Adams, U.S. 7/88	Crop and Soil Sciences	Michigan State University
Dale Harpstead, U.S. 8/88	Crop and Soil Sciences	Michigan State University
Rogelio Lepiz, H.C. 6/88	Bean Program	INIFAP, Jalisco
Jorge A.. Acosta-Gallegos, H.C. 7/88	Legume Program	INIFAP, Mexico
Co-Investigators:		
Peter Graham	Soils	University of Minnesota
Eunice Foster	Crop and Soil Sciences	Michigan State University
Ronald Ferraras	Post Graduate School	Chapingo, Mexico

RESEARCH OBJECTIVES: To develop bean varieties and associated rhizobial systems which perform better than existing varieties under conditions of low rainfall and low soil Nitrogen status prevailing on the small farms in semiarid zones. This research will include identification of the morpho-physiological characteristics that are associated with or that confer an ability to yield at a satisfactory level under moderate drought stress; applying those selection criteria to segregating populations for testing under stress conditions; screening INIFAP (Instituto Nacional de Investigaciones Forestales y Agropecuarias) germplasm bank materials; testing efficient, competitive *Rhizobium* strains under conditions of limited moisture; and combining efficient N-fixing capability with drought tolerance to test selections under water and N stress in Mexico and the U.S.

SUMMARY: The identification of genotypes of the common bean, *Phaseolus vulgaris*, tolerant to droughty growing conditions has been highly successful through the employment of a three-step selection procedure, each step being carried out under progressively more stringent environmental conditions. An analysis of materials identified as having superior drought tolerance has not revealed simple morphological or physiological traits which could be identified as major contributors to genotypic response. It is thought that multiple plant growth strategies which confer resistance or tolerance to moisture stress are operative in these populations.

Parallel studies have also revealed genetic variability among plant genotypes and among strains of the *Rhizobium* organism for the capacity to form symbiotic plant-bacteria relationships and to fix atmospheric nitrogen under drought stress conditions.

Additional studies are in progress to further quantify the physiological responses of drought tolerant bean genotypes. These studies include the rate of root growth, the capacity to remobilize carbohydrates and proteins from vegetative tissue to storage organs (seeds), and the ability of selected *Rhizobium* strains to live symbiotically on roots and to effect nitrogen fixation under drought stress conditions.

Drought tolerance studies have already identified two superior bean genotypes which are being released for commercial production in Mexico. Drought tolerance materials from this program have been incorporated into bean breeding programs for possible commercial utilization in Michigan. Efforts are continuing to select even more effective materials in both the bean plants and in the nitrogen fixing bacteria which form symbiotic relationships with bean roots.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Common bean is the most important legume crop in the semiarid highlands of central-north Mexico. During the 1988 summer season, 1,015,000 ha were planted in the states of Zacatecas and Durango alone. In this region, beans are subjected to the vagaries of unreliable or inadequate rainfall. Since the predominant agricultural soils in the region are low in nutrients and organic matter (Castanozem and luvic Chernozem), the drought problem is exacerbated by the low capacity of the soil to retain moisture. In addition, the *Rhizobium*-bean plant interaction frequently, because of drought stress, fails to fix enough atmospheric nitrogen (N) to produce acceptable yields on low-N soils.

The dry summer experienced in the U.S. in 1988 has emphasized the need for drought tolerance in bean cultivars that are adapted to the long daylengths of Michigan and are of the type required by the established markets. Even under Michigan conditions, increased efficiency in N-fixation will allow more efficient fertilizer utilization and reduce the danger of unacceptable N losses which can result from improper fertilizer applications.

Worldwide, drought has been judged to be the most serious constraint, after disease, in bean production. Because rainfed agriculture, with its possibilities of insufficient and undependable moisture, is the dominant farming system in which beans are grown, the identification of genetically-conditioned tolerance to drought in both the bean plant and its *Rhizobium* symbiont continues to hold hope for improvement of productivity.

Through a progressively more stringent three-stage screening of the INIFAP bean germplasm bank (rainfed field trials, multiple site evaluation nurseries, and comparisons under irrigated, rainfed and induced drought conditions) carried out between 1985 and 1987, a set of 49 genotypes comprising different seed classes were identified as drought tolerant. These have been used in subsequent trials reported here. Small amounts of seed of these genotypes are available upon request. These genotypes from the Mexican plateau are daylength sensitive, responding best to short-day conditions.

The following report consists of some preliminary results of project experiments conducted during the summers of 1987 and 1988 at different locations on the Mexican plateau, at the University of Minnesota and at Michigan State University.

Research in Progress

Experiment 1. Identification of Morphological and Physiological Traits Associated with Resistance to Drought.

Location: "Los Llanos" Experimental Station, Durango, Mexico.

Procedures: A randomized complete block design (RCBD) experiment was arranged as a 2 x 4 factor factorial with two replicates. Factor A, two moisture regimes--stressed and rainfed; Factor B, four bean genotypes--Durango 222, Bayo Madero, L1213-2, Pinto Nacional #1. Planting date was July 4, 1987. Drought stress was imposed at anthesis by plastic rain-out shelters. Data were collected on phenological, physiological and growth traits.

Results: Statistical analyses showed significant differences between moisture regimes for all recorded variables ($P<0.05$). Under water stress, Pinto Nacional #1 reached physiological maturity eight days earlier than under normal rainfall conditions; L1213-2 and Durango 222 were accelerated by three days; and Bayo Madero was unaffected. All four genotypes had similar crop growth rates (CGR) during the vegetative stage, 2 gm/sq m/day. During the reproductive stage, water stress produced a change in performance of each genotype. L1213-2 had the largest reduction in CGR at 61 percent, Bayo Madero diminished by 41 percent, and Pinto Nacional #1 and Durango 222 decreased by 35 percent. All four genotypes had similar yield decreases under drought stress, going from 171.1 g/sq m under rainfed conditions to 63.8 g/sq m when stressed.

Stomatal conductance was reduced coincident with soil water deficit and high atmospheric demand. This reduction resulted in an increase in leaf canopy temperature for the stressed plants. Bayo Madero showed slightly more negative values for leaf water potential than Durango 222 and, late in the day, Durango 222 recovered its leaf water potential faster than Bayo Madero. Pinto Nacional #1 showed slightly higher stomatal conductance under stress than L1213-2. Durango 222 and Bayo Madero proved to have more sensitive stomata (less stomatal conductance) than the pintos. In general, the observed responses in leaf water potential, stomatal conductance, and leaf canopy temperature were similar within a seed class and different between classes (i.e., the bayos versus the pintos).

Samples were taken from the plots in this experiment for determination of N partitioning and remobilization. Determinations were made by measuring total N content in different plant parts sampled at intervals throughout the growing season. The results indicated that data from a larger number of susceptible and tolerant genotypes will be needed and that the application of N-15 urea to designated leaves would allow a more definitive determination of N remobilization. As a result of this initial test, replicated experiments of 14 susceptible and tolerant genotypes were planted in 1988 at the Montcalm Research Farm in Michigan and at Durango, Mexico, and N-15 urea was used to label a specific leaf on designated plants. The sampled plants are currently being analyzed for N-15 content.

Experiment 2. Drought Effects on Morphophysiological Traits in Twelve Bean Gentoypes.

Location: "Los Llanos" Experimental Station, Durango, Mexico.

Procedures: Twelve bean genotypes were planted July 4, 1987, using a 2 x 12 factorial design with two replications. Factor A, two moisture regimes--stressed and rainfed; Factor B, twelve bean genotypes. The experimental plots consisted of four rows,

5 m in length and 0.76 m apart. Data were collected on phenological, physiological and growth traits.

Results: All recorded variables were affected by the water stress treatment (P<0.05). Physiological maturity was accelerated in most genotypes. BAT 477, a Type II growth habit cultivar from CIAT, reached physiological maturity (PM) eight days earlier under stress. There were significant differences in total dry matter at PM among gentoypes, the average reduction under water stress being 23 percent. CGR and fruit growth rates (FGR) were reduced by an average of 16 percent and 20 percent respectively. The best genotypes for CGR and FGR were: Mexico 265, Gto 157, Michoacan 91-A, BAT 477, Durango 222. Among yield component traits, number of pods per plant was most affected by water stress. Seed yield was reduced an average of 33 percent. The least affected genotypes were Durango 222, Ojo de Cabra Sta. Rita 83, Michoacan 91-A and BAT 477. Based on the geometric mean of stressed and rainfed treatments, the highest performance genotypes were: Gto. 157, Michoacan 91-A, 83VEF-MXA 238.

Experiment 3. Root Characteristics of Four Bean Genotypes Possessing Different Drought Tolerance Mechanisms.

Location: "Los Llanos" Experimental Station, Durango, Mexico.

Procedures: RCBD replicated four times, with experimental plots of eight rows, 6 m long and 0.76 m apart were planted July 4, 1987. Roots were sampled four times during the growing cycle, at 17, 33, 51 and 66 days after planting (DAP). Samples were collected at different depths: 0-15, 15-30, 30-45, and 45-60 cm. Other data include phenology, dry matter production and seed yield.

Results: Root weight analyses showed significant differences among genotypes (P<0.01) only at 66 DAP in the 15-30 and 30-45 cm depths. By this stage, cultivars Pinto Nacional #1 and L1213-2 had produced larger root weights. Although earlier during the growth cycle there were no significant differences among genotypes, the data suggest that the Bayo cultivars, Durango 222 and Bayo Madero produced superior root dry weights. The above-ground biomass response was similar to that of the root system.

Experiment 4. Leaf Water Retention Capacity (LWRC) of Drought Tolerant Bean Genotypes.

Location: "Valle del Guadiana" Experimental Station, Durango, Mexico.

Procedures: RCBD with eight replications. This experiment was originally designed as a split plot in order to test the cultivars under rainfed and irrigated conditions; however, because the 1988 season in Durango was characterized by above average rainfall (400 mm in July), no irrigation was required. Four drought tolerant genotypes and one susceptible genotype were planted on June 28, 1988 and LWRC was determined in leaves detached at flowering time.

Results: A preliminary experiment was conducted to determine if excision with or without the petiole affected the LWRC of detached leaves. An analysis of variance showed no difference between these methods of handling. The leaf water content (LWC) was essentially the same for all genotypes, but significant differences were found for the LWRC of detached leaves at 6 and 12 hours after saturation. As in previous experiments (Acosta 1988), it appears that genotypes under non-stress conditions lose water rapidly compared to those under stress. Among drought tolerant genotypes, Durango 222, previously reported as stomatal sensitive (Ibarra 1988) was superior in LWRC at 6 and 12 hours after saturation. Although L1213-2 is considered drought toler-

ant, it showed the lowest value for LWRC. This is consistent with a previous conclusion that drought tolerance is not based upon a single identifiable characteristic, but rather is a function of several characteristics and that different genotypes may attain a degree of drought tolerance by more than a single mechanism.

Experiment 5. Growth Analysis of Drought Tolerant Bean Genotypes.

Location: "Valle del Guadiana" Experimental Station, Durango, Mexico.

Procedure: As in Experiment 4. Starting at 25 DAP, 0.5 m of row was harvested weekly and above-ground portions of plants were dissected into their components. A cubic polynomial was fitted to the dry weight data.

Results: Only data from genotypes Gto. 157 and Bayo Madero are included because the rest of the genotypes were affected by rust and anthracnose disease resistance. During the vegetative phase of growth there were no differences in total biomass between Gto. 157, a full season cultivar, and Bayo Madero, a short season cultivar. However, after anthesis, Gto. 157 was superior to Bayo Madero in biomass accumulation. Stem weight for both cultivars was reduced during seed filling, suggesting remobilization of dry matter from the stem. This reduction was larger in Bayo Madero. Gto. 157 had the larger seed yield, due mainly to a difference in seed filling rate as indicated by the slopes of plotted growth curves of seed weight during pod filling. The differences in seed filling rate could be due to differences in the efficiency of production and translocation of photosynthates. Although Gto. 157 has been classified as drought sensitive on the basis of its yield reduction under stress, its productivity remains acceptable due to the residual effect of its high yield potential.

Experiment 6. Identification of Native *Rhizobium* Strains Most Efficient in Nitrogen Fixation.

Location: "Los Llanos" Experimental Station, Durango, Mexico.

Procedures: Seventy *Rhizobium* strains were evaluated under rainfed conditions, at two locations in the semiarid highlands of Mexico. Only the preliminary results at one location are presently available. The experiments were established on June 29, 1988. Forty-two inoculant treatments were distributed in the field in a rectangular 7 x 6 lattice with 4 replications. The host genotype was the improved cultivar Bayo Zacatecas. Experimental plots consisted of single 4 m rows, 0.76 m apart. At anthesis a 0.5 m section was harvested to determine total dry matter and total N content. At physiological maturity a 2 m section of row was used to determine seed yield and seed protein content. The same strains are being tested at Aguascalientes but data are not available at this time.

Results: **Dry matter at anthesis:** Information from this phenological stage is important because the peak of N fixation occurs at this time. In both experiments those treatments which included N fertilizer yielded the most dry matter. However, there were some *Rhizobium* strains which showed results similar to those obtained by N fertilization. Among the best were: CPMEX-145, CPMEX-139, CPMEX-77 and CPMEX-162.

Seed yield: With the exception of CPMEX-105, no *Rhizobium* strains were similar or superior in seed yield to the N treatment; however, there were some strains with higher seed yield than the control treatment (no inoculant, no N). The best strains were CPMEX-105 CPMEX-111, CPMEX-99, CPMEX-82 and CPMEX-78. Even though a single bean genotype was used in the

experiments, it was observed that there was a poor association between dry matter at anthesis and seed yield at physiological maturity (r=0.19). Since the test was conducted under rainfed conditions, this low correlation could be due to differences in time of activity and/or longevity of the *Rhizobium* strains, accentuated by a drought stress period after anthesis. Five *Rhizobium* strains were selected for further study.

Experiment 7. Breeding for Drought Tolerance and Biological N-Fixation in Common Bean.

Location: "Valle del Guadiana" Experimental Station, Durango, Mexico.

Procedures: A recurrent selection strategy will be followed to improve both drought tolerance and N-fixation capability. Two crossing blocks were planted in the field on two different dates in June 1988. Each block consisted of three sets of parental classes: blacks, pintos and colors. Biparental crosses were made mainly within sets of parents.

Results: One hundred twenty five biparental crosses were made and F_1 seed obtained. This seed was planted in the field in the 1988-89 winter season at "Valle del Fuerte" Experimental Station, Sinaloa, to produce triple and four-way crosses.

Evaluations of the fixation capacities of *Rhizobium* strains were conducted by Dr. Peter Graham, U.S. Co-Investigator at the University of Minnesota. An experiment to evaluate the severity of competition for nodulation in the different bean-producing areas of Mexico was established at Zacatecas, Durango, Celaya and Chapingo, in collaboration with Javier Castellanos and Jorge Acosta (INIFAP) and Ronald Ferrera (Colegio Postgraduado, Chapingo). Nodule isolations were made and will be used in serological determinations of the frequency of strain occupancy.

Studies have been initiated to evaluate Mexican cultivars previously identified as promising for differences in ability to fix nitrogen under drought conditions. In an initial screening with twenty-five cultivars and two strains of *Rhizobium*, cultivar differences in speed of nodulation were noted, but results were not definitive. Additional experiments in this area will be necessary.

PUBLICATIONS AND PRESENTATIONS

Anonymous. 1988. Mejoramiento genetico del frijol por resistencia a la sequia a traves de la particion de carbohidratos y la fijacion bilogica eficiente de nitrogeno: Avances de Investigacion en Mexico en 1988. Secretaria de Agricultura y Recursos Hidraulicos, INIFAP, Durango, Dgo. Mexico.

Acosta-Gallegos, J. A. 1988. Selection of Common Bean (*Phaseolus vulgaris* L.) Genotypes with Enhanced Drought Tolerance and Biological Nitrogen Fixation. Ph.D. Dissertation, Michigan State University.

Alcocer, L. E., Ferrera, C. R. and R. I. Lepiz. 1987. Seleccion de variedades de frijol (*Phaseolus vulgaris* L.) con alta capacidad simbiotica y alto potencial de rendimiento de grano, aspectos metodologicaos. Paper presented at the XX Meeting of the Sociedad Nacional de la Ciencia del Suelo, Zacatecas, Mexico, November.

Almaraz, S. J. J., Ferrera, C. R., Larque, S. A., and R. I. Lepiz. 1987. Empleo de la tecnica de raiz dividida para el estudio del estres hidrico *in situ* en la simbiosis *Rhizobium phaseoli-Phaseolus vulgaris* L. Paper presented at the XX Meeting of the Sociedad Nacional de la Ciencia del Suelo, Zacatecas, Mexico, November.

Ibarra, P. F. J. In press. Identificacion de parametros morfologicos y fisiologicos asociados con la resistencia a la sequia. Paper presented at Drought Studies Meeting, CIAT, Cali, Colombia, November 1987.

Ibarra, P. F. J. and A. R. Pajarito. 1988. Factibilidad de escape a la sequia como mecanismo de adaptacion en genotipos de frijol en Durango, Mexico. Presented at XXXIV meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA). San Jose, Costa Rica, March 21-25.

Pajarito, R. A., Ibarra, P. F. J., and R. M. Ochoa. 1988. Estudios de genotipos de frijol (*Phaseolus vulgaris* L.) en dos condiciones de humedad an la region semiarida de Mexico. Award-winning paper presented at XXXIV Meeting of the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), San Jose, Costa Rica, March 21-25.

Pajarito, A. R. and J. A. Acosta-Gallegos. 1988. La investigacion sobre frijol de temporal en el CIFAP-Durango. Paper presented at the Dia mundial de la alimentacion, Instituto Tecnologico de Durango, S. E. P., October 1.

NIGERIA - UNIVERSITY OF GEORGIA

APPROPRIATE TECHNOLOGY FOR COWPEA PRESERVATION AND PROCESSING AND A STUDY OF ITS SOCIO-ECONOMIC IMPACT ON RURAL POPULATIONS IN NIGERIA

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Kay H. McWatters, U.S.	Food Science and Technology	University of Georgia
Dickson O. Nnanyelugo, H.C.	Home Science and Nutrition	University of Nigeria, Nsukka
Co-Investigators:		
George S. Ayernor	Food Science and Technology	University of Nigeria, Nsukka
Larry R. Beuchat	Food Science and Technology	University of Georgia
Addie L. Branch	Food Science and Technology	University of Georgia
Manjeet S. Chinnan	Food Science and Technology	University of Georgia
Yen-Con Hung	Food Science and Technology	University of Georgia
Alfred I. Ihekoronye	Food Science and Technology	University of Nigeria, Nsukka
Patrick O. Ngoddy	Food Science and Technology	University of Nigeria, Nsukka
Zak O. Obanu	Food Science and Technology	University of Nigeria, Nsukka
Ikemefuna C. Obizoba	Home Science and Nutrition	University of Nigeria, Nsukka
Bridget N. Onah	Agricultural Economics	University of Nigeria, Nsukka
Veronica I. Onourah	Home Science and Nutrition	University of Nigeria, Nsukka
Nwachukwu D. Onwuka	Food Science and Technology	University of Nigeria, Nsukka
Robert D. Phillips	Food Science and Technology	University of Georgia
Adaoha C. Uwaegbute	Home Science and Nutrition	University of Nigeria, Nsukka

RESEARCH OBJECTIVES: To develop appropriate technology to increase cowpea processing efficiency and encourage increased utilization among Nigeria's rural population and urban poor. In the U.S. this research will include assessment of nutritional, functional and microbiological changes in cowpea meal as a result of long-term storage; investigation of the reduction of oligosaccharide content of cowpeas by germination; production of bread-like products by extrusion cooking of cowpea meal; determination of microbial changes of cowpea pastes under conditions of temperature and aeration simulating the Nigerian home and marketplace; development of improved methods in appropriate village-scale technology and evaluation of the hard-to-cook phenomenon. In Nigeria, the research will include installation of a mill to produce cowpea meal/flour; a study of the impact of this mill on the local economy; quality assessment of products and diffusion of project technology will be monitored.

SUMMARY: The influence of indigenous microflora on nutritional and chemical characteristics associated with akara quality was investigated. Changes in microflora were correlated with changes in pH, titratable acidity, nitrogen solubility, concentrations of simple, di- and monosaccharides, thiamine and riboflavin, water absorption capacity, emulsion capacity and viscosity. Effects of pre-decortication drying treatment on the microstructure of cowpea

seeds and subsequent products were observed. Possible mechanisms were discussed. Hard-to-cook defect on cowpea seeds followed pseudo-zero order kinetics, and hardening activation energies were calculated. The production of flatulence hydrogen upon consumption of legumes was correlated to their content of stachyose, xylose and fructose. Storage of cowpea seeds for four weeks at high relative humidity (75 percent RH) and high temperature (37°C) conditions produced seeds that were hard-to-cook. Seeds stored anaerobically became less hardened than those stored in air. Project technology was enthusiastically received when presented in workshops for groups ranging from academicians to village women. Meal processing technology is being implemented in village mills located at Ogbodu-Aba and the AFRICARE project at Isiala Ngwa. Germination and cooking improved nutritive quality of cowpeas. Enzyme modification of cowpea flour enhanced nutritional and functional properties. Proteins, polysaccharides, and minerals in cowpea cell walls were mobilized by hydrothermal treatment. Adding salt and other seasonings to cowpea paste changed rheological behavior of paste, moin-moin and akara. Cryotechnique, freeze drying, vacuum drying, critical point drying and direct observation without drying were explored as methods for preparing cowpea products for scanning electron microscopy. The most suitable of these techniques were identified for seed, flour, protein and starch fractions, paste and products.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Effect of Microbial Activity on Functionality of Cowpea Paste and Akara Quality

Cowpea paste, the principal ingredient in akara, was evaluated to determine the influence of indigenous microflora on nutritional and chemical characteristics associated with akara quality. Six formulas (with and without onion, salt and pepper), consisting of inoculated (indigenous microflora) and uninoculated pastes, were incubated for 24 hours at 30°C. A strong relationship between time of incubation and increase in titratable acidity was evident for all treatments. Nitrogen solubility and protein degradation increased during incubation. Monosaccharide content increased with incubation for all pastes, while di- and oligosaccharides decreased. No significant changes in thiamine content were observed; however, riboflavin increased in all formulations as incubation progressed.

Lactic acid bacteria populations were similar to total aerobic populations and increased with time of incubation for all treatments. A strong relationship was observed between time of incubation and decrease in emulsion capacity. A similar trend was seen for pH. Pastes containing salt were associated with high equilibrium moisture contents. Specific gravity of all pastes increased gradually with time of incubation. Apparent viscosity of inoculated pastes increased with incubation time; no such trend was observed in the uninoculated pastes. Formulation and incubation time did not affect color, water or oil-binding properties of the pastes. Information obtained from this investigation will be useful in defining the effect of environmental factors on selected chemical parameters associated with stability and nutritional quality of cowpea paste.

Processing and Utilization of Cowpea Meal

Pre-decortication drying treatment (110 and 130°C) significantly affected the microstructure of cowpea seeds and subsequent products. Severe heat treatment (110 and 130°C) damaged the middle lamella of cotyledon cells, changed the birefringence property of

starch granules, reduced the amount of air incorporated into whipped paste and produced akara with non-uniform, dense structure.

Akara, fried cowpea paste, is very popular in West Africa but is virtually unknown in the U.S. To assess attitudes of U.S. consumers toward akara, a sampling survey was conducted in metro-Atlanta over a three-month period. Consumers (450) were asked to taste akara and provide information concerning how well they liked the product, how appropriate it would be for certain uses, how likely they would be to purchase and how much they would be willing to pay for various forms of the product. Data analysis is in progress. Results of the survey will indicate marketing potential of the product and suggest areas for further research.

Utilization of Hard-to-Cook Cowpea Seeds

Studies on development of the hard-to-cook defect in cowpea were continued. Storage in an anaerobic environment did not completely eliminate hardening, but air-stored samples had a higher degree of hardening compared to nitrogen-stored seed (37°C/ 75 percent RH, 4 weeks). At a cooking time of 90 minutes and over, no significant difference in the hardness of stored beans was obtained. The total extractable pectin was 81.8, 74.0 and 71.6 mg/g of cell wall material from control, four-week air and four-week nitrogen-stored samples, respectively. The cell-wall yield and protein content of the cell-wall material were similar for all samples. There were more extractable minerals (Ca, Mg) from stored seed cell-wall indicating membrane damage.

Cowpea seeds were also stored at a combination of three temperatures (30, 37 and 44°C) and three relative humidities (75, 85 and 97 percent) for up to six weeks to investigate reaction rate in development of the hard-to-cook defect. Degree of hardness was obtained from the peak force of the Kramer shear-compression test. Cowpea seeds doubled their hardness in five weeks when stored at 30°C and 75 percent RH, whereas seeds stored at 44°C and 97 percent RH only require one week. Cowpea seed hardening followed pseudo-zero order kinetics. Hardening activation energies for seeds stored at 75, 85 and 97 percent RH were 78, 82 and 80 kJ/g mole, respectively.

Carbohydrate Composition and Flatulence Potential of Nigerian and American Legumes

Sixteen samples of dry, mature legume seeds representing eight species purchased in markets either in Port Harcourt, Nigeria or Griffin, Georgia were cooked in boiling water until tender and freeze dried along with the cookwater. Flatulence potential measured as ml H_2 produced per gram of legume solids consumed was measured with rats housed in glass life-support chambers designed to collect hydrogen while supplying oxygen and absorbing water and carbon dioxide. Hydrogen was quantified by gas liquid chromatography (GLC) using a molecular sieve column. Mono-, di- and oligosaccharides were determined by high pressure liquid chromatography (HPLC). Starch content was measured as glucose in a YSI analyzer, and digestibility was determined *in vitro* with pancreatic amylase. Hydrogen production was positively correlated with contents of xylose and fructose as well as stachyose and an unknown thought to be verbascose, not correlated with raffinose, and negatively correlated with galactose and indigestible starch.

Impact Assessment and Workshops

Correlation of the socio-cultural survey with the nutrition survey has been initiated by validating and pretesting a questionnaire in Ibagwa village near the village mill. Impact assessment in Ogbodu-Aba community and

Enugu urban is now in progress. Two major workshops on processed cowpea utilization were conducted in Nsukka, one with fifty local home economics teachers and the second (a Food Crop Utilization and Nutrition Workshop in collaboration with IITA) with forty participants from colleges and polytechnics of all States in Nigeria. The workshops included lectures on nutritional quality, utilization and storage of cowpeas and demonstrations on uses of processed cowpea products in different dishes. Typical demonstrations included use of electric blender vs mortar and pestle to whip paste for making akara and moin-moin; dishes demonstrated included combinations of cowpea with corn, wheat, yam, cassava, plantain and rice. Response to the workshops was enthusiastic, and the cowpea products were highly acceptable as judged by organoleptic methods. Results of other smaller workshops showed similar responses.

Village Mill Technology Implementation

A major goal of this project is to benefit ultimate consumers of cowpeas by implementing project technology at the village level. The primary focus of implementation is the village of Ogbodu-Aba near Nsukka where a complete mill has been installed. In the past year, additional equipment (plastic tanks for wetting cowpea seeds, seed cleaner, plate mill and sifter) has been installed here. Unfortunately, the current exorbitant cost of cowpeas in Nigeria (₦ 5,000-6,000 per MT) has seriously hindered the ability of the project and the village cooperative to proceed with routine production of cowpea meal. A drought last year seriously reduced cowpea yields and consequently drove up prices. Better weather in the current crop season should improve yields and prices. The production of approximately one ton of flour for survey and demonstration purposes was anticipated by the end of FY 88. Ogbodu-Aba remains the site of numerous, continuing workshops which are preparing the way for utilization of cowpea meal when it becomes available.

A village mill utilizing CRSP-developed processing technology is operating in Isiala Ngwa in Imo State. It is part of a very successful State Ministry of Health-AFRICARE Child Survival Project, which features a uniquely integrated approach. The project includes plots for producing crops and demonstrating their improved production; the mill which produces cowpea and maize meals, weaning foods and other products and does custom milling for local farmers; and a clinic which treats seriously malnourished/ill children and trains mothers in nutrition and child health. The mill was built under the direction of H.C. scientists and features a large dryer, decortication equipment, hammer and plate mills, and packaging equipment. The project manager, Mrs. C. L. Oriuwa, is a graduate (M.S.) of the Department of Home Science and Nutrition in Nsukka and was aided in preparing the proposal which brought the project to reality by Mr. D. O. Nnanyelugo, H.C. PI, and other H.C. collaborators. Although the mill is presently operating at a financial loss, a break-even operation is anticipated when the price of the raw material falls. It is considered so successful by the Ministry that plans are being developed to "clone" it at other locations in Imo State.

Flatulence/Abdominal Discomforts Associated with Cowpea Consumption

A metabolic study was undertaken on seven adolescent boys and girls who often experienced problems when consuming cowpeas. One girl and one boy served as controls. Subjects were fed diets containing dehulled or undehulled cowpeas. Frequencies of belching, flatulence, diarrhea, abdominal rumbling, distension, stool frequency and stool weight were recorded. Boys consumed significantly more dehulled and whole cowpeas than the

girls. All symptoms were observed but increased flatulence, belching and stool frequency were the most common. Pooling all complaints, boys experienced symptoms significantly more often than the girls. The differences were more pronounced when undehulled cowpeas were fed. Adolescent boys and girls complained of the most severe discomfort following cowpea consumption at lunch followed by breakfast, then dinner.

Effects of Germination, Dehulling and Domestic Cooking on Cowpea Nutritive Value

Dry cowpeas were either cooked (WUCB), germinated (18 hours at 29°C) and cooked (WGCB), dehulled (DUUB), or germinated and dehulled (DGUB). Each lot was dried in a laboratory oven at 85°C for 24 hours to 96 percent dry matter, hammer-milled to 70 mesh flour, sealed in polyethylene bags and stored at 4°C until used. Twenty adult rats (Wistar) received cowpea and cooked dried polished rice (R) (70:30) mixtures which furnished 1.6 g N/100g diet in a twelve-day balance study. Mixtures WUCB:R and WGCB:R caused significantly higher increases than DUUB:R in food and N intakes, maintenance body weight, digested and retained N, and liver N. DGUB:R (70:30) produced significantly ($P<0.05$) higher positive calcium and magnesium balances than WUCB:R and WGCB:R. Germination and cooking appear to hold great promise as processing methods to provide low-cost, ready-to-serve, nutritious cowpea foods.

Effects of Infestation by *Callosobruchus Maculatus* on Cowpea Flour Storage Stability

Cowpea flour (initial moisture content of 10 percent, wet basis) was packaged in ventilated polyethylene bags containing 15 live insects. Bags were stored for 12 weeks at 22, 44, 64 and 86 percent RH and 23, 28 and 38°C. At RH <64 percent, insect activity and growth were severely inhibited. RH >64 percent encouraged insect proliferation. Mold growth occurred at 86 percent RH/28° and 38°C. Caking and discoloration increased with intensity of insect activity. Crude protein, crude fiber, ash and moisture contents of flour increased with infestation and insect activity while carbohydrate and fat contents decreased. Flour of 10 percent moisture content was stable at all temperatures between 23 and 38°C when stored at a RH of 44 percent or less for 12 weeks.

Enzyme Modification of Cowpea Flour

A sequential treatment of whole cowpea flour using amyloglucosidase followed by a protease improved the flour's nutritional and physicochemical characteristics. Carbohydrate decreased by 5.8 percent, but protein content and digestibility increased. Emulsification and foaming capacity, viscosity, and whippability increased. Oligosaccharide and amino acid content are being measured.

A Model System Study of Changes in Cowpea Seed Coat Anatomy Induced by Hydrothermal Pretreatment

Structural changes in the anatomy of cowpea, rice and maize seed coat induced by sequential soaking in water and drying were examined. Soaking cowpea seed in water even for a few minutes induces loss of minerals, proteinaceous bodies, pectic substances and other soluble solutes from the cell wall and middle lamella of cells located in the bran layers. For seeds that are only moistened (not soaked), the moisture induces redistribution or translocation of solutes within the cellular layers of the bran. In all cases, polyvalent cations diffuse away from their original sites. These processes are pronounced in bran tissue cells which make the earliest and longest contact with moisture. Redistribution of solutes causes disruption of bonds between macromolecules and subsequent change in polysaccharide orientation. These changes weaken the

middle lamella and induce cell separation and even cell collapse. They are manifested most significantly at the interface between the bran layers and the starchy endosperm, probably due to their morphological differences. These findings explain the effectiveness of project-developed hydrothermal treatment technology for milling cowpea seeds and other cereals/legumes.

Physicochemical Characteristics of Cowpea Products

Viscosity of Cowpea Paste Systems. Cowpea pastes exhibited pseudoplastic flow behavior. Cooked paste viscosity was highest for 80°C-pretreated cowpea flour at higher (to 120°C) and lower (to 30°C) temperatures. Salt addition reduced viscosity rate increase. Salt (1-2 percent) more than doubled the final viscosity after 10-20 minutes of heating, increased shear stress and flow consistency values but decreased the flow behavior index. Addition of 4-8 percent salt decreased all parameters except the flow behavior index and delayed or severely restricted gelatinization of cowpea starch. Addition of 1-8 percent salt to heated cowpea-starch paste decreased all parameters except flow behavior index. Viscosity of unwhipped akara paste decreased with rising pretreatment temperature between 30 and 120°C. Wet-milled cowpea exhibited higher paste viscosities than pastes made of flour. Addition of salt or oil to moin-moin pastes had insignificant effects on flow behavior; however, the combined addition of all ingredients increased viscosity significantly. Moin-moin paste made from 60°C pretreated cowpea flour exhibited the highest viscosity and shear stress, both of which decreased with higher and lower pretreatment temperatures.

Microstructure of Cowpea Products. Cryotechnique, freeze drying, vacuum drying, critical point drying and direct observation without drying were explored as methods for preparing cowpea products for scanning electron microscopy (SEM). Fixing followed by freeze drying was the most suitable treatment for cowpea cotyledons. Freeze drying only was most suitable for moin-moin. Direct observation without drying was most suitable for cowpea flour, starch or protein. SEM micrographs showed that starch granules isolated from cowpea seeds pretreated at 100 and 120°C had surface defects. Flour from cowpea seed pretreated at 30°C had starch granules with increased surface roughness, larger clumps of protein bodies and larger segments of cell wall than flour from seeds pretreated at higher temperatures. There was evidence of cotyledon shrinkage when cowpeas were dried at temperatures >80°C. Force applied during specimen cutting dislodged starch granules and sometimes the entire cell content, suggesting that adhesive forces between cell components were weakened by high temperature pretreatment. SEM of akara crumb showed a light and porous structure for pretreatment at <60°C, while crumb samples from 80-120°C pretreatment temperatures were heavy and compact. Akara prepared from wet-milled paste was porous. The size of the fiber network in moin-moin gel decreased as pretreatment temperature increased.

Texture of Cowpea Products. The texture of akara samples measured as force and energy required to shear-compress a unit weight of akara ball was derived from Kramer cell force-deformation curves. Both energy and force required increased significantly between pretreatment temperatures of 80 and 120°C. The addition of ingredients was found to lower these textural parameters in all cases. Textural parameters of moin-moin samples decreased significantly between pretreatment temperatures of 100 and 120°C. The three cowpea varieties studied: large brown eye Kano white (LBRE), large black eye Kano white (LBKE) and small brown eye Kano white (SBRE) exhibited individual but insignificant variations in the textural

parameters measured. Thus, blending of flour from different cowpea varieties may be an acceptable practice.

RESEARCH RESULTS DISSEMINATED AND IN USE

Team members continue to disseminate research findings in refereed scientific journals, at professional scientific meetings, and in seminars and workshops. Developments in cowpea processing technology have publicized the importance of legume consumption, production, and potential sales around and beyond the mill site. Project findings, in particular the appropriate technology and infant weaning foods formulated and tested by the H.C. team, are being utilized by other community intervention programs. The AFRICARE Program, a child survival project of the Ministry of Health, Imo State, Nigeria in collaboration with AFRICARE International, has now developed a strong link with the CRSP project to improve the health and nutritional status of Nigerians. Commercial food processors in Nigeria benefit from cowpea processing technology as it evolves from the project. Several small food processors are emerging in villages as the desire for nutritious, low-cost food increases.

Publicity on reduction of oligosaccharides/flatulence in legumes by germination generated considerable interest in the U.S., Europe and Latin America. Numerous newspaper, magazine and radio interviews were given to media people from as far away as Italy and British Columbia. An inquiry from a commercial company, which markets a large volume of various legumes in Great Britain, raised the possibility that additional research funds might be available to examine other aspects of the effects of germination on the sensory quality of beans.

Representatives of a U.S. commercial firm met with the U.S. team to discuss processing/marketing potential for akara in the U.S. Akara prepared by the traditional process and from project-technology flour was well received. The company generates large quantities of split blackeye seeds (58 percent moisture content) during its blanching operation which could be used for akara preparation if functional properties are not impaired. Trials will be conducted to determine akara-making quality of blackeye splits and semi-dry (18 percent moisture content) green acre cowpeas.

Inflation and the recent Nigerian government ban on importation of wheat present new opportunities for using cowpea flour to enhance the protein quality of composite flour products. New cowpea formulations developed for weaning foods await the final testing on children. Meanwhile, recipes developed for using dehulled cowpea splits have been found to be highly acceptable in organoleptic evaluations by mothers. Other products containing cowpea mixed with corn, plantain, yam or cassava have been developed, tested and found to be highly acceptable.

Data collected for socio-cultural and nutrition studies have established a baseline of cowpea consumption, storage and usage patterns in selected areas of Nigeria. Methodology developed for decortication and milling of cowpeas to produce a convenient-to-use flour has expanded to an AFRICARE Child Survival Project in a neighboring state in Nigeria. Impact assessment of project technology is in progress both in Nigeria and the U.S. The milled product is desirable from a nutritional and microbiological standpoint and has excellent functional and sensory qualities in preparation of traditional foods. Germination has been applied successfully to cowpeas to improve their digestibility. The Hard-to-Cook Workshop held in conjunction with the annual meeting of the American Association of Cereal Chemists brought together CRSP and non-CRSP scientists to discuss the defect in legumes, the mechanism(s) involved and possible research strategies.

PUBLICATIONS AND PRESENTATIONS

Bulgarelli, M. A. and L. R. Beuchat. 1988. Influence of Indigenous Microflora on Functional Properties of Cowpea Paste. Paper presented at 48th Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 19-22. (Abstract 329, p. 158).

Bulgarelli, M. A. and L. R. Beuchat. 1988. Influence of Indigenous Microflora on Nutritional Properties of Cowpea Paste. Paper presented at 88th Annual Meeting, American Society for Microbiology, Miami Beach, FL, May 8-13 (Abstract P-30, p. 279).

Bulgarelli, M. A., L. R. Beuchat and K. H. McWatters. 1988. Microbiological Quality of Cowpea Paste Used to Prepare Nigerian Akara. Journal of Food Science 53:442-444, 449.

Damola, T. A. 1988. Changes in Cowpea Texture and Solubility of Cell-Wall Components in Response to Aerobic and Anaerobic Storage and Their Relationship to Development of the Hard-to-Cook Defect. M.S. Thesis, University of Georgia-Athens.

Damola, T. A. and R. D. Phillips. 1988. Accelerated Storage Effect on Texture and Cell-Wall Composition of Cowpea (*Vigna unguiculata*). Paper presented at 1988 Annual Meeting, Georgia Nutrition Council, Pine Mountain, GA, February 25-26 (Abstract, 1 p.).

Falcone, R. G. and R. D. Phillips. 1988. Effects of Feed Composition, Feed Moisture, and Barrel Temperature on the Physical and Rheological Properties of Snack-like Products Prepared from Cowpea and Sorghum Flours by Extrusion. Journal of Food Science 53:1464-1469.

Hung, Y.-C., M. S. Chinnan and K. H. McWatters. 1987. Effect of Predecortication Treatment on the Textural Quality of Cowpea Products. Paper presented at 1987 Summer Meeting, American Society of Agricultural Engineers, Baltimore, MD, June 28--July 1 (ASAE Paper 87-6062).

Hung, Y.-C., M. S. Chinnan and K. H. McWatters. 1988. Effect of Predecortication Drying Treatment on the Textural Quality of Cowpea Products: Seeds and Akara. Journal of Food Science 53:1778-1781.

Hung, Y.-C., K. H. McWatters and M. S. Chinnan. 1988. A Microscopic Method to Quantify Whippability. Journal of Food Science 53:1566-1569.

Hung, Y.-C., K. H. McWatters, R. D. Phillips and M. S. Chinnan. 1988. Effect of Pre-decortication Heat Treatment on the Microstructure of Cowpea Products. Paper presented at 48th Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 19-22 (Abstract 467, p. 189).

McWatters, K. H. and A. L. Branch. 1988. Quality Characteristics of Akara (Fried Cowpea Paste) Made from Stored Cowpea Meal. Paper presented at 1988 Annual Meeting, Georgia Nutrition Council, Pine Mountain, GA, February 25-26 (Abstract, 1 p.).

McWatters, K. H. and M. S. Chinnan. 1988. Developing a Village Mill to Process Cowpea Flour in Nigeria. International Development Communique, January, p. 1. Athens, GA: University of Georgia, Office of International Development.

McWatters, K. H., M. S. Chinnan, Y.-C. Hung and A. L. Branch. 1988. Effect of Predecortication Drying Temperature on Cowpea Paste Characteristics and Functionality in Preparation of Akara. Cereal Chemistry 65:23-27.

McWatters, K. H., D. Nnanyelugo, P. O. Ngoddy and M. S. Chinnan. 1987. CRSP Research Develops a Village Mill to Process Cowpea Meal in Nigeria. Pulse Beat, Winter/Spring 1987:1-2. East Lansing, MI: Michigan State University, Bean/Cowpea CRSP Management Office.

McWatters, K. H., R. D. Phillips and A. L. Branch. 1987. Influence of Storage on Quality of Cowpea Meal for Use in Akara, Fried Cowpea Paste. Paper presented at 72nd Annual Meeting, American Association of Cereal Chemists, Nashville, TN, November 1-5 (Abstract 106, Cereal Foods World 32:564).

Ngoddy, P. O. 1988. Cowpea Processing and Storage. Paper presented at Food Crops Utilization and Nutrition Training Course, University of Nigeria, Nsukka, Nigeria, April 10-23.

Nnanna, I. A. 1988. Reduction of Oligosaccharide Content of Cowpeas (*Vigna unguiculata*) by Germination and a Study of Changes in the Nutritional and Functional Quality of the Treated Flour. Ph.D. Dissertation, University of Georgia-Athens.

Nnanna, I. A., T. Damola and R. D. Phillips. 1987. Isolation and Purification of Phytase from Germinated Cowpea (*Vigna unguiculata*). Paper presented at 72nd Annual Meeting, American Association of Cereal Chemists, Nashville, TN, November 1-5 (Abstract 101, Cereal Foods World 32:564).

Nnanna, I. A., R. D. Phillips, K. H. McWatters and Y.-C. Hung. 1988. Effect of Germination on the Physical, Chemical, and Sensory Characteristics of Cowpea Flour. Paper presented at 48th Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 19-22 (Abstract 526, p. 202).

Nnanyelugo, D. O., E. K. Ngwu and A. I. Chukwunyelu. 1987. An Analysis of Urinary and Faecal Nitrogen Excretion and Some Anthropometric Indices in Response to Various Levels of Protein Intake. Nutrition Reports International 36:507-519.

Nnanyelugo, D. O. and A. C. Uwaegbute. 1988. Cowpea Utilization and Nutrition. Paper presented at the Food Crops Utilization and Nutrition Training Course, University of Nigeria, Nsukka, Nigeria, April 10-23.

Obizoba, I. C. In press. Effects of Germination, Dehulling, and Cooking on the Nutritive Value of Cowpea (*Vigna unguiculata*) Flour. Journal of Food Science.

Obizoba, I. C. and C. Egbuchunam. In press. Effects of Domestic Processing and Cooking on Nutritional Quality of Two Varieties of Cowpea Assayed in Rats. Journal of Nutritional Science .

Okeke, E. C. 1987. Time Allocation of Rural Women in Farm Families in Anambra State. Paper presented at Nutrition Society of Nigeria Conference, Benin, Nigeria, November.

Okeke, E. C. 1987. Energy Intake and Expenditure of Rural Farm Women in Anambra State, Nigeria--a Baseline Study. Paper presented at the Nutrition Society of Nigeria Conference, Benin, Nigeria, November.

Okeke, E. C. and I. C. Obizoba. 1986. The Nutritive Value of All-Vegetable Protein Diets Based on Legume, Cereal and Tuber in Weanling Rats. Qualitas Plantarum: Plant Foods for Human Nutrition 36:213-222.

Onuorah, V. I., A. C. Uwaegbute and N. J. Enwere. 1988. Cowpea Recipes. Paper presented at Food Crops Utilization and Nutrition Training Course, University of Nigeria, Nsukka, Nigeria, April 10-23.

Phillips, R. D. 1988. Proceedings of CRSP Workshop on the Hard-to-Cook Defect in Beans and Peas, Nashville, TN, November 4-5, 1987.

Phillips, R. D. and B. W. Abbey. 1987. Flatulence-Producing Potential of Selected Nigerian and American Legumes. Paper presented at 72nd Annual Meeting, American Association of Cereal Chemists, Nashville, TN, November 1-5 (Abstract 15, Cereal Foods World 32:651).

Phillips, R. D., B. W. Abbey and I. A. Nnanna. 1988. A System for Determining Flatus (Hydrogen) Production in Laboratory Rats. Nutrition Reports International 37:623-628.

Phillips, R. D., B. W. Abbey and I. A. Nnanna. 1988. A System for Determining Flatus (Hydrogen) Production in Laboratory Rats. Paper presented at 1988 Annual Meeting, Georgia Nutrition Council, Pine Mountain, GA, February 25-26 (Abstract, 1 p.).

Phillips, R. D., M. S. Chinnan, A. L. Branch, J. Miller and K. H. McWatters. 1988. Effects of Pretreatment on Functional and Nutritional Properties of Cowpea Meal. Journal of Food Science 53:805-809.

Phillips, R. D. and I. A. Nnanna. 1988. Protein and Starch Digestibility and Flatulence Potential of Germinated Cowpea. Paper presented at the 1988 Annual Meeting, Georgia Nutrition Council, Pine Mountain, GA, February 25-26 (Abstract, 1 p.).

Phillips, R. D. and I. A. Nnanna. 1988. Protein and Starch Digestibility and Flatulence Potential of Germinated Cowpea. Paper presented at 48th Annual Meeting, Institute of Food Technologists, New Orleans, LA, June 19-22 (Abstract 121, p. 111).

Uwaegbute, A. C. 1988. Cowpeas in Infant and Preschool Child Feeding. Paper presented at Cowpea Workshop, Community Secondary School, Isienu, Nigeria, April.

Uwaegbute, A. C. 1987. Infant Feeding Patterns and Comparative Assessment of Formulated Weaning Food Based on Vegetable Proteins. Ph.D. Dissertation, University of Nigeria, Nsukka, Nigeria.

SENEGAL - UNIVERSITY OF CALIFORNIA-RIVERSIDE

A PROGRAM TO DEVELOP IMPROVED COWPEA CULTIVARS, MANAGEMENT METHODS, AND STORAGE PRACTICES FOR SEMIARID ZONES

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
Anthony E. Hall, U.S.	Botany and Plant Sciences	University of CA-Riverside
Limamoulaye Cisse, H.C. 6/88	Crop Production	ISRA
Francois Faye, H.C. 5/88	Crop Production	ISRA
Co-Investigators:		
Amadou Bocar Bal	Crop Production	ISRA
Ndiaga Cisse	Crop Production	ISRA
Madiagne Diagne	Farming Systems	ISRA
Alan N. Eckard	Botany and Plant Sciences	University of CA-Riverside
D. G. Gaikwad	Crop Production	ISRA/Government of India
Mamadou Gueye	Crop Production	ISRA
Famara Massaly	Crop Production	ISRA
Prabodh N. Patel	Botany and Plant Sciences	University of CA-Riverside
Dogo Seck	Crop Production	ISRA
Samba Thiaw	Crop Production	ISRA

RESEARCH OBJECTIVES: To increase seed production and yield stability of cowpeas grown in hot semiarid zones by subsistence farmers. The focal point of this research will be the development of "Mini-Kit" pre-extension trials to compare local methods with experimental treatments of cowpea cultivars, management methods and conservation practices. Research on experiment stations and experiments in farmers' fields will focus on breeding, agronomy, plant pathology, rhizobiology, entomology and cowpea storage. In the U.S., research will focus on the development of techniques for screening cowpeas for resistance to drought and heat and on other factors limiting yield potential.

SUMMARY: "Mini-Kit" experiments were conducted by farmers in northern Senegal with 35 trials in 1987 and 1988. The average yield in 1987 was substantially lower than 1986, due to drought and other stresses during midseason, and the medium-cycle spreading varieties produced higher yields than the early erect varieties. Intercrops of spreading and erect varieties are being studied in three locations in 1988 as a means for stabilizing cowpea yields of grain and hay. Advanced yield trials were conducted with thirty-eight lines in five locations, and preliminary yield trials were conducted with one hundred forty-four lines in one location in Senegal in 1987. Selected lines which have resistance to mosaic viruses, bacterial blight and cowpea weevil are being evaluated in advanced yield trials in 1988. One line looks sufficiently promising that it may be included in the "Mini-Kit" experiments in 1989. On-farm storage experiments completed in June 1988 demonstrated that sealed-drum

storage can be very effective under farm conditions. In California, 80,000 F_2 plants were screened for heat tolerance, delayed leaf senescence, disease resistance and agronomic characters in 1987, and 2,000 plants were selected and advanced two generations. More than 1,000 of these selections were screened at the F_5 generation in four field nurseries in California in 1988 for multiple characteristics. Studies are being conducted on the influences of pod-picking at color-break, on the rate of leaf senescence and resistance to drought during mid-season with contrasting genotypes. Evidence was obtained indicating that selection for high harvest index but moderate to low vegetative vigor could produce cultivars with high yield potential under high planting densities. Leaf discrimination against heavy carbon isotopes was studied as a potential screening technique for selecting plants with higher water-use efficiency. Significant differences among genotypes were observed but with some genotype x environment interactions. Increases in water-use efficiency due to drought were associated with decreases in carbon isotope discrimination. However, no associations were discovered between genotypic differences in carbon isotope discrimination and water-use efficiency.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

This report covers the analyses of experiments conducted during the 1987 cropping season which were completed during the 1988 fiscal year and the experiments initiated during the summer of 1988.

"Mini-Kit" On-Farm Experiments in Senegal

The objectives of these farmer-managed experiments are: (1) to evaluate the best cowpea varieties available and any sufficiently advanced breeding lines under realistic farm conditions; (2) to evaluate the sealed-drum cowpea storage system; (3) to demonstrate the most effective crop management methods to extension workers and farmers; and (4) to enable the researchers to gain an improved understanding of the advantages and disadvantages of the cowpea production technology and of the constraints to improving cowpea production and utilization.

In 1987, thirty-five "Mini-Kit" experiments were conducted in four villages in the central zone around Bambey and three villages in the north of Senegal, in Louga region, with five farm families per village (Bal, 1988a). Sufficient rain was received by July 20 to permit planting. The seasonal rainfall was higher than recent years with 454 mm in the northern zone and 480 mm in the central zone and provided 61 to 91 percent of the maximal water requirements of the cowpeas (Diagne, 1988). A serious drought occurred in the middle of August together with hot, dry winds which stressed the early varieties (CB5 and Bambey 21) more than the later-flowering varieties. As was observed in 1986, drought during mid-season and low plant stands caused the early-flowering erect varieties to have lower yields in both zones than the medium-cycle spreading varieties (58-57, Ndiambour [illegible] Mougne) which were favored by the late rains. The average yield in the "Mini-Kit" trials in 1987 of 436 kg/ha was substantially lower than in 1986 (31 percent less for the same farmers). A survey of 22 fields in 20 villages not involved in the "Mini-Kits" gave average yields of 362 kg/ha (Diagne, 1988). Surveys of farm families involved in the "Mini-Kits" (Bal, 1988a) indicated that their primary criterion in choosing a cowpea variety was earliness to help overcome the

period of hunger just before the beginning of the cereal harvest and their second criterion was yield, but their favorite varieties were the high-yielding, later-flowering varieties (Ndiambour, Mougne and 58-57). The farmers said that they do not sell cowpea hay, but use it to feed animals in the village, and they do not eat the green leaves of cowpea. They said that an improved marketing system was needed for cowpea grain. The second major on-farm test of sealed-drum storage of cowpea was completed in June 1988 (Seck, 1988). After eight months of storage, 89 percent of the drums had cowpeas of adequate quality for local markets, and 52 percent had grain of export quality (Table 1). This research confirmed the conclusion from last year that the sealed-drum system can be effective under farm conditions in storing cowpeas for local markets. This research also demonstrated that initial levels of damage were high enough (>5 per cent) in 18 percent of the samples to limit their value as an export crop, indicating the need for more rapid harvesting, drying and threshing.

During the 1988 cropping season, thirty-five "Mini-Kit" experiments were initiated in seven villages (Sagatta, Ndatt Fall, Coki, Sakal, Sine Dieng, Gatt Ngarafe and Keur Galo). Follow-up surveys of the extent of adoption of technologies are being conducted at Ndatt Fall, Gatt Ngarafe and three villages where "Mini-Kit" experiments have just been phased out: Keur Boumi, Thilmakha and Sam Thialle.

Examination of fields adjacent to the "Mini-Kit" experiments in 1988 demonstrated that the parasitic weed of cowpea, *Striga gesnerioides*, is widespread and a potential major problem for the future.

Agronomic Experiments

Studies at Bambey in 1985 and 1986 had shown that varietal intercrops of alternating rows of a medium-cycle spreading variety and an earlier erect variety can improve stability and increase yields of grain and hay compared with sole crops of these varieties (Hall, 1988c). In 1987, mixtures of two varieties were compared with sole crops at both Bambey and Louga (Cisse et al., 1988). Overall yield levels were low and the mixtures performed similar to the highest yielding sole crop. There may have been insufficient difference in growth habit and earliness between the two varieties to provide an adequate test of the stabilizing influence of mixtures. In 1988, varietal intercrops are being compared with sole crops at Bambey, Thilmakha and Louga using alternating rows and pairs of varieties with distinct differences in growth habit and earliness, and studies of mixtures are being repeated.

Pods of early cowpeas are often harvested at the color-break stage in Senegal to provide an early source of food. Studies at Riverside in 1987 by C. O. Gwathmey demonstrated that this can delay leaf senescence so that hay yield is increased and an additional flush of pods is produced. A breeding line (7964) which has delayed senescence produced a greater second flush of pods than CB5 (Figure 1). An experiment was initiated in 1988 to test whether delayed senescence due to either genotype or early pod removal can enhance resistance to mid-season drought and to determine the influence of genetic "stay-green" on yield potential.

Plant characters which influence yield potential of bush-type cowpeas have been studied over three years at Riverside. M. B. Kwapata observed for contrasting bush genotypes that yield response to extremely high plant densities was positively correlated with harvest index at final harvest and negatively correlated with leaf area and total shoot biomass at early bloom for plants grown at the low

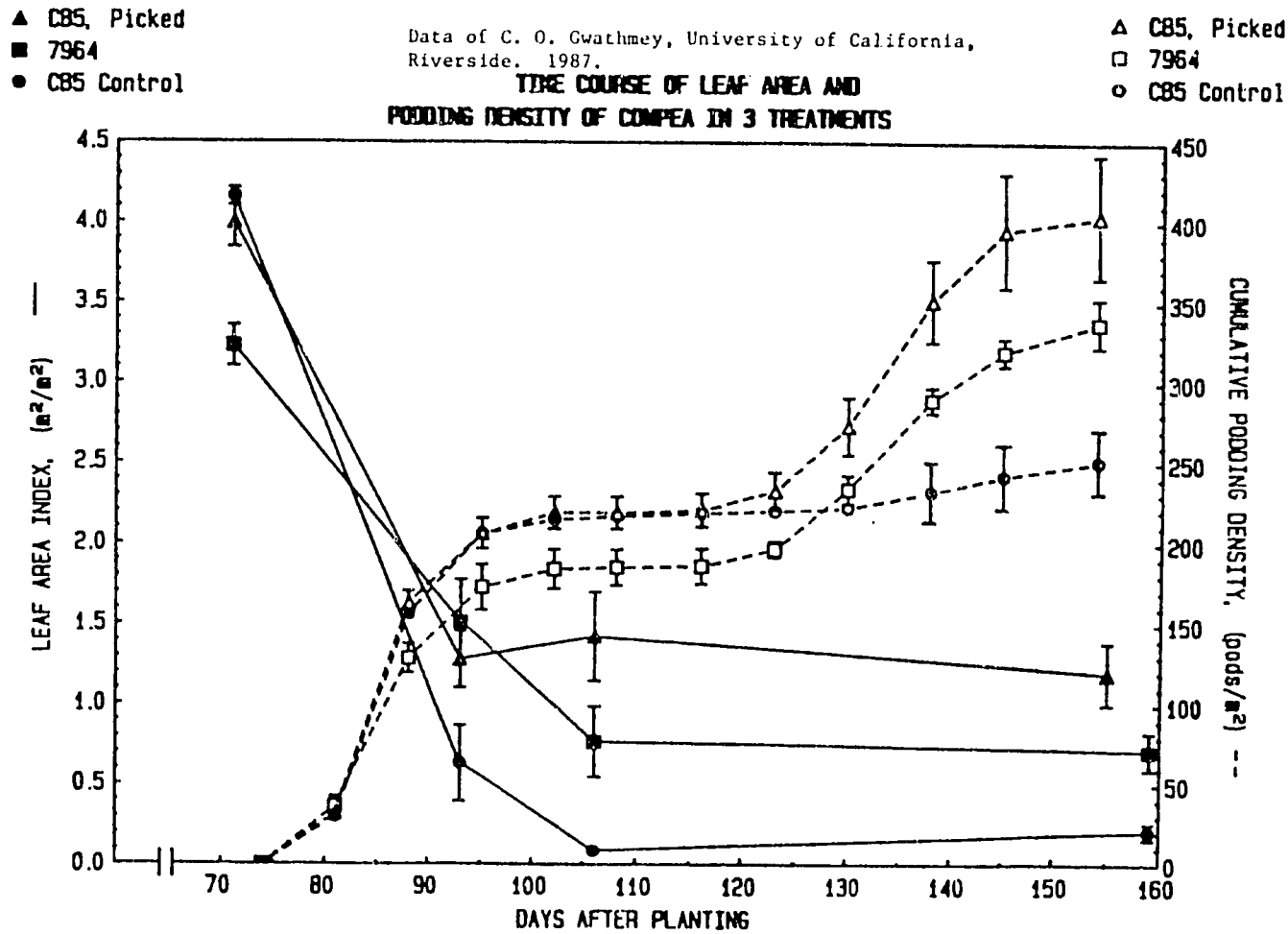
Table 1

Changes in Cowpea Production in Senegal

Year	Hectares Planted		Yield/Hectare		Total Production	
	Louga*	Total	Louga	Total	Louga	Total
	---- hectares ----		---- kg/ha ----		---- tons ----	
1970-79	25,203	63,300	295	293	7,746	18,568
1980	28,516	54,247	370	315	10,539	17,080
1981	30,218	68,484	401	420	12,110	28,777
1982	28,627	47,930	233	276	6,671	13,245
1983	12,658	40,000	371	325	4,696	12,000
1984	8,400	53,000	-0-	302	-0-	16,000
1985	63,557	121,000	434	545	27,588	66,000
1986	53,733	117,607	451	466	24,001	54,863
1987	35,114	71,480	325	400	11,412	28,625

* Louga is a Region in the northern peanut basin.

Figure 1



plant densities required in efficient breeding nurseries (Table 2). This indicates that cultivars with higher yield potential can be developed by selecting plants with high harvest index and moderate to low vegetative vigor. The cultivars would be grown at very high plant densities. This research has relevance to the development of improved grain-type cultivars for California and improved edible-pod cultivars for developing countries where they are grown in irrigated gardens near to major cities.

Breeding Research

Thirty-eight advanced lines were selected based upon preliminary yield trials in 1986, placed into three groups based upon cycle length, and yield tested in several locations in Senegal in 1987 (Cisse et al., 1988). Lines IS 86-283N and IS 86-279N were selected from advanced yield trials I and II as potential replacements for the medium-cycle varieties. These lines have similar yields as 58-57 but larger grain and improved resistance to mosaic viruses and bruchids. Line IS 86-275N was selected from advanced yield trial III as a potential replacement for the early varieties. This line had high yield and resistance to bacterial blight and mosaic virus. Entomological studies (Seck, 1988) demonstrated that IS 86-283N and IS 86-275N have some resistance to cowpea weevil. These and other promising lines are included in multi-location advanced yield trials in 1988 to see if they have sufficient yield stability and desirable agronomic characters to warrant inclusion in the "Mini-Kit" on-farm trials in 1989. IS 86-275N is performing very well and is exhibiting a high level of resistance to mosaic viruses. Three preliminary yield trials were conducted in 1987 at

Table 2

Correlation between yield responsiveness to high planting density $\{[Y_{high} - Y_{low}]/Y_{low}\}$ and various plant characteristics, data of M. B. Kwapata, 1987.

	Low Density		High Density	
Plant Characteristics	r	significance	r	significance
Apparent harvest index (HI)	0.71	*	0.95	*
Apparent main stem HI	0.27	ns	0.82	*
Apparent branch HI	0.85	*	0.99	*
Structural HI	0.54	*	0.91	*
Structural main stem HI	0.21	ns	0.74	*
Structural branch HI	0.79	*	0.99	*
+Shoot dry matter	-0.79	*	-0.69	*
+Leaf area index	-0.61	*	-0.38	ns

+At full bloom
*Significant at $p < .05$
nsNot significant at 5% level

Bambey with 144 new lines (Cisse et al., 1988). Several of these lines have been selected for inclusion in the advanced yield trials in 1988. All advanced lines were screened for resistance to bacterial blight and mosaic viruses. Some progress was made in selecting for resistance to thrips, cowpea aphids and bruchids. Nine edible-pod cowpeas from IITA and UCR were yield tested at Bambey in 1987 for potential use in market gardens, and these studies are being repeated in 1988.

In California, 80,000 F_2 plants were screened for heat tolerance, delayed leaf senescence, disease resistance and agronomic characters in 1987 by P. N. Patel and A. E. Hall, and 2,000 plants were selected. During the winter of 1987/88, these plants were screened for resistance to fusarium wilt and seed quality characteristics and advanced two generations. In the summer of 1988, more than 1,000 F_5 selections were screened in row sections in Riverside (to evaluate delayed leaf senescence and agronomic characters), Imperial Valley (to evaluate heat tolerance), Denair and Moreno (to evaluate resistance to fusarium wilt and root-knot nematodes). Advanced yield tests were conducted with 28 lines including material with heat tolerance and delayed leaf senescence at Riverside and Kearney Field Stations in the summer of 1988. A yield trial was conducted with ten vegetable cowpea lines at Riverside in 1988.

Genetics and Physiological Research in California to Support the Breeding Programs

Evaluations by K. O. Marfo of the pod set of F_1, F_2 and backcross progenies in Imperial Valley during 1987 indicated that Prima may be a more effective heat-tolerant parent than TVu 4552 and that Prima has a dominant gene conferring heat tolerance at pod set. Further studies are being conducted in Imperial Valley and hot controlled-environment chambers during 1988 to attempt to confirm these results, and field studies are being conducted on response to selection for heat tolerance. K. O. Marfo has generated F_2 plants from crosses between cowpea varieties from Ghana and heat-tolerant parents from UCR, and he is screening them for heat tolerance in Imperial Valley. Studies of heat-induced brown discoloration in seed coats of cowpeas (Patel and Hall, 1988) have shown that a single nuclear dominant gene is responsible for this detrimental response to heat stress, which is present in the important cowpea genotypes TVx 3236 and TVu 4552. For TVu 4552, no linkage was observed between this trait and the recessive gene governing heat tolerance during floral bud development, and we have shown that it is possible to incorporate this heat tolerance while excluding the seed coat browning response.

Leaf discrimination against the heavy isotope ^{13}C was evaluated by A. E. Hall and R. G. Mutters with 18 contrasting cowpea genotypes subjected to drought and well-watered conditions at Riverside in 1987. We tested the hypothesis that significant genotype x environment interactions were occurring with respect to leaf discrimination and discovered significant changes of ranking with two genotypes due to drought (Table 3) and significant rank changes with four genotypes from year-to-year. We made measurements on these plants of the ratio of CO_2 assimilation rate to leaf conductance to water vapor as an estimate of intrinsic water-use efficiency. We observed higher water-use efficiency in the plants subjected to drought which is consistent with the smaller discrimination against ^{13}C under drought. The data on photosynthesis and leaf conductance did not provide a clear explanation for the genotypic differences in ^{13}C discrimination. Twelve of these genotypes are being subjected to three levels of drought at Riverside in 1988 and measurements will be made to determine the correla-

Table 3

Carbon isotope discrimination (Δ) by leaves of cowpea genotypes grown under well-watered and stored soil moisture conditions in 1987 (Data of Hall, Mutters, Hubick, and Farquhar, 1987).

		Wet Conditions		Dry Conditions			
Rank	Genotype	Δ x 10^{-3}	Flowering Time	Δ x 10^{-3}	Rank	Rank Change	
(1)	CB46	20.70	E	18.76	(4)	NS	
(2)	8049	20.51	E	19.05	(1)	NS	
(3)	Prima	20.40	E	18.88	(2)	NS	
(4)	3-4-13	20.36	E	18.81	(3)	NS	
(5)	CB5	20.32	E	18.48	(7)	NS	
(6)	4R-0267-1F	19.98	M	17.81	(16)	***	Down
(7)	PI 293579	19.97	M	18.53	(5)	NS	
(8)	1-12-3	19.90	E	18.29	(9)	NS	
(9)	Bambey 21	19.82	M	17.89	(13)	*	Down
(10)	M39	19.72	M	18.52	(6)	NS	
(11)	Chino M1	19.66	E	18.29	(8)	NS	
(12)	CB3	19.45	M	17.82	(14)	NS	
(13)	TVx309-1G	19.43	M	17.82	(15)	NS	
(14)	IT82E-18	19.40	E	18.13	(10)	NS	
(15)	Magnolia	19.35	E	18.05	(12)	NS	
(16)	58-57	19.32	L	18.10	(11)	NS	
(17)	Vita 7	18.89	L	17.31	(17)	NC	
(18)	UCR 237A	18.67	L	16.89	(18)	NC	
	Mean	19.77		18.19	P<	.05	.001
Irrigation effects		***					
Genotype effects		***	LSD (G x I)			.39	.66
Genotype x Irrigation		*					

*,*** Significant at the 0.05 and 0.001 probability level, respectively. NS = not significant at the 0.05 probability level. NC = no change in ranking. E,M and L denote early, medium, and late time of flowering, respectively.

tions present between genotypic differences in leaf discrimination against ^{13}C, intrinsic water-use efficiency, CO_2 assimilation and transpiration. Possible breeding strategies would involve selecting for low carbon isotope discrimination in developing cultivars for dryland conditions, and selecting for high discrimination to develop cultivars with high yield potential. Further studies are needed to determine whether these strategies will be effective.

Biological Nitrogen Fixation Studies

Concentration of ureides in stems thirty-five days after sowing was compared with total nitrogen per plant in shoots of eight erect and ten spreading genotypes grown in infertile soil in Senegal (Gueye and Ndiaye, 1988). The correlation coefficient (r=.54) was significant at the 5 percent level, but this was due to the substantially larger amounts of nitrogen in spreading plants which were planted at wider spacing. However, total nitrogen in shoots per unit land area was only 26 percent higher for the spreading than the erect varieties. Measurement of total shoot nitrogen/ha in plants grown on soil with extremely low nitrogen is probably the most reliable method for evaluating nitrogen fixation. It is not clear whether other measures of nitrogen fixation, such as ureide concentrations or acetylene reduction, have adequate reliability even for use in late stages of breeding programs to screen out individuals with low nitrogen fixation.

Entomology Studies

Studies of threshold levels indicated that the first treatment with

insecticide against flower thrips potentially should be applied before flowering when floral buds are present and should be based upon the number of thrips present on floral buds (Bal, 1988b). The next treatment with insecticide could be based upon the number of thrips present in flowers. Specific threshold levels have to be determined.

Studies to detect cowpeas with resistance to cowpea aphid were initiated in Senegal and Riverside. Khady Diop discovered that certain cowpeas which have been reported to have resistance in Africa did not have resistance to *Aphis craccivora* in California. During the summer of 1988, contrasting cowpea genotypes were screened by Mubarak Abdallah to search for parents which have resistance to the California biotype(s) of cowpea aphid. Lines found to be resistant to cowpea aphid in Georgia by CRSP scientist R. Chalfant were evaluated. None of the lines tested had adequate resistance to the California aphid either in the form of antibiosis or tolerance. Contrasting cowpea genotypes are being screened against the Senegal biotype(s) of cowpea aphid by Amadou Bal.

Plant Pathology Studies

Plants selected with resistance to mosaic viruses under field conditions were screened again for resistance under screenhouse and field conditions. Lines in the advanced yield trials were screened for resistance to mosaic viruses and bacterial blight. The main disease in the disease nursery at Bambey, and many farmers' fields in 1987, was Ashy Stem Blight (Bal, 1988a). The major diseases at Bambey in 1988 were mosaic viruses and the spreading variety, 58-57, was badly damaged. Studies were initiated on the use of chemical seed dressings because inadequate plant stands appear to be a major problem on farmer's fields that is particularly damaging for erect varieties.

RESEARCH RESULTS DISSEMINATED AND IN USE

As a result of the "Mini-Kit" on-farm experiments, the following varieties developed by the Senegal government (58-57, Ndiambour, Mougne and Bambey 21), by IITA (TVx 3236) and from California (CB5) have become more widely disseminated in Senegal. Survey results indicate that they are distributed throughout the villages involved in "Mini-Kit" experiments and in several neighboring villages (Bal, 1988a).

In these villages, some cowpeas are now being sown in rows, with mechanical sowing and weeding, and higher densities than the traditional practice. Sealed-drum storage of cowpeas is being adopted and is resulting in higher quality cowpeas being available for food and seed. The extent of adoption is being evaluated in 1988 in five of the "Mini-Kit" villages and surrounding areas.

Germplasm Conservation and Use

The USDA collection of cowpea germplasm presently consists of 2300 accessions for which seeds are available to scientists. IITA in Nigeria has the major collection in the world with 14,000 cowpea accessions. The Vigna Crop Advisory Committee of USDA considers the U.S. collection to be inadequate for potential future needs of U.S. and world agriculture. UCR presently has 1,300 cowpea accessions collected from many countries in the world as part of CRSP activities. Most of these accessions are not in the USDA collection. In 1987, 330 of these accessions were grown in the field at Riverside for characterization and seed multiplication. USDA provided some funds to UCR starting in the summer of 1988 for a cooperative project. Under this project,

UCR has grown 600 new accessions in a greenhouse and produced disease-free seed. Another 349 accessions which had already gone through this procedure under CRSP funding were grown in the field for characterization and seed multiplication. A computerized system is being installed and the data base and seed of the accessions will be provided to USDA to enhance the U.S. collection at the Regional Plant Introduction Station in Griffin, Georgia. The UCR cowpea germplasm collection has increased 300 percent since the initiation of the CRSP project and continues to grow since we have an active program of germplasm exchange, receiving and sending cowpea accessions to cooperators throughout the world.

Seed Production

The ISRA/Senegal project for producing foundation seed, which was initiated with funds and advice from this CRSP project, continued to produce cowpea seed in 1987 and 1988 (Massaly, 1988) but with funding from the Government of Senegal. Harvests during the beginning of this project year produced 1,684 kg of disease-free seed of seven varieties. During the dry season of 1988, 2.9 hectares of cowpeas were grown under irrigation to produce additional quantities of foundation seed. The CRSP project continues to provide advice concerning the appropriate varieties for different regions and the control of seed-borne diseases and insects in seed-production fields. The level of production of foundation seed of 2 to 3 tons/year is adequate for the present system involved in producing certified seed but is much lower than the potential need for foundation cowpea seed in Senegal. This has been estimated as being 20 tons/year, which would make possible the production of 400 tons/year of certified seed, which is the estimated need of farmers in Senegal.

Impact of Other CRSP-Produced or Recommended Technology

The farmers involved in the "Mini-Kit" experiments are essentially producing certified seed and, through the use of sealed-drums, they are able to make available high quality seed to neighboring farmers. These experiments are training a cadre of farmers who could work with the official agencies involved in producing certified seed in the future. One of the "Mini-Kit" farmers at Sine Dieng had large seed multiplication fields in 1988 that were in excellent condition. The European Economic Community (EEC) promoted the extensive use of insecticides on cowpeas in the CB5 project in 1985. There has been less use of insecticides on cowpeas after 1985 due to the demise of the EEC project and the promotion of minimal insecticide-use by the CRSP through the "Mini-Kit" experiments.

Project Impact on Production and Consumption of Cowpeas

A major challenge for this project is to cooperate with extension agencies to assist farmers to increase total production and yields/ha of cowpeas in Senegal. The statistics for cowpea production are described in Table 1.

Total production of cowpeas in Senegal in 1987 was 54 percent higher than the ten-year average prior to the CRSP project but was substantially less than the production achieved in 1985. Growing conditions for cowpea were not good in 1987 resulting in lower productivity in the "Mini-Kit" experiments compared with 1986 and lower average yields in Senegal of 400 kg/ha compared with 466 in 1986 and 545 in 1985. However, the average yields in 1987 were still 37 percent higher than the ten-year average prior to the CRSP project. The decline in area planted to cowpeas since 1985 is probably due to a series of factors

such as ease of marketing, prices received by farmers and ability to store cowpeas on the farm, as well as production constraints such as inadequate supplies of good seed and critical insecticides. An analysis of the factors needed to achieve sustained increases of cowpea production in Senegal was conducted by Bingen, Hall and Ndoye (1988). The extent of cowpea production also depends upon the conditions for peanut and millet production. Better conditions for these crops result in less planting of cowpeas. One factor not included in the statistics is the expanded consumption of early cowpeas as fresh southern peas, which improves living conditions during the traditional period of hunger just prior to the millet harvest. For example, the EEC estimated cowpea production in 1985 as being in excess of 80,000 tons, whereas the Government of Senegal estimated production as being 66,000 tons; some of the difference in these figures is due to the inclusion of cowpeas as southern peas in the EEC estimate. Substantial quantities of CB5 and Bambey 21 are being harvested as fresh southern peas.

Meeting the Needs of Families on Small Farms

A major focus of this project is the Louga region which had become depressed due to earlier droughts. Conditions improved in this region in 1987, compared with recent years, due to increased production of millet and peanut. Improved cowpea production systems which provide more fresh southern peas, dry grain and hay per unit land area and per unit labor input enhance the security of farming and living in this region, especially during dry years. Surveys are being conducted as part of the "Mini-Kit" experiments, which specifically seek the opinions of women and men. Our present impression is that the expanded cowpea production and improved technologies are of benefit to all members of farm families.

PUBLICATIONS AND PRESENTATIONS

Bingen, R. J., A. E. Hall and M. Ndoye. 1988. California Cowpeas and Food Policy in Senegal. World Development 16(7):857-865.

Hall, A. E. 1988a. ISRA/UCR Collaborative Research Support Project on Cowpeas: Summary of California Research and Plans. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from Dr. A. E. Hall, Department of Botany and Plant Sciences, University of California-Riverside).

Hall, A. E. 1988b. Role of Conventional Hybridization/Selection and Genetic Engineering in Breeding Plants with Resistance to Insects. Invited talk to Eighth Biennial Workshop on Plant Resistance to Insects, Asilomar, CA, February 28-March 2.

Hall, A. E. In press. Stabilizing Dryland Production of Cowpeas by Using Varietal Intercrops. International Conference on Dryland Farming, Bushland, TX, August 15-19.

Mutters, R. G. 1988. Reproductive Physiology of Cowpea (Vigna unguiculata (L.) Walp.) at High Temperatures with Different Photoperiods. Ph.D. Dissertation, University of California-Riverside.

Patel, P. N. and A. E. Hall. 1988. Inheritance of Heat-Induced Brown Discoloration in Seed Coats of Cowpea. Crop Science 28:6.

Bal, Amadou. 1988a. Essais niebe en milieu paysan (Mini-Kit--1987). CNRA, Bambey, Senegal: Institut Senegalais de Recherches Agricoles.

Bal, Amadou. 1988b. Rapport de synthese--1987 sur l'entomologie du niebe. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Cisse, Ndiaga, Waly Ndiaye, Assane Sene and Mbaye Diagne. 1988. Amelioration du niebe-projet CRSP-NIEBE rapport annuel-1987. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Diagne Madiagne. 1988. Principaux resultats obtenus sur le niebe en 1987. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Gaikwad, D. G. 1988. Rapport de synthese--1987 sur la pathologie du niebe. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Gueye Mamadou and Mamadou Ndiaye. 1988. Criblage des varieties de niebe pour la fixation biologique de l'azote. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Massaly, Famara. 1988. Note sur le programme de multiplication des semences de niebe-campagne 1987. Report to project annual meeting, University of California-Riverside, February 22-26. (Available from CNRA, Institut Senegalaise de Recherches Agricoles, Bambey, Senegal.)

Seck, Dogo. 1988. Synthese des resultats: La protection des stocks de niebe an Senegal (Campagne 1987-88). Report to ISRA/UCR CRSP Project, September 1988. (Available from Laboratoire d'entomologie, Institut Senegalaise de Recherches Agricoles, Nioro du Rip.)

TANZANIA - WASHINGTON STATE UNIVERSITY

BREEDING BEANS (PHASEOLUS VULGARIS L.) FOR DISEASE, INSECT AND STRESS RESISTANCE AND DETERMINATION OF SOCIO-ECONOMIC IMPACT ON SMALLHOLDER FARM FAMILIES

NAME	DEPARTMENT	INSTITUTION
Principal Investigators:		
M. J. Silbernagel, U.S.	Plant Pathology/USDA	Washington State University
J. M. Teri, H.C.	Crop Science	Sokoine Univ. of Agriculture
Co-Investigators:		
D. C. Davis	Mechanical Engineering	Washington State University
P. R. Dimoso	Crop Science	Sokoine Univ. of Agriculture
J. Due	Ag Economics	University of Illinois
A. Femi Lana	Crop Science	Sokoine Univ. of Agriculture
E. E. Maeda	Food Science and Technology	Sokoine Univ. of Agriculture
F. T. B. Magayane	Ag Education and Extension	Sokoine Univ. of Agriculture
M. T. Mmbaga	Botany	University of Dar es Salaam
E. R. Mbiha	Rural Economy	Sokoine Univ. of Agriculture
A. N. Minjas	Crop Science	Sokoine Univ. of Agriculture
G. I. Mink	Plant Pathology	Washington State University
R. N. Misangu	Crop Science	Sokoine Univ. of Agriculture
O. D. Mwandemele	Botany	University of Dar es Salaam
S. Nchimbi	Crop Science	Sokoine Univ. of Agriculture
J. J. B. Rugambisa	Rural Economy	Sokoine Univ. of Agriculture
C. L. Rweyemamu	Crop Science	Sokoine Univ. of Agriculture
M. P. Salema	Soil Science	Sokoine Univ. of Agriculture
R. T. Schotzko	Ag Economics	Washington State University
K. P. Sibuga	Crop Science	Sokoine Univ. of Agriculture
B. G. Swanson	Food Science/Human Nutrition	Washington State University
A. J. Tesha	Botany	University of Dar es Salaam
J. G. Yarro	Zoology	University of Dar es Salaam

RESEARCH OBJECTIVES: To develop high yielding, widely adapted disease and insect resistant bean cultivars for the smallholder family. To estimate the economic viability of the new cultivars and their impact on women's roles in the production, consumption and marketing process. In the U.S. this will include breeding to combine multiple disease resistant factors; evaluation and standardization of bean common mosaic virus diagnosis and strain identification through the use of monoclonal antisera; studying the inheritance of a new source of resistance to halo blight; developing a set of diagnostic differential bean hosts; and evaluating heat and drought tolerance, cooking and nutritional characteristics of parental lines. In the H.C., research will include additional smallholder farm family surveys; initiation of a macro study of bean marketing; expansion and improvement of germplasm and screening methodology; developing rapid screening techniques to identify drought and heat tolerant hybrid segregants; continuing agronomic and physiologic studies of

beans in intercropping and crop mixture systems, and undertaking on-farm trials of new cultivars; improved production and storage practices in the areas where farming systems data have been collected.

SUMMARY: In many respects the Bean/Cowpea CRSP project in Tanzania shows real progress. Presentations at the 7th Annual Bean Workshop were greatly improved. In spite of some hindrances, considerable work was done in revival of the breeding program and in the areas of agronomy, food science, and plant pathology. The entomology work, the on-farm testing and the marketing study need further attention. The drought had a major impact on research efforts this year. Data collection by biological and social scientists led to a better understanding of the smallholder's constraints *vis-a-vis* availability of improved cvs, planting and cultivation practices and marketing produce.

The 7th Annual Bean Workshop at Sokoine University of Agriculture (SUA) was well attended by SUA and CIAT researchers, students, Tanzanian Agricultural Research Organization (TARO) and Uyole Agricultural Research Center (UAC) collaborators from within the country and some visitors from Zambia, Angola, and the U.S. This workshop was co-sponsored by the CIAT/SADCC bean outreach team from Arusha, four of whom attended. The CIAT efforts to support and coordinate national and regional bean improvement programs are the primary driving force for bean improvement in eastern and southern Africa. The CIAT/CRSP collaboration is highly complementary and provides opportunities to accomplish more than either agency working alone.

At Prosser, research emphasis is on using A55 as a source of upright plant habit and multiple root rot resistance to improve domestic bean types. Sources of heat and drought tolerance have been identified and are being hybridized into domestic and African material. A new BCMV pathotype from Adzuki bean has been identified. Screening and selection for combined resistance to necrotic strains of BCMV and halo blight in various U.S. and H.C. bean types continues.

SPECIFIC RESEARCH CONTRIBUTIONS TOWARD AMELIORATION OF NATIONAL, REGIONAL AND GLOBAL CONSTRAINTS

Research in Process

United States

Breeding for Disease Resistance. Hybridized best new materials to sources of heat and drought tolerance. Used CIAT line A55 extensively as parental to convey upright 2A habit to domestic and African materials. Continued screening and recurrent selection of hybrid populations for combined resistance to necrotic BCMV and halo blight in various U.S. and H.C. types. One of three wild legume species from Morogoro is a host of BCMV-TN-1. Preliminary studies with a strain of BCMV from Adzuki beans indicate a distinct biotype with very limited host range in *Phaseolus vulgaris* cvs. Cooperative winter increase nurseries with the University of Puerto Rico Bean/Cowpea CRSP project will greatly accelerate the domestic breeding program. Now that Dr. Susan Nchimbi is on the job in Tanzania, most of the Prosser breeding efforts will be directed towards specific U.S. program needs, using several sources of exotic germplasm to help diversify our domestic germplasm base. A55 is particularly useful as a source of multiple root rot resistance (Fusarium, Pythium and Aphanomyces).

Tanzania

Breeding. Dr. Mwandemele (geneticist), University of Dar es Salaam (UDSM) Department of Botany, was contracted by SUA to carry on the bean breeding program in 1988 until Dr. Nchimbi's graduation from the University of Wisconsin and return to Morogoro. Dr. Mwandemele had the able assistance of Mr. Peter Dimoso (M.S.-UK) to put out trials and gather data, etc. for the 1988 season. While they planted extensive experiments at several locations, most of the trials (and seed) were lost to the severe drought. The remnant materials were planted in a small irrigated plot they managed to obtain on the Hort Farm. Before the recent workshop, a breeders' meeting was held to review the program and to outline the near-term and long-term objectives. The most immediately pressing task is to salvage the best of "old" hybrid materials and to organize a forceful, carefully directed, large-scale program of recurrent selection and disease screening at Morning Side, using no inputs but *Rhizobium*.

Dr. Susan Nchimbi received a Ph.D. in horticulture from the University of Wisconsin and has returned to Tanzania. She will apply immediate rigorous single plant selection to the advanced populations, which have never been properly "purelined" for stable resistance to BCMV, HB, anthracnose, rust and ALS. The more recently acquired (1987) Prosser lines (F_5 to $_8$) also need careful screening and large-scale selection to identify combinations of resistance to two or more of the above diseases. Appropriate hybridization within these selections to combine resistance to all of the diseases then needs to be done. The populations of F_1 to F_3 hybrids from Robert Misangu's crosses of TMO216 to the various Prosser lines need to be screened for plant and seed characteristics followed by controlled disease screening at Morning Side to identify single plants with combinations of multiple disease resistances. Enough genetic variability is now present at SUA for a succession of incremental disease resistance improvements in a series of releases over the next decade as fast as the SUA team can identify, evaluate and release them. Beyond that, an active hybridization program at SUA will provide a continuing basis to broaden the program to include insect resistance, improved BNF and superior cooking characteristics.

Plant Pathology. Disease work at SUA is primarily on rust, angular leaf spot and bean common mosaic virus. Professor Allan Femi Lana (Nigeria) has been hired as the first virologist at SUA. This past season he and P. Njau tried to evaluate 150 of the SUA breeding lines to BCMV in a field trial. Drought wiped them out, but they managed to evaluate 20 lines in a greenhouse trial. This kind of controlled testing coupled with selection of resistant individuals in segregating populations (working with Dr. Nchimbi) will quickly stabilize resistance to both the mosaic mottle phase and the systemic necrosis due to temperature insensitive strains of BCMV.

Several rust field trials of Dr. Mmbaga which were planted at Morogoro were wiped out by drought. Next year Dr. Mmbaga may be in Nebraska working with Professor Steadman on the race non-specific resistance provided by leaf pubescence (long and dense). Professor Steadman's lecture and field demonstrations of this rust control approach stimulated a great deal of interest among the workshop participants. Professor Teri's field rust trials at SUA were also lost to drought. However, with the help of M.S. student candidate Mr. A. H. Urio, they were able to evaluate 40 breeding lines and parentals to rust. Numerous bulk lines have various levels of resistance. However, no

selection pressure was applied to pull out single plants with resistance from segregating populations in order to develop stable, uniformly resistant populations and to provide the breeders with identified individual sources of rust resistance to combine with sources of resistance to ALS and BCMV. In the future, all rust resistant materials will also be rated for pubescence (length and density) according to the Steadman guidelines.

Professor Teri also worked with student Mr. L. P. Kiboka on the effects of intercropping on bean diseases and yield. Yields were extremely low, and the expected foliar fungal diseases rust and ALS did not develop because of the drought. BCMV was prevalent as were ashy stem blight and sclerotium root rot (promoted by the drought). Interestingly, the drought tolerant TMO 101 is also tolerant to ASB and SRR and, conversely, TMO 216, which is highly tolerant to foliar diseases, was very susceptible to ASB and SRR. Furthermore, ASB was more severe in the intercropped (with maize) plots. This new information needs to be confirmed and, if proven, will be taken into consideration for the breeding and disease screening program. Perhaps the reason for the drought tolerance of TMO 101 is related to its tolerance to ASB, which is known to be more severe under drought conditions.

The field trials of Ms. Rose A. Mohamed and Professor J. M. Teri to study ALS were wiped out by drought, so they conducted another trial using potted plants and a humidity chamber constructed of wet burlap and plastic to screen 73 accessions and breeding lines. Ample variation was found for useful levels of resistance. Again, no single plant selections were made in segregating materials to provide breeders with stable resistance for crossing. Most of the best sources of ALS resistance are susceptible to rust and/or BCMV. So these best sources of resistance to individual diseases (and with the best plant and seed types) now need to be hybridized with each other in order to pyramid the factors needed for multiple resistance to all five of the major diseases found in Tanzania. Ms. Mohamed also conducted a very insightful survey of methods of bean disease management in smallholder farms in Megeta. For the first time, some light was shed on why farmers sole-crop beans during the February-May season but intercrop them during the September-December season. During the September-December season, the rains are not very heavy, are well distributed, and the season ends during a warm dry period. All of those factors favor suppression of foliar fungal diseases. Farmers also prefer to plant as soon as rains start because they know from experience that early crops suffer loss from pests. During the February-May season, rains are heavy at first but short and unreliable. Also this season ends in a cool wet period (favorable for diseases). Their cabbage, leeks and onions need supplemental irrigation before the end of the February-May season, but beans mature early enough not to need to be irrigated. Furthermore, they know if they do irrigate beans during this season, there is a great increase in what they termed root rot but which turns out to be bean fly maggot damage. Thus, farmers produce the beans as a sole crop during this season. They also know that beans produced during this season are less damaged by storage bruchids. Farmers are generally more familiar with the insect pests than with the diseases. They generally cannot differentiate causal agents of diseases as well as insects, nor are they as aware of the seriousness of the damage caused by the respective pathogens, although they are aware of the environmental factors which contribute to or lessen disease development. Several other traditional practices which affect

disease management were also noted. This kind of survey needs to be extended to other production areas and the collated information published. It is an excellent beginning into a more complete understanding of the socio-biological interactions taking place at the smallholder level which helps biologists design programs suitable to the needs of the smallholders.

Entomology. SUA contracted Dr. Yarro (entomologist, UDSM) to continue the work on bean fly and ootheca, since Dr. Karel left Morogoro. Investigation for variation in insect tolerance within the disease resistant materials is proposed because some of the same parents were used in both programs. The arrival of Dr. Ampofo, who recently joined the CIAT-Arusha team, will benefit research in this most difficult area. In the meantime, crosses to CIAT line A-55 which has a very strong stem, a character that seems to be correlated with tolerance to bean fly stem damage, will be made.

Socio-Economic. The bean marketing study, although far from complete, has documented the marketing flows of beans to major urban markets and bean deficit areas as production occurs in different parts of the country at different periods of the year. The Dar es Salaam market in the capital is by far the most important; in a large measure this market is the price setter. High transportation costs increase consumer prices.

The biweekly surveys of marketing activities at Mgeta have given only a fair estimate of how many bags of beans in large lorries were presumably shipped to the Dar es Salaam market. The Mgeta enumerators (extension agents) were not able to estimate how many beans (in three forms--dry, green shell and green pod) were sold locally or how many went to the Morogoro market.

The proposed collaborative study with CIAT on the rate of acceptance and socio-economic impact of 'Lyamungu 85' in the Lushoto (Tanga) area looks promising.

Food Science. Dr. Maeda analyzed the tannin content of 49 bean cvs and breeding lines of seven different seed color groups. As expected, white seed coated types had the lowest tannin content (least preferred) and reds had the greatest (most preferred by Tanzanians). Tannins bind proteins in insoluble complexes thus reducing protein bioavailability. However, there is a great deal of variation within the brown and red seeded types preferred in Tanzania. This has significant implications in respect to the breeding program. In addition to identifying low tannin content parental lines to use in hybridization, Dr. Maeda will help in screening hybrid bean lines for tannin content in the preliminary yield trial stage. In order to breed beans for fast cooking and storability under tropical conditions, some basic background studies need to be done first to pureline the parentals and to characterize them for hard seed coat, hard-to-cook cotyledons and rate of water uptake at various initial seed moisture levels and then to establish the relation of rate of water uptake (minus the confounding effects of hard seed coat or hard cotyledons) in each parental to actual cooking time (Mattson cooker and traditional). The response of purelines to various storage conditions in respect to the above cooking characteristics must be studied. Then it will be possible to use soak time to study the inheritance of cooking time (being able to save seed from a soak test) to determine the heritability of these most important characteristics for the tropics.

Soil Microbiology. Dr. Salema's large inoculant trials and OFTs with Mr. Dimosa were lost to drought. Large numbers of inoculant packets

will be available for distribution to growers next season, as well as for all CRSP research work and OFTs. The U.S. and H.C. PIs have agreed that all CRSP-supported field studies should routinely include an inoculant treatment. At the Morning Side disease screening plots, the only input used will be inoculant (no tractors, no fertilizers, no pesticides). Materials that survive the disease screens must also be capable of BNF or they will not be advanced to the preliminary yield trials. It is expected that this will increase the acceptance of new cvs in OFTs. Dr. Susan Nchimbi will hybridize high BNF breeding lines with the best SUA disease resistant lines to be sure that high BNF capacity is present in future cv releases.

On-Farm Trials. Dr. Mwandemele and Peter Dimosa set up many off station and OFTs at several locations to evaluate promising lines. All trials in the Dumila and Morogoro areas were lost to drought. At a demonstration plot planted by one of the Bwana Shambas about 30 farmers (18 men and 12 women), including the farmers who were to have put in the OFTs, were invited to a field day for demonstrations and discussions. The five farmers and their extension agents who had been given seed that was destroyed by the drought were also invited to the field day at the SUA-managed trials, so they could see what failed to develop on their own farms. On the whole, farmers were impressed and requested seed to try again next season. A preliminary yield trial with 64 entries in an 8 x 8 partial lattice design was also lost to drought, as were one national bean yield trial and seed multiplication plots for next year's trials.

The off-station trial of four promising lines and a local check at Mgeta had extremely low yields because of the drought stress. This study will be repeated with reselected promising lines from which the BCMV susceptible components are removed; and, instead of artificial N_2, inoculant will be compared to the zero fertilizer the growers use. On-farm trials in 1988/89 are going to be undertaken in conjunction with CIAT's trials using the same formats. Thus, results can be compared across sites for the whole country.

Agronomy. An extremely well-designed experiment was set up by student Mr. L. J. F. Kasuga and Dr. Cornell L. Rweyemamu to study the response of the so-called promising lines to various stand densities and N_2 application rates. The drought reduced emergence and yields drastically, and induced a severe outbreak of ashy stem blight and southern blight (Sclerotium rolfsii). So their results were non-conclusive.

Cv Release Production and Distribution System. Professor Due reviewed the documentation procedures for the official national cv release, multiplication and distribution system in anticipation of eventual release of new cvs into the existing Tanzanian system. She also tried to ascertain the relationship between actual practices and the official procedures through extended interviews with heads of the various parastatal organizations involved and visits to their production sites and facilities to learn how much seed and exactly what kind of evaluation data would be required at each stage of the release procedure(s). While the process of cv release, certification, multiplication and distribution of seed in Tanzania is straight forward and well documented, there are some serious deficiencies. There are the "normal" implementational constraints found in any developing country of insufficient foreign exchange to replace worn out equipment, provide spares, transportation and to hire and retain highly skilled technically competent personnel at all levels of the system infrastructure. While the CRSP cannot

address those problems, it was hoped that documentation would call attention not only to the need for refurbishing the physical components but also to the urgent need for SUA to develop a training and research capability in seed technology. If the Tanseed system is to be maintained and improved, a continuous supply of technically trained people at all levels of the entire operation needs to be maintained.

However, perhaps the most disturbing finding in the entire study was that Tanseed management informed Professor Due that three bean varieties were sufficient for Tanzania and that if a new cv were to be released, one of the old ones may have to be dropped! Since TARO-SUA and UAC collectively plan to develop several new cvs for each of the different agro-ecological production zones in the next decade, other ways, perhaps the private sector, may need to be found to produce, maintain and distribute them.

Farming Systems Considerations. Bean straw as cattle feed. Dairy cattle are an integral part of the smallholder farming system in the Arusha area, so it is useful to biological scientists, working primarily on seed production for human consumption, to realize there is a socio-economic value to the bean straw as well.

Bean Spacing Arrangements. Studies of population density and arrangement effects on cv yield responses, like those of Ndakidemi et al., and Kasuga and Rweyemamu, are useful from a biological production point of view. However, these studies may also provide an overlooked opportunity for a better understanding of a key consideration in the mind of the smallholder farmer. Farmers consider the cost in labor, time, and fatigue involved in using different planting arrangements and the effects on subsequent weeding and harvest operations. How far apart hills are spaced and whether each hill contains one, two, three, four or five plants has much more serious implications to the farmer than simply yield/acre or yield/plant. That's obviously why farmers generally don't follow "official" yield-based research recommendations of 50 cm between rows and one seed per hill every 10 cm within the row. So if small farmers don't use those spacings or fertilizer input levels that are tested on station trials, why are we using them? A better understanding of why smallholders use the spacings they do in terms of labor, time and fatigue is needed and then means need to be developed to improve that system's yield output.

RESEARCH RESULTS DISSEMINATED AND IN USE

A bulletin, Tanzania Cultivar Release Procedures and Subsequent Seed Multiplication and Distribution System, has been released in Tanzania through the Principal Investigator, Dr. James Teri. Copies were also distributed to government personnel in TARO and the Ministry of Agriculture, University of Dar es Salaam and Sokoine University libraries and Heads of Extension Education and Crop Service, Sokoine University of Agriculture. Copies were also mailed to CIAT offices in Colombia and SADCC, Bean/Cowpea CRSP Malawi and the farming systems project in Malawi.

BCMV-monoclonal antibodies and sets of differential bean cvs have been requested by and distributed to about six research labs worldwide.

The proceedings of the 6th Annual Bean Workshop were distributed to about 50 researchers in Tanzania and other regional bean research programs.

Germplasm. CIAT line A55 was found resistant to a wide range of

root rots which are problems in the U.S. (Fusarium, Pythium, Aphanomyces). In addition, A55 is useful as a parental line to transfer the upright 2A plant habit to viny type 3 habits characteristic of most U.S. dry beans. It is being distributed to other U.S. breeders for the above purposes.

Rhizobium inoculant packets for beans will be distributed to several hundred smallholder bean farmers in the 1989 bean season.

PUBLICATIONS AND PRESENTATIONS.

Due, Jean M. In press. Assisting with Food Increases and Famine Relief in Tropical Africa. College of Agriculture Newsletter.

Due, Jean M. 1988. Intra-Household Gender Issues in Farming Systems in Tanzania, Zambia and Malawi. In S. Poats, M. Schmink and A. Spring (eds.) Gender Issues in Farming Systems Research and Extension, Boulder, CO: Westview Press, 331-344.

Due, Jean M. 1988. Tanzania Cultivar Release, Seed Multiplication and Distribution Systems. Technical Report No. 7. Morogoro, Tanzania: Sokoine University of Agriculture, Department of Rural Economy. Also available as aAE-4637. Urbana-Champaign, IL: University of Illinois, Department of Agricultural Economics, 15 pp.

Due, Jean M. In press. Women and Technology in African Smallholder Agriculture. Canadian Journal of African Studies.

Silbernagel, M. J. and R. M. Hannan. 1988. Utilization of Genetic Resources in the Development of Commercial Bean Cultivars in the U.S.A. In P. Gepts (ed.) Genetic Resources of *Phaseolus* Beans. Dordrecht/Bacton/ London. Kluwer Academic Publishers, 561-596.

Nchimbi, Susan F. 1988. Breeding for Increased Percentage Seed Protein and Seed Yield of Bean Germplasm Adapted to Tanzanian Conditions and the Evaluation of Bean Lines for Response to Nitrogen Fertility. Ph.D. Dissertation, University of Wisconsin.

Salema, M. P. and A. N. Minjas (eds.). 1988. Bean Research Volume 2. Tongea, Tanzania: Benedectine Publications (Proceedings of the 6th Bean Research Workshop, Sokoine University of Agriculture, Morogoro, Tanzania, October 1-3, 1987), 261 pp.

In preparation:

"The Potential of Some CIAT Common Bean Lines in Tanzania." Z. J. Malley, R. N. Misangu and A. L. Doto.

"Evaluation for Yield Performance of Different Bean Cultivars under Morogoro Conditions." S. Slumpa, A. L. Doto and K. P. Sibuga.

"Yield Evaluation of Four Elite Bean (*Phaseolus vulgaris* L.) Lines Under Farmers' Conditions." E. M. K. Koinange and O. S. Mbuya.

"Comparative Performance of a Newly Released Bean (*Phaseolus vulgaris* L.) Cultivar 'Lyamungu 85.'" E. M. K. Koinange and O. S. Mbuya.

"Performance of Selected Bean Varieties/Lines When Planted Twice a Year. M. Mkuchu, C. Madata and C. M. Mayona.

"Performance of Selected Bean Varieties/Lines in the Southern Highlands of Tanzania." M. Mkuchu, C. Madata and C. M. Mayona.

"The Malawi *Phaseolus vulgaris* L. Germplasm: Collection, Conservation, Evaluation and Documentation." H. Mloza-Banda.

"Estimating Superior Yield Performance in Genotypes from Bean Mixture Populations." E. Ayeh.

"Fungicide Seed Treatment for the Contorl of Angular Leaf Spot of Beans." L. B. Mbilinyi and J. M. Teri.

"The Effect of Intercropping and Fertilizer Application on Bean Diseases and Yield." A. L. Katunzi, J. M. Teri and K. P. Sibuga.

"Effect of Angular Leaf Spot on Six Selected Bean Cultivars." L. G. Mukandala and J. M. Teri.

"Screening of Bean Hybrids for Resistance to Black Root and Rust." J. S. K. Sembosi, J. M. Teri and R. N. Misangu.

"Effect of Spacing on Grain Yield of Beans Grown in Association with Maize." M. Mkuchu, C. Madata and C. M. Mayona.

"Chemical and Hand-Hoeing Manipulations for Weed Management in *Phaseolus vulgaris* L. with Reference to Broad-Leaved Weeds." B. Gondwe.

"Variation in Nodulation, Nitrogen Fixation and Yield in Various Bean (*Phaseolus vulgaris* L.) Genotypes." M. P. Salema.

"Partitioning of Plant Nitrogen in Common Bean (*Phaseolus vulgaris* L.)." M. P. Salema.

"Nitrogen Requirement of Uninoculated and Inoculated Common Beans (*Phaseolus vulgaris* L.)." M. P. Salema.

"Field Evaluation of Bean Rhizobial Strains for Use in Inoculum Production." M. P. Salema.

"Effect of Rhizobial Inoculation, Nitrogen and Phosphorus Fertilizers on Nodulation, Growth and Yield of Climbing Fresh Bean (*Phaseolus vulgaris* L.)." R. O. Kileo, G. Evers and M. P. Salema.

"Bean Water Absorbing Capacity and Its Use for Predicting Bean Cooking Times." E. E. Maeda.

"*In Vitro* Digestibility of Trypsin Inhibitor Levels in 16 Bean Lines." E. E. Maeda.

"Construction and Testing of an Appropriate Bean Thresher for Small Scale Farmers." K. H. H. Shemsanga, V. Y. El-Nshau and P. M. Kyando.

"Bean (*Phaseolus vulgaris* L.) in the Farming Systems in Tanga Region, Tanzania." J. M. Due and J. Rugambisa.

"Bean Research in Tanzania: A Bibliography." J. M. Teri.

APPENDIX A: THE FIRST REGIONAL REVIEW, EVALUATION AND PLANNING MEETING SUMMARY REPORT

San Jose, Costa Rica
February 25-27, 1988

INTRODUCTION

The Bean/Cowpea CRSP is an integrated set of research projects which brings together U.S. and H.C. scientists to increase the availability of beans and cowpeas for food deficit populations.

To achieve this goal, one of the major tasks of the Bean/Cowpea CRSP is to strengthen the institutionalization of CRSP efforts in participating institutions. An additional task is to reinforce the ability of those institutions to backstop and otherwise provide project support.

The persons specifically responsible for such institutionalization and project support are the Institutional Representatives. The IRs are administrators from the lead institutions designated the official representatives by their institutions' Chief Executive Officer. Because each research project is managed by its U.S. lead institution, the role of the IR is critical to CRSP success. On a rotating basis, five of the ten IRs serve on the CRSP Board of Directors, representing the larger community of CRSP institutions in policy development and management oversight.

Each year the CRSP BOD holds a special annual meeting to which they invite the U.S. IRs who are not serving on the BOD at that time. This annual meeting has served to keep the non-BOD U.S. IRs apprised of CRSP-wide progress and to provide a forum for discussion of mutual concerns (e.g., the 25 percent institutional match required from U.S. institutions).

In previous years the BOD has attempted to similarly reach administrators from Host Country institutions by issuing invitations to one H.C. administrator at a time to these annual meetings. However, over the years, many H.C. administrators were not reached by this process.

This past year the BOD decided to take another tactic. Following a thorough discussion, they recommended a Regional Review, Evaluation and Planning (RREP) Meeting be held in a participating Host Country to substitute for the annual meeting in the U.S. It was decided that the first meeting would be held in Latin America and subsequently Costa Rica was the chosen site. The responsible H.C. administrators would be invited to this meeting as the official H.C. IRs. Further, it was determined that this meeting would provide an appropriate setting for sharing information with A.I.D. Mission personnel in the region who may not have been especially knowledgeable about the CRSP.

The objectives of this meeting were to:

1. Build stronger communication and professional ties between Host Country and U.S. administrators in the same CRSP project and, similarly, across projects.

2. Acknowledge the contributions of the H.C. and U.S. partners.

3. Share information about the CRSP and major achievements to date.

4. Generate strategies for strengthening CRSP research, training and long-term impact in Host Countries and around the world.

5. Strengthen relationships with USAID Missions in the region.

Invitations were extended to CRSP H.C. IRs in the countries of the Latin American/Caribbean region (LA/C) as well as to the USAID Mission personnel for their own participation and that of others in their Host Countries whom they deemed appropriate. These invitations were extended through the A.I.D. Latin American/Caribbean Bureau and individually to the Missions. Some USAID Missions (e.g., Bolivia, Peru, Brazil and Honduras) sent regrets but were most supportive of the meeting, requesting to be kept informed.

CRSP countries represented at the meeting were: Guatemala (both the national program and INCAP, a regional research center located there), Honduras, Dominican Republic and Mexico. The Brazil representative, whose statement was received in advance, at the last minute was unable to attend. Non-CRSP countries, represented through their USAID Mission's support were Costa Rica and Jamaica. Participants included the formal IRs as well as other administrators from the Host Country government and research programs.

The two-day meeting was organized with significant logistical assistance from Instituto Inter-Americano de Cooperacion on Agricultura (IICA), Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) and Linda Vista, Inc. Their support was very critical to the success of the meeting. Sessions were arranged so that U.S. and H.C. IRs arrived in time to overlap with the end of the week-long annual meeting of the External Evaluation Panel. A meeting of the BOD was held concurrently.

BRIEF MEETING REVIEW

The major activities of the meeting were the interactions between U.S. and H.C. administrators and among the H.C. administrators themselves. Where representatives from A.I.D. were in attendance, they were encouraged to participate fully. Valuable outcomes of this experience included sharing perspectives, investigating common problems and presenting to the total group successes for which both the U.S. and H.C. administrators on a team could take credit.

To prepare for the meeting and facilitate the communications, meeting materials were distributed. In addition, a professionally produced slide show oriented the participants to the goals of the CRSP, some of its major achievements and the roles of participants like themselves in program success.

As planned, the External Evaluation Panel held the annual CRSP review at the beginning of the week and thus by the second day of the IR's meeting was ready to present its findings to the total group. This arrangement allowed for insightful discussions between the EEP and the administrators having management oversight responsibility for the projects in the U.S. and in the HC. It also allowed the administrators to discuss with one another the meaning of these findings. The final EEP report is available from the CRSP Management Office.

In between the substantive sessions with the other U.S. IRs and the IRs from the Host Countries, the BOD met and discussed the EEP recommendations. From these discussions decisions were made for the upcoming extension period. The U.S. IRs not on the BOD as well as the H.C. IRs had an opportunity to sit in on these critical meetings and make relevant input as desired.

To reinforce a range of discussions, formal and informal, meals were planned as was a field trip to Linda Vista, Inc., a profitable, commercial seed production company, and to CATIE.

During the meeting, team reports, generated from statements prepared in advance of the meeting and subsequently discussed, were presented orally. All reports were not country specific as originally intended because, in a few cases the U.S. or H.C. partner had been unable to attend. IRs without their respective project partners were encouraged to work with existing teams.

A summary of these reports is presented below, highlighting what the administrators felt to be the important contributions of the projects, their projects weaknesses and recommendations to be considered.

SUMMARY OF IR REPORTS

Statement of CRSP Achievements

IRs appeared genuinely pleased with the participation of their institutions in the CRSP. They acknowledged the importance to their countries of project research achievements as well as the importance of the training.

1. ". . . the impact of the CRSP project in Mexico is tangible. On the one hand, we got two cultivars produced through the efforts of MSU and INIFAP and, on the other hand, the training of Mexican scientists, along with the motivation of new scientists that are now involved in the project." Two cultivars produced give "higher yields (800 to 2300 kg/ha), were stable across different low rainfall regimes with resistance to common diseases." These cultivars "have been released and delivered to the State Government as a way to improve bean yields in Durango along with the improvement of living conditions of the low income rural families dedicated to bean production." An additional contribution was "the generation of scientific data and publications for the benefit of the Spanish speaking scientists."

2. Establishment of a strong, well-equipped and staffed research unit for work on biological insect control was a major contribution of a CRSP/Brazil project. In a statement sent in his absence, the H.C. IR, Technical Director of the National Research Center for Rice and Beans (CNPAF), emphasized the importance of project research efforts to Brazil. "Screening and bioassay of fungal isolates identified a number of virulent pathogens with considerable potential for use in integrated control programs in Brazil and the U.S. . . [A] fungus was successfully cultured, formulated as dry mycelium and applied in New York in 1985. Tests resulted in over 90 percent reduction of leafhopper populations . . . following dispersal of infected leafhoppers . . . [Further], the project provided funding for initiation and continued collaborative support of a study on the socioeconomics of cowpea production across the whole of northern Brazil (the first such study in the country)." Graduate level training was also highlighted; the regular H.C. PI is among those presently studying in the U.S.

3. In another CRSP/Brazil project, five black bean lines with high nitrogen-fixing potential will be released jointly by Brazil and the U.S. as germplasm. This project has accomplished its objectives and is phasing out. However, its work is so highly thought of that Brazil has committed to taking over the salaries of project personnel at the end of the extension period in order that the research can continue. In the disease component of this project, a sequential inoculation technique has evolved which will facilitate disease research in all countries.

4. Basic research on photoperiod response in beans generated a Yield Systems Analysis (YSA) which--by measuring yield, days to flowering, days to maturity, and total plant weight--provides an index for selecting appropriate parents for breeding programs fitting specific environments. "The implications of the gained technological knowledge are especially important because beans are grown in three main physical environments and the development of technology to such varying conditions requires a detailed knowledge of how environment effects adaptation and yield. . . . Both Guatemala and New York have developed locally adapted germplasm with yields 20 to 30 to 40 percent above yields of current cultivars" using this method. Also developed were "germplasm with unique combinations of partitioning rate and node-to-flower that provide potential for yet higher yields." These methodologies are of relevance to other countries' breeders as well, but the Guatemalan bean program is being benefitted first because the new methodologies are already being applied to solve bean production problems in the country.

   "The steps beyond the development of new technologies are taken care of by ICTA/DIGESTA on-farm testing teams, where Rural Leaders have an important degree of participation. Thus the dissemination of new technologies, especially improved seed, is guaranteed by such efforts and by a new project that involves the production of bean seed at village level so that small farmers have ready access to it."

5. Significant disease-resistant material is being developed in the CRSP Dominican Republic project. The CRSP team is cooperating with CIAT in testing these lines. "On October 1987 we held a course for research on farms, transfer and promotion of new varieties. First phase was sponsored by SEA/DIA/ Project Title XII/CIAT. The main objective is to train the technical personnel of the Production Department, Program of Leguminosae, for its incorporation in the research activities in bean crop at a national level . . . The Department of Agronomical Research (DIA) does not have the technical facilities to carry out the corresponding studies that permit determination of the socio-economic impact in the rural villages. For this, we asked the support of the project Women-in-Development . . . The incorporation of technical personnel and workers (59.4 percent) to the payrolls of SEA is another important step." In the Dominican Republic the scientists participate in activities to gather and identify strains of bean golden mosaic virus and "selection of other strains coming from Guatemala and Mexico for the differentiation and establishment of work lines in the breeding of varieties."

6. "Bean mosaic has been identified as the limiting problem of bean production in all regions of Honduras. Rust is another disease which lowers production greatly in some areas of the country . . . Work on select lines resistant to [such] common bean diseases has continued with greater productivity and higher level of achievements. Over 100 lines out of 600 F_5 material were selected for additional testing due to superior tolerance to rust . . . Due to CRSP work and in collaboration with SRN, the cultivar Catrachita was released. CRSP scientists demonstrated that this cultivar has rust resistance in some localities in Honduras . . . Bean yields on most small farms are very low, averaging 550 kg/ha.

The release of Catrachita should impact favorably in rural areas of Honduras."

7. "This CRSP project has allowed INCAP to carry out basic research on constraints to achieve a more efficient utilization of [beans], such as the hard-to-cook phenomenon, poor protein digestibility and quality of beans [using] experimental animals . . . It has also strengthened the association between scientists in agricultural sciences and those in utilization.

   "The project also has allowed INCAP to train university students in the subject matter of the cooperative project. The training has included students from Agricultural Sciences, Chemistry, Chemical Engineering and Food Science and Technology. The training has been in studies on specific problems related to beans . . . all have become aware of the need to view bean problems from a multidisciplinary approach."

   Another important contribution indicated was the opportunity for "INCAP researchers to work in a collaborative way with researchers from other important scientific centers" in the U.S. The interactions through project activity were considered "a very positive output, benefitting all involved."

Statements of CRSP Strengths

In addition to various research and training achievements, other strengths were identified. Below are statements submitted which reflect these strengths.

1. The head of the Planning and Development Unit at INCAP indicated that:

   a. The project has strengthened the association between scientists in agricultural sciences with those in utilization.

   b. The CRSP has made it possible for INCAP to carry out basic research on constraints to the achievement of a more efficient utilization of these foods.

   c. The project makes it possible for INCAP researchers to work collaboratively with researchers from other important scientific centers.

   "The fact of having all these institutions working together is *per se* an outstanding achievement . . . All institutions have benefitted from it."

2. The Director of the Department of Agricultural Research in the Dominican Republic Ministry of Agriculture pointed out that the work going on in their CRSP project is so highly regarded that the severely strapped government recently agreed to support 59 percent of the total in-country CRSP personnel budget.

3. The Director of the host institution in Honduras, and others, emphasized the importance of the research and leadership roles assumed by returning CRSP graduates. He also noted the role of the CRSP in making that institution among the strongest in the region engaged in bean research.

4. The Director of INIFAP in Mexico reiterated this last point, demonstrating that one of the strengths of the CRSP is its institutional support.

   "Research efforts by INIFAP have been significantly improved during the last five years through the support of the [CRSP project] with Michigan State University . . .

CRSP funds have made possible the conduct of field research (80 percent in Durango) in order to screen about 10,000 bean materials from Mexico, CIAT and from Michigan State . . . [the new Ph.D. graduate trained at Michigan State] has just been appointed INIFAP's National Leader for Bean Research." Also mentioned was the importance of continuity in the established evaluation program of bean plant materials.

5. The Technical Director of CNPAF in Brazil writes of the institution-building strength of the CRSP. "Insect Pathology Research Center (IPRC) has been successfully established and staffed at CNPAF/EMBRAPA with excellent prospects for remaining a highly active center for insect pathology and microbial control research after the CRSP leaves Brazil . . . The center includes a fully equipped research laboratory and large collection of scientific literature." Additionally, the Director (as well as the IR from the Dominican Republic) acknowledged the roles and importance of women in their projects' research and training.

   As in Mexico and Honduras, it has been determined that the permanent coordinator in Brazil of this national bean program (IPRC) will be an identified CRSP graduate. Other "post-graduate students are beginning to take research and university positions where they are actively transmitting this information to their colleagues and students."

   The collaborative relationships and the shared project resources significantly reinforce the legume research programs of participating institutions, especially those in Host Countries. The activity generated across projects strengthens the regional impact of the institutions and their contributions. For example, Escuela Agricola Panamericana (EAP) is a private college based in Honduras with an active regional mission made even more effective by CRSP participation.

Statement of CRSP Weakness

Participants were asked to identify those aspects of the CRSP which needed to be strengthened. The ideas generated are listed below.

1. There is a need to coordinate better the projects which address the same constraints.

2. The absence in Latin America of product-consumption economics and farming systems/socio-cultural research in the CRSP is a significant limitation.

3. The work of food scientists, technologists and nutritionists needs to be more strongly integrated with that of plant breeders and agronomists.

4. The impact of the major drop in funding was discussed. Many concerns related to finances were brought out but some impacts were felt to be especially crucial. "The urgent need to buy certain specialized scientific equipment in order to improve the quality of the research" was cited by many as was the need to train more H.C. scientists in the U.S. This latter point was highlighted in some cases by statements reflecting the need for continued linkages with and guidance from senior U.S. scientists especially where the H.C. staff were predominantly recently returned graduates.

5. There is a need to get research more in contact with extension. Getting researchers in Host Countries out to farmers' fields in order to understand the prob-

lems is important. This should be done in contact with extension. Likewise, training in some H.C. institutions needs to be more relevant, e.g., graduates go to farmers, understand small farmers and their systems better. U.S. and H.C. students doing research can do more in Host Countries. H.C. participants need to move around to facilitate the flow of ideas.

6. There is a need to study energy use in small-farm systems. Before new technologies are introduced the impact on energy (labor) should be evaluated.

Benefits of the CRSP to Non-Participating Countries

Representatives from the two non-participating countries attending the meeting, Costa Rica and Jamaica, made significant contributions to the meeting. Ideas were exchanged on the benefits of the CRSP to such countries. The following statement was generated in their discussions.

"Ideally all developing countries needing the services of a particular CRSP should have the opportunity to participate in the programs. However, where funds limitations prevent participation in the prescribed manner, many non-participating countries can take advantage of the CRSP through (1) its publication and information system; (2) use of its improved germplasm development; (3) technical assistance from its experienced staff and collaborators; and (4) linking into its training programs.

"Through CRSPs, non-participating countries could establish links with participants with similar climate, production, systems and problems. This would enhance technology transfer and facilitate the initiation of research at more advanced levels. Such linkage would save substantial amounts of research funds and result in more efficient utilization of limited, skilled manpower resources."

Recommendations

After the general sessions, the meeting participants met in small work groups and generated the following recommendations.

1. One group's discussions led them to how the Bean/Cowpea CRSP might validate the potential integration of the CRSP effort into the total system from production through consumption, while considering the economic, social and anthropological issues. Reviewing the Global Plan, it was noted that present efforts in Latin America address all constraints except Production-Consumption Economics, Farming Systems and Socio-Cultural Factors (previously addressed in the Ecuador project terminated at the end of FY 86). This was viewed as a significant limitation for progress in Latin America.

"The group proposed the establishment of a single case-study validation research project to demonstrate the interrelatedness of the CRSP projects in Latin America and provide a format for an economic analysis. It was proposed that the best research resulting from CRSP efforts in Latin America be brought to one place and placed in a validation research effort. Such an effort would facilitate scientists' understanding of where their research fits into the system, would validate techniques, would demonstrate the practical side of research problem-solving, would facilitate technology transfer in the surrounding region, and may provide an opportunity for inter-CRSP cooperation."

2. A work group identified the need for CRSP projects addressing the same or related constraints to work more closely together in generating outputs. An example was given of the two food/nutrition projects. At this meeting, each project would identify specific constraints (both resolved and unresolved), explore the uniqueness of each constraint (biological, physical, social, economic, cultural, etc.) and discuss approaches used to resolve the constraints. Further, the discussion would review how approaches used in one project to address a constraint might be used in the other project to address a similar but unresolved constraint (as in building on initial efforts of the summer 1985 CRSP Nutrition/Bean Quality Workshop). Participants would develop joint strategies to address unresolved, commonly identified constraints. Such activities may also result in a refocusing or modification of research initiatives.

3. H.C. research teams are frequently inhibited by limited experience and small size. Notwithstanding decreases in travel budgets and general support, we need to "increase contacts between dedicated U.S. and H.C. scientists and promote the [greater] flow of ideas and information." The excellent collaboration established "will pay better dividends of research and achievement [and] its continuity should be further encouraged."

4. "CRSP-financed students should return to CRSP projects in H.C. Returned graduates are doing an outstanding job in their H.C. and other returning students will likely have a beneficial effect on the overall CRSP projects also."

5. "Scientists in many non-participating countries are unaware of the existence of the CRSP and therefore are unable to benefit from it. To sensitize scientists in non-participating countries, highlights and summaries of CRSP research activities should be sent to them. USAID country projects should be made aware of potentials for buy-ins, the availability of information and material sent to non-participants."

CONCLUSIONS

The first Regional Review, Evaluation and Planning meeting met its objectives. There was much interaction among participants, both as individuals and as convened groups. The Institutional Representatives from the U.S. and the Host Countries in the region were able to hear firsthand the evaluations of their projects from the External Evaluation Panel, evaluations which were more meaningful because they were presented in the context of the goals of the total CRSP. Likewise those representatives from A.I.D. in attendance made substantive contributions.

As the host of the meeting, the BOD opened its sessions, providing an opportunity for all to become acquainted with the process and make input as appropriate.

Many communications were received by the MO from persons in attendance indicating the effectiveness of the meeting and the extent to which it has contributed to their role in the CRSP. The BOD agreed that, while costly, the importance of the interaction was worthwhile. They subsequently voted to hold another such meeting in Africa in 1989.

TABLE OF ACRONYMS

AALS	Appressoria & Appressorium-like Structures
A.I.D.	Agency for International Development
ADD	Agricultural Development District
ALS	Angular Leaf Spot
AMMI	Additive Main Effects and Multiple Interaction Effects Analysis
AR	Acetylene Reduction
ARS	Agriculture Research Station
BCMV	Bean Common Mosaic Virus
BGMV	Bean Golden Mosaic Virus
BIFAD	Board for International Food and Agricultural Development
BNF	Biological Nitrogen Fixation
BOD	Board of Directors
BTI	Boyce Thompson Institute
CB	Common Blight
CENA	Center for Nuclear Energy in Agriculture
CFU	Colony Forming Units
CGR	Crop Growth Rates
CIAT	Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture)
CNPAF	Centro Nacional de Pesquisa de Arroz e Feijao (National Center of Investigation for Rice and Beans)
CRSP	Collaborative Research Support Program
CSRS	Cooperative State Research Service
DAP	Days After Planting
DGUB	Germinated and Dehulled
DR	Dominican Republic
DUUB	Dehulled
E	Environment
EAP	Escuela Agricola Panamericana (Pan-American Agricultural School)
EEC	European Economic Community
EEP	External Evaluation Panel
EMBRAPA	Empresa Brazileira de Pesquisa Agropecuaria (Brazilian Enterprise for Agricultural Investigations)
EPL	Preliminary Line Trial (Bliss)
EPR	Preliminary Yield Trials
F	Flowering
FGR	Fruit Growth Rates
FHH	Female Headed Households
FY	Fiscal Year
G	Genotype
GLC	Gas Liquid Chromotography
GLIP	Grain Legume Improvement Program
GN	Great Northern
HB	Halo Blight
H.C.	Host Country
HPLC	High Pressure Liquid Chromotography
HYV	High Yielding Variety
IAC	Institute for Agronomy at Campinas, San Paulo, Brazil
IAEA	International Atomic Energy Agency
IAPAR	Agronomic Foundation and Instituto of Parana
IARC	International Agricultural Research Centers
IBPGR	International Board of Plant Genetic Resources
IBSNAT	International Benchmark Site Network for Agro-Technology Transfer
ICTA	Instituto de Ciencias y Tecnolcgia Agricola (Institute of Agricultural Science and Technology)
IITA	International Institute of Tropical Agriculture
INCAP	Instituto de Nutricion de Centroamerica y Panama (Institute of Nutrition of Central America and Panama)
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias (National Institute of Forestry and Agricultural Investigations)
INTSORMIL	Sorghum/Millet CRSP
IPRC	Insect Pathology Resource Center
IR	Institutional Representative
IRA	Institut de la Recherche Agronomique (Institute of Agronomic Research)
ISRA	Institut Senegalais de Recherches Agricoles (Senegalese Institute Agricultural Research)
KSU	Kansas State University

LBRE	Large Brown Eye Kano White
LBKE	Large Black Eye Kano White
LWC	Leaf Water Content
LWRC	Leaf Water Retention Capacity
ME	Management Entity
MHH	Male Headed Households
MNR	Ministry of Natural Resources
MO	Management Office
MSTAT	Microcomputer Statistical and Data Management Package
MSU	Michigan State University
N	Nitrogen
NASH	Nucleic Acid Spot Hybridization
NCR	Northern Corn Rootworm
NCRE	National Cereals Research and Extension Project
NifTAL	Nitrogen Fixation by Tropical Agricultural Legumes
NPR	Net Protein Ratio
OFT	On-Farm Trials
ORF	Open Reading Frames
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (Central American Cooperative Program for the Improvement of Food Crops)
P	Phosphorus
PI	Principal Investigator
PM	Physiological Maturity
PSA	Performance Systems Analysis
R	Rice (McWatters)
R	Resistant (Coyne)
RCBD	Randomized Complete Block Design
RF	Rockefeller Foundation
RFLP	Restriction Fragment Length Polymorphism
RIISP	Research Initiative: Insects of Stored Pulses
RH	Relative Humidity
RU	Rust
SADCC	Southern African Development Coordinating Committee
SAFGRAD	Semiarid Food Grain Research and Development Project
SBRE	Small Brown Eye Kano White
SCR	Southern Corn Rootworm
SDY	Sabouraud Dextrose Broth Plus 1% Yeast Extract
SEA	Secretaria de Estado de Agricultura (Secretary of State for Agriculture)
SEM	Scanning Electron Microscopy
SODECOTON	Societe de Developpement du Coton (Cotton production cooperative in Cameroon)
SUA	Sokoine University of Agriculture
TARS	Tropical Agriculture Research Station
TC	Technical Committee
UAC	Uyole Agricultural Research Center -- Tanzania
UCD	University of California, Davis
UCR	University of California, Riverside
UGA	University of Georgia
UI	University of Illinois
UMN	University of Minnesota
UNL	University of Nebraska-Lincoln
UPR	University of Puerto Rico
U.S.	United States
USDA	U.S. Department of Agriculture
UWI	University of Wisconsin
VICAR	Central American Yield Nurseries
VIDAC	Vivero de Adaptacion Centroamericano
WB	Web Blight
WCR	Western Corn Rootworm
WGCB	Germinated and Cooked
WID	Women in Development
WSU	Washington State University
WUCB	Cooked
Xcp	*Xanthomonas campestrii* pv. *phaseoli*
YSA	Yield System Analysis