PN-ABG-840

Proceedings of the April 1990

Researchers Meeting

10 Years of Collaborative Research on Beans and Cowpeas

Bean/Cowpea Collaborative

Research Support Program

Michigan State University

PROCEEDINGS
OF THE INTERNATIONAL RESEARCH MEETING
OF THE
BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM

April 30 - May 3, 1990

200 Center for International Programs
Michigan State University
East Lansing, Michigan

Grant No. DAN-1310-G-SS-6008-00
Agency for International Development
Washington, DC

TABLE OF CONTENTS

LETTER FROM THE DIRECTOR

INTRODUCTION AND OVERVIEW 1

ROSTER OF BEAN/COWPEA CRSP PROJECTS 5

BEAN/COWPEA CRSP PROJECT REPORTS

Brazil/BTI/Roberts 7
Cameroon/Purdue/Murdock 11
Dominican Republic/UNL/Coyne 16
Dominican Republic/UWI/Maxwell 21
Ecuador/UMN/Graham 25
Guatemala/Cornell/Wallace 28
Honduras/UPR/Beaver 33
INCAP/WSU/Swanson 36
Malawi/MSU/Isleib (Adams) 39
Mexico/MSU/Harpstead 43
Nigeria/UGA/McWatters 46
Senegal/UCR/Hall 50
Tanzania/WSU/Silbernagel 56

CRSP PRESENTATIONS 61

NON-CRSP ABSTRACTS 91

SMALL GROUP DISCUSSIONS 103

MINI-PANEL REPORTS 113

SUMMARY 125

AGENDA 127

APPENDIX A - William R. Furtick A-131

APPENDIX B - CRSP Buy-Ins B-137

APPENDIX C - Roster of Participants C-141

APPENDIX D - Bean/Cowpea CRSP Global Plan D-145

APPENDIX E - Bean/Cowpea CRSP Management Groups E-155

MICHIGAN STATE UNIVERSITY

BEAN/COWPEA CRSP MANAGEMENT OFFICE
200 CENTER FOR INTERNATIONAL PROGRAMS
VOICE (517) 355-4693 FAX: (517) 336-1073

EAST LANSING • MICHIGAN • 48824-1035
TELEX: 263359 CRSP UR

October 1, 1990

TO: Researchers and Friends of the Bean/Cowpea CRSP

FROM: Pat Barnes-McConnell, Director

The community of scientists, administrators and producers who have worked together over the last ten years are seeing unfolded before them the successful results of their work. Working together season after season, year after year, the dedication and commitment are paying off with answers to some of the most troublesome problems facing bean and cowpea production in the developing world.

What are the factors that have contributed to the accomplishments of this exciting program?

1. Engagement of the leading scientists and research facilities at established bean and cowpea research centers of excellence in U.S.

2. Collegial partnerships established among these U.S. teams and the leading bean and cowpea scientists in identified Host Countries (HCs).

3. Equal sharing of the A.I.D. financial support between the U.S. and HC researchers.

4. Annual contributions, in dollar or in kind, from both U.S. and HC institutions.

5. Engagement of significant U.S. and HC administrators as Institutional Representatives to provide critical backup support and reinforcement.

6. Integration of biological and social science perspectives in the design and implementation of project research.

7. Program-wide integration of a Women in Development perspective.

8. Long-term financial support over a timeframe required for the research undertaken.

9. A CRSP scientific network providing timely and consistent professional monitoring and feedback to the research teams.

10. A management office facilitating program administration, communication and functioning.

MSU is an Affirmative Action/Equal Opportunity Institution

The value of these factors has been apparent over the life of the program. It is emphasized by the considerable extent to which others, not currently participating in the CRSP, are anxious to do so. Many of these scientists, not presently involved, could add to the significant contributions of the CRSP if a way were found to fund the integration of their efforts. In this period of constrained financial resources, the CRSP has had to assess its research efforts and determine the best way to make maximum use of limited resources to support program goals.

The May 1990 Research Meeting of the Bean/Cowpea CRSP was organized to consider these issues and to clarify the next research steps crucial for the coming decade. The timing of the meeting was planned to coincide with the demands of a new extension request as the current CRSP authorization period winds down. Called upon to assist the CRSP community with this planning task were colleagues from the International Agriculture Research Centers and related regional programs, interested but currently non-participating U.S. and national program scientists, representatives from the private sector and other persons with similar world food and hunger concerns.

The Proceedings is the product of this thoughtful coming together. It is designed to represent most of the major accomplishments presented by the teams as well as the subsequent thinking that grew out of the deliberations. It cannot hope, however, to convey all of the rich professional associations and program connections that resulted from the meeting's interactions.

Nonetheless, as we proceed into the second decade of bean and cowpea research and training partnerships, we are well served by the ideas and reflections offered. An increased role for both new biotechnology research at the molecular level and socio-economic/socio-cultural research is apparent. Contributions from small-scale farmers, especially women farmers, are increasingly encouraged and accepted. Further, as the scientists have carried out their individual research strategies, greater value is being placed on collaborating with colleagues in other disciplines and other programs who are working toward the same objectives and with the same crops and farm settings. Thus, we see not only a more productive CRSP but a program with greater maturity, i.e., relevance, technical sophistication and programmatic integration.

With the growing pool of bean and cowpea scientists being generated by the CRSP worldwide, we have every expectation that the next few years will witness further extraordinary improvements in the ability of beans and cowpeas to contribute to family diets and income. As you read through this document, we invite your responses and your participation in the continuing dialogues that will help to make it happen.

INTRODUCTION AND OVERVIEW

Convened by the Bean/Cowpea Collaborative Research Support Program (CRSP) at Michigan State University, bean and cowpea scientists from Africa, Asia, Central and South America and the United States met in East Lansing in May, 1990. The objectives of the meeting were to share research progress, to report relevant research achievements and needs and to define appropriate research directions for the future. Project reports, guest speakers, poster sessions, mini-panels and small group discussions helped to meet these objectives and identify bean and cowpea research needs for the 1990s.

As background for the meeting, it was acknowledged that the average annual growth rate of the per capita gross national product in low- and middle-income countries was a negative 2.9 percent in sub-Saharan Africa and a negative 1.2 percent in Latin America and the Caribbean. This phenomenon has serious implications for food production and malnutrition in these regions. Beans are an important crop in the humid tropics of Latin America and Africa while cowpeas are important in the semi-arid areas of both continents especially sub-Saharan Africa. Both legumes play major nutritional roles for family diets and income generation. The Bean/Cowpea CRSP is making significant contributions to these areas by improving production and utilization of these crops.

The Bean/Cowpea CRSP has thirteen projects which support research on plant pathology, entomology, food science, plant breeding, social science, soil science and physiology. Each project gave a full report of its research, which was then followed by a discussion. Summaries of these sessions are presented in order by country in the next section of this publication.

Brief summaries of related research by non-CRSP participants are also included. These proceedings also contain the invited papers given on "Exploring New Biotechnology for CRSP Research," "Socio-Economic Impact Assessment," and "Food Science and Technology in the Total Food Delivery System." Following the presentations, four discussion groups met and subsequently reported the outcome of their deliberations. These groups included: (1) ethical issues in research, (2) biotechnology in developing countries, (3) facilitating technology transfer, and (4) designing research for sustainable agriculture. Reports of the major outcome of these discussions are summarized. Some of the recommendations from the group discussions include: (1) increase farmer involvement in the development and implementation of the projects; (2) increase involvement of the private sector in the research program; (3) expand understanding of the farmers' complex farming systems; (4) encourage cross-CRSP collaboration; (5) utilize multidisciplinary teams to address the ethical issues in research; and (6) maintain the free exchange of germplasm. In addition, there are two papers from invited scientists reviewing the process of bridging the science-farmer gap.

Also contained in the final sections of these proceedings are the following: (1) the Bean/Cowpea CRSP Global Plan; (2) a roster of Bean/Cowpea CRSP Management Groups; (3) a roster of participants attending the research meeting, (4) "An Overview of the Future of the CRSPs" by William Furtick, Agency Director for Food and Agriculture, provided as background reading for the meeting; and (5) a brief description of "CRSP Buy-Ins," a procedure by which USAID Missions in developing countries interested in new or expanded relationships with CRSPs can become a part of the CRSP community (also provided in advance).

The reports presented by each of the CRSP projects demonstrate how they address constraints to bean and cowpea production and use identified in the Global Plan. In their summary, the Brazil/BTI project gives an overview of how they use insect pathogens to control important cowpea insect pests. Over 300 strains of cowpea pathogen have been collected, tested and stored. The Dominican Republic/UWI report discusses how biotechnology is being used to develop ways to control bean golden mosaic virus. The use of DNA probes to identify different geminiviruses is outlined. The Cameroon/Purdue project gives a brief summary of the seed storage survey conducted in northern Cameroon. It also reports how they developed a simple but effective technology using the heat from the sun to kill storage insects. The Dominican Republic/UNL paper discusses how resistant germplasm is being utilized to develop improved bean cultivars to control important diseases including common bacterial blight, rust, web blight and bean golden mosaic virus. The Ecuador/UMN project is a new initiative on biological nitrogen fixation which has begun with a baseline survey assessing fertility needs, rhizobia soil counts and other related constraints in bean production. The Guatemala/Cornell paper reviews how selecting for biomass accumulation, partitioning rate and date of maturity are used to select for high yielding beans. The Honduras/UPR summary presents an overview of the progress of breeding for disease resistance in small seeded beans. Resistant material is being developed to bean common mosaic virus, rust, anthracnose, common blight and bean golden mosaic virus. The Malawi/MSU project reports how biological and social scientists interact in the research process. It shows surveys on seed type preference, preferred varieties and cultural practice information being used by the plant breeders to develop new bean varieties for Malawi farmers. The Mexico/MSU program reports that drought tolerant bean lines have been identified and are being incorporated into U.S. and Host Country breeding programs. The Senegal/UCR paper reviews their research program and considerable accomplishment on providing drought and heat tolerance in cowpeas. Also reviewed are important new technologies for the extension program. The Tanzania/WSU paper reviews the bean common Mosaic work being conducted at WSU and the contribution of the farm-level socio-economic survey and variety development work in Tanzania. The Nigeria/UGA report discusses the newly developed cowpea mill which is being used to produce cowpea and maize meals suitable for traditional dishes usually made from hand pounded flour. It also reports on the nutritional and microbiological evaluation of the processed cowpea products. The INCAP/WSU project discusses their research to improve the nutritional quality of beans. Breeding efforts are progressing to develop germplasm with improved protein digestibility.

After extensive deliberations the following new or expanded research areas were identified as important for the Bean/Cowpea CRSP to address when additional funds become available:

1. Increased biotechnology addressing disease and insect resistance

2. Increased germplasm collection, evaluation and utilization

3. More integrated pest management systems (IPM)

4. Expanded research on insect-transmitted viruses, especially white fly

5. Concentrated food nutrition/utilization issues

6. Seed multiplication

7. Changes in economic and social policies that impact beans and cowpeas (food policy)

8. Soil conservation management

These research areas have relevance to the United States as well as to the developing world. Additional support when available will enable the Bean/Cowpea CRSP to expand research in these important constraint areas.

Other research activities were identified which could best be addressed by working with other CRSPs. These research activities include:

1. Food processing and utilization with the Bean/Cowpea, Peanut and the Sorghum/Millet CRSPs (e.g., composite flour)

2. Forage production with the Bean/Cowpea, Small Ruminant and Soil Management CRSPs

3. Sustainable agriculture project for Africa with the Bean/Cowpea, Nutrition, Soil Management, Peanut, Sorghum/Millet and Small Ruminant CRSPs

4. Integrated pest management with the Bean/Cowpea, Peanut and Sorghum/Millet CRSPs

These inter-CRSP activities and the other initiatives proposed throughout this document will strengthen the Bean/Cowpea CRSP contribution to the alleviation of hunger and malnutrition in the next decade and on into the next century.

BEAN/COWPEA CRSP ROSTER OF PROJECTS

COUNTRY OF PROJECT
Title of Project

Host Country Institution
Host Country Principal Investigator

US Lead Institution
US Principal Investigator

BRAZIL
Insect Pathogens in Cowpea Pest Management Systems for Developing Nations

Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)
Ms. Eliane Quintela

Boyce Thompson Institute (BTI)
Dr. Donald W. Roberts

CAMEROON
Preservation of Postharvest Cowpeas by Subsistence Farmers in Cameroon

L'Institut de Recherche Agronomique au Cameroun (IRA)
Mr. Zachee Boli Baboule

Purdue University
Dr. Larry L. Murdock

DOMINICAN REPUBLIC
Biology, Epidemiology, Genetics and Breeding for Resistance to Pathogens of Beans with Emphasis on Those Causing Bacterial and Rust Diseases

Secretaria de Estado de Agricultura (SEA)
Ing. Agron. Freddy Saladin Garcia

University of Nebraska-Lincoln (UNL)
Dr. Dermot P. Coyne

DOMINICAN REPUBLIC
Molecular Approaches for Control of Bean Golden Mosaic Virus

Secretaria de Estado de Agricultura (SEA)
Ing. Agron. Freddy Saladin Garcia

University of Wisconsin (UWI)
Dr. Douglas Maxwell

ECUADOR
Improving the Productivity of Phaseolus Beans Under Conditions of Low-Input Agriculture Through Genetic Selection of Host Cultivars and Rhizobium Strains for Enhanced Symbiotic Efficiency

Instituto Nacional de Investigaciones Agropecuarias (INIAP)
Ing. Gustavo Bernal

University of Minnesota (UMN)
Dr. Peter Graham

GUATEMALA
Agronomic, Sociological and Genetic Aspects of Bean Yield and Adaptation

Instituto de Ciencias y Tecnologia Agricola (ICTA)
Dr. Raphael Rodriguez

Cornell University
Dr. Donald H. Wallace

HONDURAS

Improvement of Bean Production in Honduras Through Breeding for Multiple Disease Resistance

Escuela Agricola Panamericana (EAP)
Dr. Juan Carlos Rosas

University of Puerto Rico (UPR)
Dr. James S. Beaver

INCAP

Improved Biological Utilization and Acceptability of Dry Beans

Institute of Nutrition of Central America and Panama (INCAP)
Dr. Ricardo Bressani

Washington State University (WSU)
Dr. Barry G. Swanson

MALAWI

Genetic, Agronomic and Socio-Cultural Analysis of Diversity among Bean Landraces in Malawi

Bunda College of Agriculture
Dr. A. B. C. Mkandawire

Michigan State University (MSU)
Dr. Wayne Adams (Acting)

MEXICO

Improving Resistance to Environmental Stress in Beans Through Genetic Selection for Carbohydrate Partitioning and Water Use Efficiency

Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)
Dr. Jorge Acosta

Michigan State University (MSU)
Dr. Dale Harpstead

NIGERIA

Appropriate Technology for Cowpea Preservation and Processing and a Study of Its Socio-Economic Impact on Rural Populations in Nigeria

University of Nigeria, Nsukka
Mr. Dickson O. Nnanyelugo

University of Georgia (UGA)
Ms. Kay H. McWatters

SENEGAL

A Program to Develop Improved Cowpea Cultivars, Management Methods and Storage Practices for Semiarid Zones

Institut Sènégalais de Recherches Agricoles (ISRA)
Mr. Limamoulaye Cisse

University of California-Riverside (UCR)
Dr. Anthony E. Hall

TANZANIA

Breeding Beans (Phaseolus vulgaris L.) for Disease, Insect and Stress Resistance and Determination of Socio-Economic Impact on Smallholder Farm Families

Sokoine University of Agriculture (SUA)
Dr. James M. Teri

Washington State University (WSU)
Dr. Matt J. Silbernagel

BRAZIL/BOYCE THOMPSON INSTITUTE/EMBRAPA
Donald W. Roberts and Eliane Quintela

Insect Pathogens in Cowpea Pest Management Systems for Developing Nations

Presenters: Donald W. Roberts and Eliane Quintela

Insect pests are major constraints to production and storage of cowpeas and beans in Brazil and several other Latin American and African countries with large populations of subsistence farmers. A project emphasizing pest control by biological methods, particularly by insect pathogens, was initiated with Bean/Cowpea CRSP support in 1981 by Boyce Thompson Institute (BTI) scientists in collaboration with the Brazilian Federal Agricultural Research Organization (EMBRAPA). In addition to U.S. and Brazilian project-supported staff at BTI, a series of Ph.D.-level U.S. scientists were stationed at the Brazilian National Rice and Bean Research Center (CNPAF) in Goiania, Goias. Other staff in Brazil included a Cornell University Ph.D. candidate conducting dissertation research, a project-trained M.S.-level Brazilian scientist, and several Brazilian technicians and students. The Brazilian government contributed facilities, administrative support, senior scientist collaborators and technical help.

Important insect pests of beans and cowpeas in Brazil include the weevil *Chalcodermus bimaculatus*, the leafhopper *Empoasca kraemeri*, the lesser cornstalk borer *Elasmopalpus lignosellus* and chrysomelid beetles of the genera *Cerotoma* and *Diabrotica*. Scarabaeid larvae (white grubs) cause crop and turf losses in many developing nations. These, or closely related insects, are serious agricultural pests in the U.S. as well. Germplasm conservation of entomopathogenic fungi has been an important element of the project. Almost 300 strains have been collected, cultured and stored in liquid nitrogen. These isolates are readily available to scientists worldwide.

Leafhopper Control:

Zoophthora radicans is the principal pathogen of *E. kraemeri* in central and southern Brazil. The fungus is mass producible by submerged fermentation and can be formulated as dry mycelium. Field trials in northeast Brazil with one isolate failed to initiate epizootics. Laboratory tests have been conducted to define the effects of temperature on *Z. radicans* conidial germination, appressorium formation, host penetration, in vivo development, rhizoid formation, sporulation and interaction with the host immune system. Direct observation (fluorescent microscopy) of conidia inoculated onto the leafhopper cuticle indicated that the maximum rate of appressorium formation occurs at 25°C while at 30°C appressorium formation is significantly inhibited. In bioassays, little difference was noted in percent mortality, *in vivo* incubation time, sporulation and rhizoid formation at 20 and 25°C. At 30°C, however, treatment mortality did not exceed that in the controls and no rhizoids or spores were produced. Future field trials with this fungus strain will focus on temperate regions; and a strain from a warm, dry area will be tested in northeast Brazil. Releases of a Central Brazil strain in New York induced epizootics.

Hirsutella guyana is the principal pathogen of *E. kraemeri* in northeast Brazil. During July 1988, several isolates of this fungus were collected from an epizootic outbreak discovered in Caucaia, Ceara. The fungus was mass produced

and formulated as dry mycelium and then applied to the undersides of cowpea leaves in subsistence-level farmers' fields in June 1989. The fungus rehydrated and underwent sporulation in a manner and at a rate comparable to that observed on natural fungus-killed leafhopper cadavers, producing a dense mat of conidiophores and conidia within two to three days. An unusually low density of leafhoppers resulted in an insignificant level of pathogen transmission. This test will be repeated in fields with pest-level populations of leafhoppers.

Soil-Insect Control:

Many of the principal pests of beans and cowpeas pass all or part of their larval stages within the soil environment. *Chalcodermus* weevil larvae, after completing development in cowpea seeds, exit the pods and enter the soil to pupate. Larvae of *E. lignosellus*, *C. arcuata* and scarabaeid beetles are largely subterranean, feeding on the underground portion of the stem and roots of host plants. *Metarhizium anisopliae* and *Beauveria bassiana* are important natural fungal pathogens of these insects, and tests have been conducted to asses the microbial control potential of soil applications.

Weevils: Aqueous suspensions of conidia of *M. anisopliae* applied at a rate of 1.5 kg conidia/ha to the soil surface under cowpea plants in a field in northeast Brazil in 1989 resulted in 46 percent infection of sentinel *C. bimaculatus* larvae introduced onto the treated soil. These results were similar to those obtained in 1988 field trials with both *M. anisopliae* and *B. bassiana* and indicate that soil applications of these fungi have the potential to control approximately 30 to 50 percent of weevil larvae entering the soil over a one to two week period. Use of the fungus, in combination with readily utilizable cultural practices, is expected to significantly increase yields.

Rootworms. In northern Brazil, larvae of *Diabrotica* and *Cerotoma* beetles are major pests, with well over 100 million dollars spent annually for pesticide applications. In Brazil, *B. bassiana* conidia were applied dry to cowpea seeds which were then planted in small pots. The treatment resulted in 73 percent mortality of first-instar *C. arcuata* larvae introduced into the pots after seedling emergence.

Field plot trials have been conducted in the U.S. to assess the potential of applying granulated dry mycelium of *M. anisopliae* and *B. bassiana* for control of southern corn rootworm, *Diabrotica undecimpunctata*, larvae in soil. Two dosage rates of each fungus (11.2 and 112 kg mycelium per ha) were applied to the soil surface in 45-cm wide bands in each of eight replicated treatment plots in June. The inoculum was incorporated into the soil to a depth of 15 cm and corn was then planted in the treated soil. One month later, viable eggs of *D. undecimpunctata* were injected into the soil at the base of each plant. Two sets of untreated control plots were used: one infested with rootworm eggs and another left uninfested. In August, corn plants were randomly selected from each plot, and their root systems were washed and rated (on a scale from 1 to 6) as to damage from larval feeding. Damage was significantly less in the fungus-treated plots (damage rated 2.4-3.1) compared to the untreated, rootworm-infested control plots (rated 3.4) but was substantially greater than the damage sustained by plants in the uninfested control plots (rated 1.3). The root systems of plants in the high-treatment-rate plots of *M. anisopliae* were significantly less damaged (rated 2.4) than plants in the other fungus-treated plots (rated 2.9-3.1).

Determinations were also made of the percentage of abnormally growing (goose-necked) corn plants, as this deformity is symptomatic of root damage. The high dose of *M. anisopliae* was the only treatment which reduced goosenecking to a level significantly lower than that observed in the infested control plots (viz., 21 vs. 46 percent). The emergence of adult rootworm beetles on a per plant basis was monitored during August and September. The high dose of *M. anisopliae* was most effective in reducing adult emergence (30 percent fewer beetles emerged from this treatment than from the infested control).

Changes in fungal inoculum levels were monitored by plating soil samples onto a selective medium. During the first four weeks following treatment, fungus soil titers rose due to sporulation of the applied mycelium. Titers reached highest levels in the upper few centimeters of the soil profile, probably due to aeration, and titers of *B. bassiana* were commonly higher than those of *M. anisopliae*. The amount of fungal inoculum began to decrease during the latter half of July (when the introduced larvae were active); however, even at the end of the season (21 September), titers were still above their initial levels.

White grubs. The Japanese beetle, *Popillia japonica*, is a pest of turf and ornamental plants throughout the northeastern United States. This species is a useful model for many scarab pests of the Third World because its life cycle is typical of the group. Assays conducted during 1989 tested the effectiveness of *M. anisopliae* dry mycelium and conidia preparations against *P. japonica* larvae in soil at two different levels of moisture (40 and 65 percent saturation) and temperature (15.5 and 20°C). Mortality occurred more rapidly and reached higher proportions among larvae incubated in soil inoculated with dry mycelium than in soil treated with conidia. These results were unexpected since conidia are the infectious units and two to three days are required for sporulation of the rehydrated dry mycelium. Conditions of 40 percent saturation and 20°C were generally most favorable for infection.

Lesser stalk borer. In recent screenhouse tests, application of conidia of *M. anisopliae* and *B. bassiana* to the stems and soil surrounding the stems of cowpea seedlings at rate of 2.9×10^6 conidia/cm^2 caused greater than 85 percent mortality of neonate *E. lignosellus* larvae which hatched from eggs placed on the soil near the plants.

Training and Institutionalization:

A functioning, well-equipped microbial control laboratory has been established at CNPAF. In 1989, CNPAF instituted an integrated pest management (IPM) program. The Bean/Cowpea CRSP microbial control/insect pathology project, at CNPAF's invitation, has become an integral part of this program. Two of the HC PIs have received graduate training with CRSP staff. (Bonifácio Magalhães is completing a Ph.D. degree at Cornell University/BTI and Eliane Quintela obtained an M.S. degree by completing course work at the University of São Paulo (Piracicaba) and thesis research at CNPAF with CRSP scientists.) A total of five Brazilian students have participated in M.S. degree programs, and one U.S. and one Brazilian student are completing Ph.D. degrees. Three of the seven are women. Several post-baccalaureate students have served in research internships at CNPAF for periods of up to one year. In addition, six short courses (one to two weeks) have been used to train approximately one hundred students (47 percent female) from Brazil and five other Latin American nations on microbial control and entomology.

Question and Answer period: BRAZIL

Q: How did you spray Beauveria in the field and how did you verify that no natural epizootic of this organism would have occurred in the field?

A: We used a pressurized sprayer similar to those used for insecticides and chose a field site where it was highly unlikely that an epizootic of Beauveria would occur.

Q: Do you have plans to extend your research and technology to Africa?

A: We are interested in working in Africa on the control of insect pests. This could include cowpea aphids, flower thrips and soil insects.

Q: Are there any hazards to the farmers from the fungi considered for use in insect pest control, either in handling the materials or eating plants on which the materials have been applied?

A: The only potential problems the presenter could think of are allergies--but they are not aware of any specific cases where problems occurred.

Q: Have toxicology tests been conducted in fungal agents for controlling insect pests?

A: Toxicology tests have been conducted which indicate no problems to people, but there may be problems to specific cold-blooded animals such as tortoises under cold-stress conditions such as in zoological gardens.

Q: Do these fungal agents have any negative effects on beneficial insects?

A: There are some cases of negative effects but honey-bee hives are not harmed.

CAMEROON/PURDUE UNIVERSITY/IRA
Larry Murdock and Zachee Boli Baboule

Preservation of Postharvest Cowpeas by Subsistence Farmers in Cameroon

Presenters: Larry Murdock and Zachee Boli Baboule

Storage pests are a major constraint to the availability of cowpeas as food in developing nations. One major pest, the cowpea weevil, *Callosobruchus maculatus*, enters storage granaries at harvest in low numbers but reproduces rapidly--each generation is completed in a few weeks, each female reproduces herself twenty-fold each generation--after a few months, unprotected cowpeas in stores can become riddled, inedible and worthless. The IRA/Purdue CRSP project is devising implementable technologies to reduce losses caused by the cowpea weevil and other storage pests. We developed our research with three strategic assumptions, namely: (1) that we should listen to the people in the countryside who grow, store and utilize cowpeas, indeed, that we must learn from the people if our research is to produce relevant results and implementable technologies; (2) that we should develop several alternative storage technologies to meet the needs of the diverse ethnic groups in the region who follow various cowpea production and storage patterns, this variety of technologies being combinable in different ways to meet the range of needs; and (3) that we should engage in short-term, mid-term and long-term research.

Survey:

Northern Cameroon, where our project is based, has a variety of ethnic groups and multiple systems of cowpea production, storage and utilization. To improve cowpea storage it is essential that we have first-hand knowledge of the people concerned, their relationship to cowpea and their perception of the problem. In particular, we need to have objective information about (1) cowpea storage practices of farmers of different ethnic groups and socio-economic strata, including how long cowpeas are stored, in what form and what measures are taken to reduce losses; (2) what the different storage pest species are at different times during the storage season. To obtain this information, Dr. Jane Wolfson has carried out three month-long surveys in northern Cameroon over the last three years. The results have provided us with baseline data and a framework for our research.

The surveys involved (1) interviews with farmers, storers and users of cowpeas in the area within an 80 km radius of Maroua; (2) observations of cowpea storage techniques in use; and (3) sampling of stored cowpeas to determine degrees of damage and the nature of the insect problem. Findings include evidence that:

1. Women play important roles in all aspects of cowpea production, storage and processing;

2. The cowpea weevil is the principal insect pest for long-term storage but that another bruchid, *Bruchidius atrolineatus*, is a pest of cowpeas at and shortly after harvest;

3. Cowpeas are generally stored in pod form for an extended period on pole platforms called *dankis*, then threshed and stored as seed in various ways;

4. Low-resource farmers are well aware of storage weevils and utilize a variety of "traditional" storage techniques designed to stop their losses. A common technique is to store the threshed cowpeas with ash, with herbs or a combination of the two;

5. Cowpea hay is an important forage;

6. Many farmers utilize green and dried cowpea foliage as a vegetable.

Knowledge that farmers commonly store cowpeas in pod form for long periods encourages us to pursue our long-term goal of combining seed and pod resistance through breeding/selection. Combined pod/seed resistant cowpea types will probably be acceptable because they are compatible with storage techniques people are already using. Knowledge that farmers often store their cowpeas in ash has prompted us to verify the value of the technique and develop a recommended procedure. Knowledge that cowpeas are eventually threshed and stored in seed form has encouraged us to see threshing time as a window of opportunity for using solar radiation to eradicate existing bruchid infestations. Confirmation that there are two bruchid pests, not one, will help us direct our research in ways that will enable us to deal appropriately with both pests.

Storage Technology Development or Testing

Solar technology: Experiments conducted at Purdue University revealed that exposing cowpeas to temperatures of >57°C in an oven for 1 hour killed cowpea weevil eggs, larvae and pupae living within the seeds and adults living among the seeds. Using only the sun's rays and a simple heater constructed from cheap, widely available materials, we demonstrated the feasibility of using solar energy to eliminate cowpea weevil infestations from cowpea stores. The temperatures and exposure times necessary to disinfest cowpeas had no significant effect on the cooking time and percentage germination of cowpea seeds.

In Cameroon, simple solar heaters were constructed using locally available and affordable materials that produced and maintained temperatures of >57°C within seeds during the initial, coolest part of the cowpea storage season (November to January). Additionally, the effectiveness of these heaters in eliminating *C. maculatus* infestations in stored seeds was demonstrated. Solar disinfestation of cowpea stores using this simple technology represents a new approach to preserving cowpea stores which may be useful at the level of subsistence farmers in developing nations, not only for cowpea, but for other stored grains as well. Currently we are developing a simple solar heater package and protocol and will be testing it in our network of farmer-cooperators in Cameroon during the coming year.

Ash storage: Results from experiments conducted at IRA facilities in Maroua, Cameroon and Purdue University confirm that wood ash, when mixed in equal volumes with cowpea seeds, effectively stops cowpea weevil population growth. Larvae living within the seeds when the seeds are put into ash continue to grow and develop, but the adults have difficulty emerging from the seed, crawling through the ash, finding mates and oviposition sites. When the volume ratio of ash to cowpea seed is reduced below 0.75, however, ash begins to lose its effectiveness to retard cowpea weevil population growth. Results also show that an uninfested store of cowpeas can be protected from cowpea weevil infestation by a 3 cm layer of wood ash layered on its surface. Currently we are developing a simple ash storage protocol that can be used by low-resource farmers to preserve cowpeas

from bruchids. We hope to test this protocol in the coming months. We plan further research into the effectiveness of wood ash from various species, as well as ash from animal dung.

We anticipate that it may be possible in the future to combine solar heating to eradicate weevil infestations together with ash storage to prevent reinfestation. This combination of methods should effectively reduce losses and allow long-term storage of cowpeas free from further damage.

Botanicals: The effect of various botanicals on *C. maculatus* adult emergence and oviposition were studied in Maroua, Cameroon. Neem oil and shea nut oil (*Butyrospermum parkii* [G. Don] Kotschy) were effective even at quite low concentrations. The powders and flowers of nine other botanicals tested did not appear to be markedly effective, although all did have a statistically demonstrable effect on adult emergence and oviposition. With the exception of the two oil treatments, the practical value of other botanicals is unclear. Some of the effect of most botanicals tested appeared to result from mechanical effects on behavior, similar to wood ash.

Development of Seed and Pod Resistant Cowpea Cultivars:

One of our longer-term goals is to develop, through plant breeding, varieties which combine seed and pod resistance and which are adapted to conditions in northern Cameroon. To achieve this goal, two major research thrusts are required:

1. Pod and seed resistance screening to identify or develop varieties possessing seed or pod resistance to *C. maculatus*;

2. Yield trials to identify varieties which are adapted to growing conditions, preferences and practices in northern Cameroon. Yield trials, begun during the Georgia phase of the project and continuing under Purdue, have assessed the performance of large numbers of locals and exotic lines and laid a good foundation for the development of the planned breeding work for combined seed and pod resistance.

Screening for resistance to cowpea weevil in cowpea pods:

A major effort toward screening for seed and pod resistance has been carried out during the past year. Several cowpea varieties developed by the International Institute of Tropical Agriculture (IITA) possess seed resistance to *C. maculatus* (derived from local cultivar TVu 2027). We screened intact pods of several of these lines in the laboratory (1) to determine if any possess pod resistance in addition to seed resistance and (2) to ascertain whether this resistance was due to seed factors, pod-wall factors or an interaction between the pod and seed factors. Physical measurements were made of several pod and seed characteristics.

Numerous seed resistant lines gave evidence of also having pod resistance. The primary manifestation of pod resistance was pre-establishment larval mortality (PLM)--those larvae dying after egg hatch but before penetrating into the seeds. PLM ranged from 57.9 percent to 99.4 percent among the 30 varieties examined. Several varieties combined seed and pod resistance and exhibited overall pod and seed mortality of between 95.3 percent and 99.9 percent. This combination of seed resistance and pod resistance should represent a very durable form of weevil resistance.

We developed a practical method for measuring pod resistance to breakage (breakage from handling plus pod dehiscence). Although resistance to breakage is a necessary characteristic for overall pod protection, this factor alone is not sufficient to confer a maximum level of whole pod resistance. Other factors contribute importantly to whole pod resistance. By combining pod resistance with seed resistance, a higher level of overall resistance is attainable and the resistance may be more durable.

Measurements were made of (1) the space surrounding individual seeds in the pod; (2) pod wall thickness; (3) pod wall strength; (4) pod:seed ratio; (5) seed coat thickness; and (6) seed coat texture. Seed coat thickness and texture were the factors most highly correlated with pre-establishment larval mortality. Our results suggest that interactions between pod wall and seed coat characteristics may play an important role in pod resistance to *C. maculatus*.

We anticipate that the use of seed and pod-resistant varieties, combined with solar disinfestation and ash storage, could be implemented by low-resource farmers and provide, at low cost in materials, money, time and effort, a substantial degree of protection to cowpeas in storage over the long term. Other techniques, such as drum storage with insecticides, double-bagging, use of co-storage with botanicals or oil treatments, may be integrated into this system of storage as well.

Question and Answer period: CAMEROON

Q: Does the ratio of ash/cowpea in storage influence the taste of the cowpea when cooked?

A: The ratio that we are recommending is one ash/one cowpea by volume and is presently used by some farmers in Cameroon and considered to be acceptable.

Q: Why isn't ash storage used more widely by farmers?

A: This may be because ash storage is sometimes not effective.

Q: Do farmers differentiate between storing cowpeas for use as seed vs. for use as food?

A: Farmers using ash storage may not differentiate, but farmers using less effective methods for storing cowpeas as food may use ash storage for storing cowpeas for use as seed.

Q: What about using oil to protect cowpea seed in storage?

A: One ml of vegetable oil per 100 g of seed will protect cowpea to some extent by suffocating the weevils, and Jane Wolfson found one person out of 300 persons interviewed to be using oil to store cowpeas in Cameroon.

Q: Could the arcelin compound that occurs in common bean seed protect cowpea seed against the cowpea weevil?

A: We are investigating ways for testing this possibility.

Comment: Researchers should develop a menu of different control methods for cowpea weevil to cover the many different economic and social circumstances under which cowpea grain is stored at the village level and in stores and markets in Africa.

DOMINICAN REPUBLIC/UNIVERSITY OF NEBRASKA-LINCOLN/SEA

Dermot P. Coyne and Freddy Saladin Garcia

Biology, Epidemiology, Genetics and Breeding for Resistance to Pathogens of Beans with Emphasis on Those Causing Bacterial and Rust Diseases

Presenters: Dermot P. Coyne, James R. Steadman, James S. Beaver and Freddy Saladin Garcia

Collaborative research cannot be conducted without Host Country scientists and facilities. In 1982 these were insufficient in the Dominican Republic (DR) legume program. Through training (ten advanced degrees), improvements at the Arroyo Loro Station and increased government support, there is an enthusiastic research team capable of collaborating on reducing constraints to bean production as well as attracting other sources of support (i.e., funding to initiate Caribbean Cooperative Agricultural Research Network). Continued training will be needed along with collaborative research efforts to improve the quality of research in the DR. Basic information to guide pest management strategies and breeding approaches as well as improved bean cultivars for small-scale farmers will be the pay off. Linkages with other CRSP projects and CIAT bean networks will be expanded.

Diseases of beans, particularly common bacterial blight (CBB), rust (RU), web blight (WB), and bean golden mosaic virus (BGMV), are major constraints to bean yields and seed quality in the DR. The overall objectives were to identify resistant 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 to educate graduate students. The expected impact is (1) improvement of breeding programs and disease management strategies in the DR, U.S. and other CRSPs and (2) improvement of yields and income to small-scale farmers in the DR.

Major Results by Constraint:

Common bacterial blight (CBB): (1) A semi-selective medium (MXP) was developed (a "breakthrough") for isolation of *Xanthomonas campestris* (*Xcp*) from common blight infected bean tissue and infested soil. (2) The MXP medium was used to study epiphytic populations of *Xcp* on leaves of different bean genotypes (University of Nebraska-Lincoln [UNL], DR) and weeds in and around bean fields (DR). Resistant bean genotypes supported lower populations of *Xcp* than susceptible genotypes. A relationship between disease incidence and epiphytic populations (10^5 cfu/ml) was established. A common bean breeding line BAC-6 (Brazil) was found to have highly resistant pods and no seed infection when inoculated with *Xcp*. Many pathogenic *Xcp* strains were found on the weed *Echinoclon colonum* in different locations in the DR. (3) The MXP medium was also used to study survival of *Xcp* in infested bean debris incorporated in the soil or on the soil surface (DR). Survival was limited to one month in the soil but *Xcp* was isolated after five months from surface debris. (4) Heterogeneity and randomness of *Xcp* strains was observed using bacteriophage typing (DR). (5) Strains of *Xcp* were differentiated into pathogenic races based on their reactions (hypersensitive/compatibility) on cotyledons of tepary genotypes, but differential reactions of this type were not observed on leaves and pods of both tepary and resistant common bean germplasm; a bean genotypes *Xcp* strain statistical interaction was observed on leaves and pods (differential compatibility reactions). (6) A rapid and

reproducible detached leaflet bioassay was developed to isolate pathogenic and virulent mutants of *Xcp*. Co-inoculation experiments of *Xcp* and bean common mosaic virus (BCMV) on bean showed that screening for reaction to those pathogens can be done simultaneously but, because of interactions of *Xcp* and the rust pathogen, it is recommended to inoculate separate leaves. (7) The determinate plant habit of the Pompadour germplasm was associated with increased and severe necrotic reaction to *Xcp* but with reduced leaf chlorosis compared to indeterminate Pompadour germplasm. Some bean genotypes developed a rapid leaf chlorosis (high levels of C_2H_4) when inoculated with *Xcp*. (8) Photoperiod affected the adaptation and also the reaction of some germplasm to *Xcp*. (9) Tepary and common bean germplasm was identified with high resistance to *Xcp*. (10) Leaf and pod disease reactions to *Xcp* were inherited quantitatively with low narrow sense heritabilities and were not associated. Earliness and determinate plant habit were associated with susceptibility to *Xcp*. (11) Red mottled Pompadour, Great Northern (GN) and Pinto lines have been developed with resistance to *Xcp*.

Rust: (1) A new common set of rust differentials was used to monitor and study rust variability in the DR, UNL and elsewhere. The DR rust races differed from those in the state of Nebraska. Greater virulence, as measured by the number of differential cultivars with large pustules, occurred in the DR rust populations. The "cluster" patterns indicated similarity of DR and Florida isolates and also similarity of midwest U.S. isolates. (2) Positive correlations were observed between rust race nonspecific resistance (reduced rust intensity) in trifoliolate pubescent leaves (long straight abaxial hairs) of PC-50 (DR), Jamaica Red and Alubia selections (Argentina). The glabrous primary leaves of these varieties were highly susceptible to many rust races while the hairy leaves were observed to be resistant in field studies. (3) The pubescent trait does not appear to be influenced a great deal by environment; however, genetic background can reduce rust resistance effects. A rating scale to measure pubescence was devised. Plastochron index is a superior indicator of leaf development. Rust pustule size showed a negative correlation with leaf age and was also influenced by nutrition and pH of the media. Bean genotypes growing in a calcareous soil (high pH) had smaller pustule sizes than when grown in potting media. (4) Single plant selections within the Pompadour landrace were made for specific and nonspecific (leaf pubescence) rust resistance. Some components of this landrace were highly susceptible. (5) Specific resistance in Pompadour Checa was controlled by one or two major genes depending upon the cross and rust isolates used. Different major genes controlled the leaf pubescence in rust resistant Jamaica Red than in PC-50. (6) Rust resistant Pompadour, black (H-270) and white bean-V031 (DR, University of Puerto Rico [UPR]) and GN (UNL, USDA) and Pinto dry beans (UNL) have been developed. GN BelNeb rust resistant -1 and -2 (USDA, UNL) were released for resistance to 33 rust and to *Xcp* and BCMV.

Bean golden mosaic virus (BGMV): (1) Bean lines DOR303 and A429 (CIAT), which were reported to have field resistance to BGMV, were found to have much lower feeding and oviposition preference to white flies than BGMV susceptible lines. (2) A leguminous weed species was found to serve as an alternate host for BGMV. (3) Two Pompadour selections (DR) were found to have high leaf resistance (tolerance to BGMV but pod set and seed development was limited in severe BGMV nurseries. Early maturing lines appear to have less BGMV than later lines. The CIAT lines DDR301, DOR302, DOR303, A471, A420 and A429 had high field tolerance to BGMV.

Web blight: (1) The fungus causing web blight was found to be transmitted through the seed. (2) Web blight was more severe on determinate beans

intercropped with corn than in monoculture. (3) Red mottled lines have been selected with low incidence (5-11 percent) of web blight infection.

Ashy stem blight: (1) Variations in virulence of isolates of *Macrophomina phaseolina* (*Mp*) was observed and an effective inoculation method was developed. (2) Three lines from the Pompadour germplasm collection showed moderate levels of resistance to all *Mp* isolates.

Adaptation and yield improvement of different grain types: (1) Small seeded indeterminate dry bean lines had higher and more stable yield than large seeded determinate lines (DR). Narrow sense heritabilities were generally low for yield, yield components and several morphological traits in progenies derived from crosses of the above plant types. (2) A breeding strategy to select and develop GN and Pinto dry bean lines for multiple disease resistance based on pathogen interactions, seed quality, adaptation and yield was developed (UNL). Promising lines were developed and will be released in 1990. (3) Lines with tolerance to high temperature and high BNF were identified (DR, UPR). Indeterminate, early, high-yielding Pompadour types are being developed. (4) High outcrossing (16-39 percent) was observed in a do dwarf bean mutant line which has potential for population improvement. (5) Enough seed has been increased in the DR of the new PC-50 (Pompadour Checa) to supply the country's needs in 1990. It is proposed to release new rust resistant white seeded and black seeded beans in 1990 (DR). Small white seeded varieties Arroyo Loro (DR) and Monument (UNL) were released in 1985.

Implications for the Small-Scale Farmer:

(1) The new improved PC-50 variety will provide higher yields to the growers and better quality grain to the consumer. The introduction of new black seeded and white seeded varieties in 1990 will also improve the yields and disease resistance of these grain types for growers. The future introduction of DR grain types with multiple disease resistance, indeterminate plant habits, earliness and higher yields should be a major contribution to dry bean growers (DR). (2) The adoption of sanitation (removal of debris), rotation, removal of weeds (host of *Xcp*) and burying *Xcp* infested bean debris will reduce common blight without much added expense. (3) Removal of specific weed hosts of BGMV, early planting and use of earlier maturing bean varieties can reduce losses due to BGMV. (4) Use of disease-free seed (common blight, web blight) can reduce yield losses and prevent spread of the diseases. (5) The introduction of bean varieties with multiple disease resistance should benefit the farmer by reducing costs of production, stabilizing yields and reducing pesticide usage.

Future Research:

(1) Determine the inheritance of the different types of leaf reaction to *Xcp* and also of resistance to seed infection in common and tepary beans. (2) Transfer major genes determining the reaction to *Xcp* in tepary to common beans through interspecific hybridization and congruity backcrosses. (3) Develop a protocol for regeneration of common bean and tepary. Develop transgenic common beans with resistance to *Xcp*. (4) Genes controlling leaf pubescence should be incorporated into glabrous bean types with specific resistance. Additional information is needed on the inheritance of pubescence and the mechanism of nonspecific resistance. The possible effects of pubescence versus glabrousness on bean performance needs to be evaluated in isogenic lines in diverse environments. (5) Additional screening should be done in Pompadour to identify higher levels

of resistance to BGMV (DR). The inheritance of the reactions to web blight and BGMV and also their association with other traits needs to be investigated. (6) Possible biocontrol for the web blight organism needs to be studied. (7) Heat tolerant lines with resistance to CBB need to be developed in the DR. (8) Multiple disease resistant, higher-yielding indeterminate red mottled lines will be developed for small-scale DR farmers and development of cultivars for UPR and UNL will be continued. (9) Impacts of PC-50, other newly developed cultivars and disease control strategies need to be documented.

Linkages:

Present linkages are with personnel in the Regional Research Project W-150, CIAT, North Dakota State University (K. Grafton), Michigan State University (J. Kelly) and Bean/Cowpea CRSP projects in Dominican Republic/University of Wisconsin, Honduras/UPR and Tanzania/Washington State University-Prosser. New linkages will be established with personnel in Oregon State University (tissue culture and Restriction Fragment Length Polymorphism [RFLPs]), University of California-Davis (RFLPs), Michigan State/Malawi Bean/Cowpea CRSP project, CIAT/African Bean Network, CIAT/Central America and Caribbean (COSUDE) and Caribbean Co-operative Agricultural Research Network.

Question and Answer period: DOMINICAN REPUBLIC (Coyne)

Q: Have you used the bean golden mosaic resistant lines from Los Mochis, Mexico?

A: Not yet, but Rafael Solinas is preparing a nursery containing these lines for testing throughout the Caribbean.

Q: How did you identify low seed transmission of common blight in BAC6?

A: Graduate student Ammad Aqqour used several different inoculation methods (blossom, pod) and BAC6 was the only genotype with this low level of seed transmission.

Q: What is the inheritance of dense pubescence and are there any undesirable traits associated with dense pubescence?

A: Results from the University of Nebraska and the University of Puerto Rico have found a fairly simple inheritance involving one to two genes. We have not observed association with undesirable traits although there is a need to better understand the relationship between pubescence density and white flies.

Q: Why was PC-50 selected as a pure line rather as a heterogeneous mixture?

A: PC-50 was selected for superior performance and disease resistance in a wide range of environments in the Dominican Republic. There are some bureaucratic problems in releasing a mixture of genetypes in the Dominican Republic. This observation is a very valid issue.

DOMINICAN REPUBLIC/UNIVERSITY OF WISCONSIN/SEA
Douglas P. Maxwell and Freddy Saladin Garcia

Molecular Approaches for Control of Bean Golden Mosaic Virus

Presenters: Douglas P. Maxwell and Freddy Saladin Garcia

Bean golden mosaic geminivirus (BGMV) and other bean-infecting geminiviruses (e.g. bean dwarf mosaic geminivirus [BDMV]) are major constraints on bean production in subtropical and tropical Americas. Some fields experience 100 percent losses. In the Host Country of the Dominican Republic, the severity of BGMV is increasing because of changing agricultural practices, which favor increases in the population of the whitefly insect vector, *Bemisia tabaci*, of BGMV. Evidence indicates that considerable genetic variation exists among BGMV strains causing the disease in the field and that this variation will be a major complicating factor in attempts to control this disease by classical breeding methods. Our project has the following major objectives:

1. Molecular characterization of bean geminiviruses;

2. Development of general and strain-specific DNA probes for rapid identification of geminiviruses-infecting weeds, crops and beans;

3. Evaluation of virus-derived resistance schemes for the eventual production of beans resistant to geminiviruses.

Progress to Date:

Molecular characterization of bean geminiviruses: Isolates of BGMV thought to represent the greatest genetic diversity were obtained from Brazil (BGMV-BZ), the Dominican Republic (BGMV-DR) and Guatemala (BGMV-GA). Additionally, an isolate of bean dwarf mosaic virus from Colombia was characterized since this geminivirus causes dwarfing but no golden mosaic symptoms and is very important in Argentina. Each of these virus isolates was cloned and sequenced. The genome for each was shown to be composed of two distinct DNA components, designed A and B. Component A had four open reading frames (ORFs) and component B had two ORFs. This genome organization is similar to that described for other bipartite geminiviruses such as tomato golden mosaic geminivirus. Sequence similarity between BGMV-BZ, which is not mechanically transmitted, and the two mechanically transmitted isolates, BGMV-DR and BGMV-GA, was about 75 percent, which is the percent sequence similarity between BGMV-BZ and tomato golden mosaic geminivirus. Therefore, we concluded that two distinct strains of BGMV exist. BDMV is not closely related to either of these two distinct strains of BGMV and should be considered a separate virus. Our results indicate that breeding for disease resistance will require evaluation of germplasm using these two strains. We have also obtained full-length clones of another geminivirus, bean calico mosaic, from beans grown in Mexico and this virus is being characterized.

Development of general and strain-specific DNA probes: Nucleic acid spot or squash hybridization methods were developed to detect geminiviruses or a particular strain of bean-infecting geminiviruses. This technique involves squashing a 1 cm diameter leaf disc onto a special nylon membrane, which binds DNA. This membrane can be mailed or stored for later processing. The membrane with the squashed leaf tissue is treated to denature the DNA (create

single-stranded DNA) and then placed in a hybridization solution of probe DNA, which is also radioactive and single stranded. Complementary DNA sequences anneal (hybridize) and the radioactivity is detected by exposure of the membranes to X-ray film. This technique has been effectively used to detect BGMV in samples that had typical golden mosaic symptoms from Puerto Rico, Dominican Republic, Brazil, Guatemala, Colombia and Honduras.

General probes have been developed which will detect a broad range of geminiviruses from beans, other commercial crops and weeds. Also, strain-specific probes are being developed and initially the B component has served as a useful probe to distinguish between the different bean-infecting geminiviruses. These probes will be used to determine the extent of genetic variability of BGMV isolates from a given region as well as to determine which weeds or crops are an important reservoir of bean-infecting geminiviruses. To date, several weeds have been found to contain geminiviruses, but only one weed, *Rhynchosia minima*, from the Dominican Republic has hybridized to the strain-specific BGMV-DR probe. It also hybridized to the other strain-specific probes which indicates that it might be a mixed infection or a unique geminivirus infecting this weed. Major efforts are planned for the future to use these probes to study variability and weed reservoirs in Dominican Republic, Mexico, Honduras, Brazil and Argentina.

Virus-derived resistance scheme for transgenic plants: Recent experiments with RNA plant viruses indicate that viral sequences can be used to create transgenic plants which are resistant to the virus. This approach is facilitated by an understanding of the functions of the viral genome, and this requires the use of infectious clones of the viruses. Many attempts at infecting beans with cloned viral DNAs by mechanical inoculation failed. However, cloned DNAs of the four geminiviruses, BGMV-BZ, BGMV-DR, BGMV-GA and BDMV, were infectious when inoculated into beans by electric discharge particle acceleration. Viral DNA of BGMV-GA has been mutated in two genes of component A, and these mutated DNAs and wild-type component B have been introduced into beans by particle acceleration. Mutational analysis will be continued to determine the functions of various domains in the replication, symptom development and movement of the virus in plants. Also, the possible involvement of certain genes in insect vector transmission can be studied.

Future Research Directions:

Molecular characterization of geminiviruses: Our efforts will continue on the molecular characterization of bean-infecting geminiviruses. Bean calico mosaic geminivirus from Mexico will be partially cloned and sequenced. Also, the geminivirus in the weed, *Rhynchosia minima*, will be studied to determine if it is the same virus that infects beans in the Dominican Republic.

Application of geminiviral DNA probes to epidemiological studies: The general and strain-specific probes will be used to determine the importance of weeds as reservoirs of bean-infecting geminiviruses and to determine the variability of bean-infecting geminiviruses in a specific region. These efforts will concentrate on the Dominican Republic, Honduras, Mexico, Brazil and Argentina.

Virus-derived resistance schemes for transgenic beans: Much of our effort will be devoted to understanding the functions of the various DNA regions of the virus genome and developing approaches to utilize this information to create resistant transgenic beans. Also Agracetus Inc. will modify the methods, which were developed for soybeans, to transform beans. Initial experiments have indicated that this will be possible.

Breeding and inheritance of resistance to bean infecting geminiviruses: Germplasm will be evaluated in the field in the Dominican Republic and in growth chambers at the University of Wisconsin. Since immune cultivars exist for BDMV, an inheritance study has been initiated.

We will continue to provide training in molecular biology for visiting scientists in our laboratory at the University of Wisconsin and attempt to maintain the linkages which have been established during the past three years. New cooperative efforts will be initiated with scientists in Jamaica, Honduras, Nicaragua, Mexico and Argentina.

Question and Answer period: DOMINICAN REPUBLIC/Maxwell

Q: Why has the importance of BGMV been increasing in the Caribbean Basin?

A: The population of the white fly vector has increased because more hosts of this insect have been planted as part of an effort to increase production of such crops as tomatoes, peppers and melons.

Q: Are the infectious clones you have sequenced representative of the BGMV in a particular region?

A: Recently, Maria Rojas and Robert Gilbertson have used polymerase chain reaction techniques to show that the BGMV DNA clones from the Dominican Republic are typical of isolates from five diverse geographical regions. Now this needs to be done for isolates from Central America and Brazil.

Q: When do you think transgenic bean plants will be produced?

A: David Russell from Agracetus, Inc., Middleton, Wisconsin, is using the particle gun to transform beans with the coat protein gene from BGMV-GA. It is expected that the seed-lines with the coat protein gene should be produced by July 1991.

ECUADOR/UNIVERSITY OF MINNESOTA/INIAP
Peter Graham and Gustavo Bernal

Improving the Productivity of Phaseolus Beans Under Conditions of Low-Input Agriculture Through Genetic Selection of Host Cultivars and Rhizobium Strains for Enhanced Symbiotic Efficiency

Presenters: Peter Graham and Gustavo Bernal

While this project has been underway for only a year, it builds upon an earlier Bean/Cowpea CRSP program in Ecuador, on a limiting factors grant between the PI and INIAP, on collaborative studies between INIAP and NifTAL, and on basic studies that were already underway in the U.S. laboratory. Where appropriate, aspects of these ongoing studies will be mentioned alongside new initiatives in this report.

Beans are a major commodity in Ecuador with some 50,000 ha sown annually for an average yield of 560 kg/ha. Crop production is centered on holdings of less than 3 ha and at altitudes from 1300 to 2300 m above sea level. Technical inputs are limited, with the crop commonly sown without fertilization. Despite this there has been little done to improve rates of nitrogen (N_2) fixation. Major problems limiting N_2 fixation in beans are likely to include:

1. Cultivars limited in capacity for N_2 fixation and susceptible to insect and disease pests;

2. Soil nutrient deficiencies;

3. Competition for nodulation sites between indigenous organisms and inoculant strains;

4. Problems in the use of chemical seed treatments.

Given these constraints, we believe this program should have a dual focus: (1) to enhance N_2 fixation in *Phaseolus vulgaris*; and (2) to improve bean yields and profitability in Ecuador. As the only project within the CRSP which is to emphasize nitrogen fixation, we foresee considerable interaction in our nitrogen fixation work with other projects and programs, and in particular with CIAT.

Activities to date have emphasized four main areas:

1. <u>A baseline study to better define problem areas</u>: The five main bean producing areas of Ecuador will eventually be sampled. To date attention has been focused on Imbabura province. Soils from 49 farms have been analyzed, with soil zinc and manganese levels below deficiency levels in 65-70 percent of them. Iron is also likely to be limiting in some 35 percent of soils. In an earlier study undertaken by the Cornell group, 83 percent of the farmers in this region reported the use of foliar- rather than soil-applied fertilizers. Most, but not all, foliar preparations contained micronutrients. We may have to give this problem more attention than anticipated.

   As part of the same study, most probable number counts of rhizobia in soil have been made. Most soils had more than 10^4 rhizobia per g of soil, a level at which indigenous organisms are sure to interfere with nodulation by

inoculant rhizobia. A dot-blot serological method was developed to type the indigenous organisms and to select from among them a common serogroup to be used in the evaluation of cultivars for host restriction of nodulation.

2. Cultivar evaluation for traits affecting N_2 fixation: Studies on cultivar variation in traits affecting nodulation and nitrogen fixation have been initiated. Traits being considered include speed in nodulation, nodulation efficiency, nodule duration and activity, phosphorus use efficiency and tolerance to low pH. Ninety cultivars, including a number previously identified as active in N_2 fixation, have been evaluated for earliness in nodulation. Superior lines have included N80014 (MSU), 21-58 (UWI), Preto 143 (Brazil) and Negro Argel. Preto 143 is of particular interest because of its known tolerance to acid soil conditions. A similar number of cultivars have been evaluated for growth at low soil phosphorus using the aluminum phosphate/sand system of Gabelman and co-workers. A breeding program to combine traits contributing to enhanced N_2 fixation with sources of disease resistance will initiated in 1991.

3. "Competition" for nodulation sites in *Phaseolus* beans: In soils with abundant indigenous rhizobia, inoculant strains rarely produce more than 5-10 percent of the nodules, and yield response to inoculation is uncommon. This has been perceived as a problem of "competition for nodulation sites" between the inoculant strain(s) and less effective soil organisms. However, in studies with soybean we have shown that the inoculant strains are quite competitive for nodulation sites at the crown of the plant but are immobile in soil and so produce very few nodules on lateral roots. These studies are being repeated for *Phaseolus* in Ecuador. From preliminary data it appears that N_2 fixation supplies from 37-41 percent of overall plant nitrogen needs, but that indigenous strains do limit inoculant strain response. A number of bean rhizobia have been selected for enhanced competitive performance, speed in nodulation and efficiency in N_2 fixation. We must also enhance the duration of crown nodules and develop methodologies for greater lateral root nodulation.

4. Acid-pH tolerance in Rhizobium: In studies initiated in 1983, the PI had sought bean cultivars and rhizobia capable of persistence and nodulation in acid soils. As part of this study, six uniquely acid-tolerant bean rhizobia were identified. All were markedly different to previously studied bean strains. Studies to clone the pH tolerance genes from these organisms are underway; we have also induced pH "shock" proteins and are studying host-strain interaction at acid pH.

As with the other CRSP programs, collaboration and training are integral parts of the project. Students from Colombia, Ecuador, Uganda and the U.S. have initiated studies in the PI's laboratory; a post doctoral fellow has been stationed at INIAP where he will help in the selection and in-country training of recent graduates. Contacts have been established with CIAT personnel and with the Tanzania project.

Question and Answer period: ECUADOR

Q: Do acid-tolerant bean rhizobia give better responses to inoculation under acid conditions in the field?

A: In two studies where low pH was the major factor limiting nodulation and N_2 fixation, use of acid-tolerant strains permitted good yield response to inoculation. We would recommend use of such strains under acid conditions in the field.

Q: Is nitrogen fixation quantitatively inherited?

A: We assume that this trait is quantitatively inherited, however, Bliss has shown that significant gains in nitrogen fixation can be obtained without recourse to recurrent selection programs.

Q: Is competition from native soil strains likely to be important in Ecuador?

A: We have only preliminary results but they suggest that most soils have indigenous bean rhizobia, and that these can limit response to inoculation.

GUATEMALA/CORNELL UNIVERSITY/ICTA
Donald H. Wallace and Raphael Rodriguez

Physiological, Genetic and Agronomic Aspects of Bean Adaptation and Yield

Presenters: D. H. Wallace and Raphael Rodriguez

For each different geographical site, yield system analysis of ongoing yield trials can raise efficiency of improving genetic adaptation and yield potential. This can maximize regional and worldwide yields. Within each ongoing yield trial, yield system analysis identifies the genotypes having superiority for each of the major physiological components of yield. These superior genotypes will represent the alternative pathways to yield discussed in the next three paragraphs. Intercrossing these superior genotypes selectively places the large, site-adapted genetic variability needed for yield improvement into the also needed common gene pool.

The proposed increased breeding efficiency is based on evidence that the three major components (total biomass accumulation, harvest index, and the time a cultivar requires to develop to harvest maturity) are simultaneously controlled by partitioning of the available photosynthate. In turn, the partitioning is controlled by maturity genes.

One pathway to yield is partitioning the larger proportion of the photosynthate to existing organs of yield (flower buds, pods and seeds). This reduces the time to harvest maturity, because these organs grow rapidly and therefore develop (flower and mature) in a short time. The early maturity is reinforced through the correlated restriction of continued vegetative growth, which will be supported only by the small proportion of the photosynthate not partitioned to the re-productive organs. The high daily rate of yield accumulation combined with the also correlated high harvest index will give high yield for short growing seasons. Earlier maturity and its correlated higher yield per day will maximize yield per growing season for sites with long growing seasons, if there can be change from one to two successive plantings. Bean farmers of highland Guatemala are beginning to do this.

Alternatively, high yield can come from the increased biomass accumulation that results from partitioning predominantly to continued vegetative growth. This will increase the node number (potential sites for yield) and leaf area (photosynthetic capacity), in correlation with the longer growth duration. The lower rate of yield accumulation will be compensated by the longer growth duration, if the growing season is long enough.

For both short and long growing seasons, yields will be yet higher if the genotype provides a high daily rate of biomass accumulation.

High yield is selected for at all geographical sites. Development to harvest maturity varies between 80 and 270 days for bean cultivars at different geographical sites. We have shown that partitioning and the consequent rate of development and correlated time to maturity can be strongly controlled by a single photoperiod gene. A cultivar may have a (control 1) genotype which is insensitive or moderately or highly responsive to (control 2) daylength. Progressively more sensitive genotypes will cause progressively larger delays of flowering and maturity as will progressively longer daylengths. With synergism

that is positively correlated with the combined effected by the genotype plus the daylength, a (control 3) higher mean temperature at the site will additionally enhance the level of activity of the photoperiod gene(s). This will further reduce the partitioning to the yield organs and further delay flowering and maturity. Supporting this, yield system analysis across 52 geographically dispersed yield trials indicated, with 0.0001 statistical probability of error, that harvest index (partitioning) is negatively correlated with days to maturity. The higher temperature also (and simultaneously) accelerated (control 4) the rate of node development, i.e. decreased the days needed to develop a node and thereby tended to cause earlier flowering. This effect by temperature is acceleration of the rate of vegetative growth and development. The accelerated rate of node production due to higher temperature will tend to reduce the days to flowering and maturity. Therefore, the extent to which a higher mean temperature will lengthen or, alternatively, will shorten the time required to develop to flowering depends on the larger of temperature's simultaneous but opposite effects: a) through delayed reproductive development vs. b) through more rapid vegetative development. For each combination of genotype and daylength, there is an optimum temperature, at which the opposite effects exactly cancel. This optimum temperature results in the most rapid reproductive development, i.e. the fewest days to flowering. At temperatures below this optimum, changes of days to flowering by temperature are largest through vegetative development. The changes are largest through reproductive development at temperatures above the optimum for flowering. Other classes of maturity genes also interact. These genes alter partitioning and days to flowering and maturity by determining (control 5) the number of nodes on the plant shoots, (control 6) the minimal node to flowering, and (control 7), specific gene(s) may exist which give major control over the rate of node development.

As predicted by the above, biological causes of correlations among biomass, partitioning and maturity, selection in the past for only yield has raised yield primarily by causing a larger proportion of the biomass to be partitioned to the yield. This occurs because as few as 10 to 12 maturity genes, some with multiple alleles, control the time to maturity (cultivar adaptation). These few maturity genes join with the thousands of other genes in controlling total biomass accumulation. Control by few genes gives maturity much higher heritability than is given to biomass accumulation through its control by many genes. Selection for only harvest index (partitioning) will lead to early maturity accompanied by correlated tendency toward lower yield. This can be corrected by simultaneous selection for later maturity and/or higher aerial biomass. Selection for only larger biomass will lead to late maturity plus correlated reduction of harvest index and yield but can be compensated by simultaneous selection for earliness and/or rate of biomass accumulation. <u>The conclusion is that efficient improvement of genetic potential for yield requires simultaneous selection pressure on all three of yield's major components: the rate of biomass accumulation, the partitioning rate and the time required to develop to harvest maturity.</u>

For each geographical site, the complex, multiple-trait, maturity genotype interacts with the daylength and the temperature to establish the "adapted" range of the continuum of partitioning predominantly to continued vegetative growth vs. partitioning predominantly to continued reproductive growth. This partitioning controls the rate of yield accumulation vs. the rate of total biomass accumulation and their combined effects on adaptation, maturity and yield. These effects on yield interact with a final influence by the actualized duration of the growing season. For plantings at a repeated time of year, daylength is fixed and therefore tends to always cause the same effect on both yield and the length of

the growing season. Nevertheless, every site has a range of maturity that will give acceptable yield. The narrow to wide range depends on the variability of the mean temperature and/or of moisture availability within the growing season and upon the irregularity of the cessation(s) of plant growth which these environmental variabilities cause.

Temperate sites have wide variations of temperature, moisture and growing season duration. This causes the earlier cultivars of the "adapted" range to give the highest yields for some years, while the latest "adapted" cultivars yield most for other years. Tropical sites have more repeatable mean temperature. With irrigation, therefore, they have higher potential for effective selection for yield during the early segregating generations after a cross.

A major constraint to breeding for higher yield has been inability to quantify genotype x environment interaction effects on yield. The largest physiological genetic causes of this interaction are described above. Quantification of this genotype x environment interaction, determining the yield potential of cultivars, and establishing true relationships of yield with its physiological-genetic components all require yield trials of multiple genotypes grown across multiple site-seasons. A new statistical procedure called AMMI analysis quantifies the genotype x environment interaction effect caused by each genotype and by each environment. The procedure uses the measurement of the genotype- and environment-caused positive or negative deviation around the grand mean of all the data. The analyzed trait may be yield or a physiological component of yield. The larger the number of genotypes tested, and especially the number of environments, the more accurately the mean of the genotype and the deviations from the grand mean will be measured.

Yield system analysis of each yield trial identifies the physiological genetic components of yield and demonstrates that the genotypes are adapted to the site-season's environment. Yield system analysis across multiple site-seasons combined with AMMI analysis will provide advancement, by each yield trial, of understanding of the complex yield system. It will quantify the genotype x environment interaction. It will also support mathematical modeling of plant development and yield and its application to breeding and crop production practices. Collaborative research on yield will be facilitated among agronomists, horticulturalists, breeders, geneticists, physiologists and biotechnologists. The theoretical basis is described above. Its application via yield system analysis has been described. The theoretical basis, yield system analysis and AMMI analysis can stimulate interdisciplinary and regional collaboration on yield research of beans and most other crops.

The delay in days to flowering is caused by the sensitive allele of a single photoperiod gene. This gene largely controls the difference in days to flowering and adaptation between two Guatemalan cultivars. Photoperiod gene activity was indicated by late flowering under 16 hour daylength in a greenhouse in New York, compared against earlier flowering for this genotype in 12 hour daylength. Also shown, the 29°C temperature of a Guatemalan lowland site delayed flowering by this photoperiod sensitive genotype. AMMI analysis showed that the photoperiod gene activity caused the mean days to flowering to increase in correlation with increasingly positive deviation from the grand mean days to flowering. The 29°C of the Guatemalan lowland site caused positive deviation like the long daylength. The 19°C of the Guatemalan highland site caused negative deviation like the short daylength.

Control of early vs. late flowering by other classes of maturity genes does not cause correlation between the progeny mean and the deviation from the grand mean. Both the early and the late genotype expressed the full range of deviation around the grand mean. Another difference was that the 16 hour daylength did not cause positive deviation above the grand mean days to flowering, but caused negative deviation like that for the 19° temperature.

During the 1990 and 1991 growing seasons, the F_8 progenies that are homozygous for the different classes of maturity genes will be grown at low, intermediate and high temperature Guatemalan sites. The data will be subjected to yield analysis followed by AMMI analysis. This will reveal the effect of mean temperature on the rates and durations of aerial biomass accumulation and its partitioning and the correlated developmental times to flowering and maturity. Research is underway to find molecular markers on the same chromosomes as the different maturity genes. This will facilitate selection for maturity genotype using seedlings, rather than having to grow the plants to flowering and maturity.

Question and Answer period: GUATEMALA

Q: Sampling aerial biomass may be too expensive for our breeding program. How much do we sacrifice by not measuring this trait?

A: You cannot estimate total biomass, biomass/day or harvest index without measuring aerial biomass. There may be a line which produces a large amount of biomass but has poor yield. We need to work with physiologists to better understand how high biological yield can be converted to economic yield.

Q: Did you state that "growth habit" was controlled by maturity genes?

A: Yes, in a sense. The 10-15 genes that control harvest index have a great influence on the economic yield and adaptation of a genotype. Selection only for harvest index, however, may result in earlier maturity and lower yield potential. High harvest index lines are often more sensitive to stress environments.

Q: How much can be achieved by selecting for enhanced biomass/day?

A: The yield system analysis (YSA) is new. Therefore, the value of this approach has not been determined.

Q: Can YSA method be used for cowpeas?

A: Yes, the approach should be useful for all grain legumes.

HONDURAS/UNIVERSITY OF PUERTO RICO/EAP
James S. Beaver and Juan Carlos Rosas

Improvement of Bean Production in Honduras Through Breeding for Multiple Disease Resistance

Presenters: James S. Beaver and Juan Carlos Rosas

Several diseases limit the productivity of beans in Honduras. Results from field trials conducted at the Escuela Agricola Panamericana (EAP) found both rust and anthracnose to significantly reduce the yield of susceptible genotypes. Many of the small red varieties currently planted in Honduras are also susceptible to bean common mosaic virus (BCMV). During the "primera" growing season common blight can reduce both the yield and quality of beans. Since seed from the "primera" season is usually used to plant the "segunda" crop, seed transmission of common blight often occurs. During the 1989 growing season bean golden mosaic virus (BGMV) infected several thousand hectares of beans in Honduras. Consequently, 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. The principal objective of the project is to identify and incorporate genes for disease resistance into bean genotypes having seed types that are acceptable to the Honduran consumer. Due to the great amount of variability in virulence among indigenous bean rust isolates, Honduras provides an ideal environment for studying the life cycle and epidemiology of this important disease. The project also strives to strengthen the bean research programs of the EAP and the Ministry of Natural Resources (MNR).

Small red breeding lines with resistance to one or more of the most important diseases have been developed or identified. Thus, the first step toward the development of small red bean varieties with multiple disease resistance has been accomplished. Small red lines having both the "I" and "bc_3" genes for resistance to BCMV have been developed by the project. These breeding lines are resistant to all known strains of BCMV. All available sources specific of resistance to bean rust have proven to be susceptible to the races present in Honduras. However, results from field trials have found bean genotypes having dense pubescence on the abaxial surface of the leaves to have less rust infection than glabrous genotypes. Small red bean lines having dense leaf pubescence have been developed by the project using Dominican red mottled genotypes as the source of the dense pubescence. Anthracnose resistance has been identified in the recently released small red variety "Cathrachita" and in breeding lines HND30-40 and EAP12-88.

Moderate levels of resistance to common blight are found in breeding lines EAP10-88 and UPR64-1. Small red lines have also been selected from populations derived from crosses with BAC6. These lines will be screened for reduced seed transmission of *Xanthomonas campestris* pv. phaseoli. Small red lines DOR364 and DOR391 have proven to be moderately resistant to BGMV in Honduras. These lines have been used as parents in the breeding program. In addition, seed of DOR364 has been increased at the EAP in the event that the incidence of BGMV continues to increase. The performance of promising small red breeding lines produced by the project are tested on farms in Honduras by the MNR. Elite small red lines developed by the project are also included as entries in the CIAT coordinated VIDAC nursery which is conducted in several Central American countries.

Bean germplasm continues to be screened for additional sources of resistance and for other useful agronomic traits. Honduran landrace varieties have proven to be a very useful source of early maturity for indeterminate beans. In Honduras, early maturity helps to avoid disease, drought and low market prices. Results from inheritance studies indicate that selection for earlier maturity would be most effective in replicated, advanced generation nurseries. These studies also produced breeding lines with longer reproductive periods by combining earlier flowering with later harvest maturity. Field experiments are currently being conducted to determine the relationship between the length of the reproductive period and yield. Screening for common blight resistance during the summer months has also resulted in the identification of small red breeding lines that yield well under the hot and humid conditions that prevail during that growing season. Greater levels of heat tolerance would permit more bean production in the lower altitude valleys in Honduras and other Central American countries where agriculture would be more sustainable. Studies are presently underway to estimate the heritability of this trait.

A method for extraction of high molecular weight genomic DNA from rust spores has been developed. The extracted DNA was used for Restriction Fragment Length Polymorphism (RFLP) comparisons among seven single pustule isolates selected on the basis of virulence. These isolates represent rust populations from the U.S., Honduras and the Dominican Republic. Differences in hybridization bands among the different isolates have been observed. These preliminary results indicate that this technique may offer a unique method for studying the relationship among rust races and for facilitating the identification of virulence patterns.

Training is provided by both the U.S. and HC institutions. At present, the project provides support for an agronomist from the MNR to pursue an M.S. degree in plant breeding and genetics at the University of Puerto Rico. The University of Nebraska provides training in research techniques for working with bean rust. At the EAP, "Ing. Agrónomo" thesis research projects related to bean breeding and pathology are supported by the project. Informal training in bean research techniques is also provided to the MNR agronomist stationed at the EAP.

During the next extension period the project will concentrate on combining the different disease resistances that now exist in small red breeding lines. Particular emphasis will be placed on seed-borne diseases such as BCMV, common blight and anthracnose since most farmers in Honduras continue to grow their own seed. Screening for BCMV resistance will be conducted in the screenhouse in Puerto Rico using the appropriate strains of BCMV. Breeding lines will be screened for field reaction to common blight, rust, anthracnose and BGMV in nurseries planted during seasons when particular diseases are prevalent. Since many of the crosses will be between adapted small red genotypes, the likelihood of releasing small red varieties with multiple disease resistance should be good. However, it will be necessary to remain vigilant of interactions which may result when different sources of resistance are combined. Germplasm will be screened for resistance to BGMV and common blight since only moderate levels of resistance for these diseases are present in small red beans. The project will continue to collaborate with CIAT in conducting nurseries for rust, common blight and BGMV. Evaluation of the EAP bean germplasm collection will be supported by the Bean /Cowpea CRSP project and the International Board of Plant Genetic Resources (IBPGR). Researchers at the EAP have gained experience using the congruity backcross method to transfer drought tolerance from tepary beans to common beans. A similar approach will be used to transfer high levels of resistance to common blight and heat tolerance from tepary beans that were selected from field trials that were conducted during the summer in Puerto Rico.

Question and Answer period: HONDURAS

Q: Why not use determinate growth habit if you wish to develop early maturity beans?

A: (1) Farmers in Honduras often grow beans in association with corn. Indeterminate habit is more appropriate for this cropping system. (2) Very good sources of earliness are available in indeterminate "Criollo" lines. (3) Research has found determinate growth habit more sensitive to stress and less stable in yield than indeterminate growth habit.

Q: Are the common blight strains in Honduras and Puerto Rico the same?

A: Probably not. Initial screening was conducted in Puerto Rico to select lines with moderate levels of resistance. However, the lines are sent to Honduras as soon as possible in order to expose them to the indigenous strains of *Xanthomonas campestris*.

Q: Could you provide more details concerning the RFLPs of the single spore isolates of rust?

A: The research is in the initial stages. High molecular weight DNA has been isolated from single pustule isolates of rust. We will attempt to relate variability in RFLPs with virulence patterns.

Q: Could the project use more help with white fly research?

A: Yes, there are entomologists at UPR with experience with white fly who have provided assistance to us. A better understanding of the white fly and natural enemies is needed to develop more effective management techniques. Incidence of bean golden mosaic was reduced in the DR by a two-month fallow period of host crops. The reduction was attributed to a decrease in the white fly populations.

Q: In your heterogeneous mixtures, how can you insure that the mixtures are genetically diverse? Any evidence of transgressive segregation?

A: We plan to maintain records of pedigrees to insure that different parents are used. The only transgressive segregation observed has been with reproductive period (RP) where the RP of the progeny have exceeded the RP of the parents.

Q: What do farmers do to control diseases?

A: The farmers plant early varieties to avoid disease. There is some evidence from Africa that intercropping with corn helps to reduce the incidence of foliar fungal pathogens such as rust and angular leaf spot. Many of the pathogens in Honduras are seed-borne. If we could improve the resistance to the seed-borne pathogens, the incidence of disease could be reduced.

Q: What is the status of your work in Jamaica?

A: Research is supported by Jamaican Agricultural Research Foundation. The goal of the project is to improve disease resistance and biological nitrogen fixation of Jamaican red beans. The first year of research has been initiated. We look forward to a more formal relationship with the Bean/Cowpea CRSP.

INCAP/WASHINGTON STATE UNIVERSITY/INCAP
Barry G. Swanson and Ricardo Bressani

Improved Biological Utilization and Acceptability of Dry Beans

Presenters: George Hosfield, Ricardo Bressani and Barry Swanson

Genetic Improvement:

The genetic control of tannin and protein content, cookability and tactile and visual culinary quality traits of dry beans is quantitative in nature, implying that small effects of several genes are involved in inheritance and that the environment strongly influences the food quality of dry bean cultivars and breeding lines. The predominant genetic cause of variability for the nutritional and quality traits in breeding populations was the existence of genes with partial to completely dominant expression acting in an additive fashion, i.e., responding linearly to an increase in the number of active genes affecting trait expression. Some genetic strains of beans lost up to 3 percent reserve protein during preparation for consumption while others showed no protein loss during soaking and cooking. Variation among genotypes for protein retention is of particular interest because it indicates that consideration other than the original protein content is important when beans are used in human diets. Recurrent selection which seeks to concentrate favorable alleles in a population may effectively improve the food quality of beans through breeding.

"Calima" beans, when cooked as a pure line, reduced firewood needs of Rwandan small farmholders by 16 percent compared to the fuelwood required to cook traditional mixtures. Extrapolation of the bean cooking results indicated that the adoption of fast-cooking bean cultivars in diets of 50 percent of Rwandans will save 76,000 tons of wood annually. Although significant firewood and labor savings accrued with the use of fast-cooking beans, Rwandan women preferred mixing the fast-cooking genotypes with traditional types that are slower cooking thus negating some of the benefit. The use of the haybasket cooker reduced firewood needed for cooking beans by 40 percent compared to the traditional open fire cooking method. Projected fuelwood savings using the haybasket at a 50 percent adoption rate was 173.3 thousand tons. A 2 percent increase in family income may also occur due to labor savings with the haybasket. Current annual household income in Rwanda is 55,000 Rwandan francs or $550.

Nutritional Quality:

For many people in developing countries, beans constitute the most important complementary source of protein to maize and other cereal grains. The nutritional quality of beans is of significant importance. The main constraints limiting consumption and nutritional quality of beans are acceptability characteristics, cooking time being perhaps the most important; protein quality, since protein digestibility is relatively low compared to protein from animal products; and antiphysiological factors including tannins, lectins and enzyme inhibitors that may not be eliminated by cooking. These factors limit bean consumption by people, consumption which could be increased if common beans were used in more acceptable and convenient food products. The reasons for the low protein digestibility are being investigated; seed coat, dietary fiber and tannins decrease protein digestibility. Reduced protein digestibility is extended to complementary bean cereal diets as well. Bean seed coats contribute great

concentrations of dietary fiber and tannins. During cooking or processing, dietary fiber binds irreversibly 9-12 percent protein unavailable to the consumer. Tannins may bind dry bean proteins or inhibit gastric proteolytic enzymes. A number of acceptable food products have been developed using beans including high protein dried powder soups, chili beans with texturized soy protein and cereal-bean-vegetable mixtures with improved nutritional value.

Protein Digestibility:

The resistance of native legume proteins to proteolysis by mammalian digestive enzymes contributes to the poor nutritive value of dry bean proteins. Attention is focused on phaseolin, the major storage protein of dry beans (*Phaseolus vulgaris*). While heated phaseolin is susceptible to proteolysis, native phaseolin has been shown to be largely resistant to hydrolysis of trypsin, chymotrypsin and pepsin. Theories proposed for resistance to proteolysis include compact structure, stability and steric hindrance imparted by protein glycosylation. There are a number of factors which suggest that *in vitro* enzymatic hydrolysis of legume proteins may not be expected to correspond to *in vivo* hydrolysis. The binding of starch with protein is an important consideration for *in vitro* assays but is unlikely to be important for *in vivo* assays. Although supplementation with sulfur-amino acids improves legume protein quality, limiting methionine and cysteine concentrations will not normally be a problem since legumes are often utilized in conjunction with animal or cereal proteins.

The deficiency of sulfur amino acids alone is not the only factor which limits the nutritive value of cooked legumes. The interaction of proteins and procyanidins increases polymerization of procyanidins occurring during soaking and heating of dry beans. As procyanidin polymerization increases, the interaction of proteins and procyanidins becomes irreversible and results in reduced protein quality. Recent evidence suggests procyanidin interaction with proteins may be hindered considerably by polysaccharides present in storage tissues.

Question and Answer period: INCAP

Q: Do white beans exhibit greater digestibility than colored beans?

A: White beans contain few or no procyanidins, yet the digestibility is not always better than the digestibility of colored beans. The digestibility of proteins in white beans is poor.

Q: How was gas volume related to bean digestibility?

A: Bean flour was used as the substrate. Pig feces isolates were used as the inoculum, and volumes were assessed by water replacement.

Q: Do lectins in beans play a role in nutritional quality?

A: Comprehensive studies have isolated and characterized lectins in beans. Currently, none of the isolated lectins are heat stable, so lectins are destroyed by cooking. Lectins are peptides containing quality amino acids, so denatured lectins add protein quality to beans.

Q: How does the INCAP project interface genetics and food technology?

A: George Hosfield is proposing research with single genes in model systems to characterize the contribution to food quality. It is essential to conduct food quality assays with "standard" and "known" cultivars as lines of beans. Beans with known histories are necessary to conduct storage, processing, and food preparation studies of consequence and reproducibility.

The INCAP project has led the way for collaboration utilizing "standard" cultivars in breeding studies and related food quality studies. The project has published numerous methods of value for the assessment of bean quality and acceptability. The project is completing a manual that will describe analytical methods to assess bean constituents, quality and acceptability. The INCAP team believes that the food science component of the Bean/Cowpea CRSP has set an example for the integration of breeding and biochemistry as well as using other interdisciplinary and collaborative studies.

MALAWI/MICHIGAN STATE UNIVERSITY/BUNDA COLLEGE
M. Wayne Adams (Acting PI) and A. B. C. Mkandawire

Biological and Socio-Cultural Parameters of Bean Improvement and Host/Pathogen Co-Adaptation in Malawi, a Secondary Center of Diversity

Presenters: Anne Ferguson and A. B. C. Mkandawire

Project Objectives--The primary objective of this second phase of the genetic diversity project is to assist the Malawian National Bean Program in developing improved bean varieties (and/or mixtures) and production technology. The secondary objective is to study host-pathogen specialization with respect to two important diseases: anthracnose (ANTH) caused by *Colletotrichum lindemuthianum* and angular leaf spot (ALS) caused by *Phaeoisariopsis griseola*. Both objectives involve biological and socio-cultural research.

Ongoing Research:

Socio-cultural surveys of bean production practices and preferences were carried out in the Northern, Central and Southern Regions of Malawi. These surveys gathered information on regional preferences in seed types and data on preferred varieties and cultural practices among different groups of smallholders. The survey results are used in the National Bean Improvement Program. They provide a basis on which to make decisions regarding seed types and traits selected for improvement efforts and allow crop improvement efforts to be directed toward the needs of specific vulnerable groups.

One outgrowth of the collaboration between biological and social scientists has been the development of a breeding strategy suitable for use in areas of the world such as Malawi where farmers grow beans as intravarietal mixtures. Termed component breeding, this strategy is being employed in the Malawian National Bean Improvement Program and considered for use in other bean programs in eastern and southern Africa.

In conjunction with the Adaptive Research Unit in the Ministry of Agriculture, efforts are currently underway in Malawi to develop a system of bean varietal testing and release that involves farmers in all stages of the research process. Efforts are also being made to develop a system of seed multiplication for use in Malawi.

Germplasm screening: Disease resistance--entries from the Malawian national germplasm collection comprising preferred seed types and lines resistant to halo blight (*Pseudomonas syringae* pv. *phaseolicola*) are evaluated for resistance to ALS and ANTH under natural infection in field nurseries. Twenty-two indigenous accessions were challenged by two virulent isolates of ALS in controlled inoculation tests.

Drought resistance--entries in irrigated, rain-fed and imposed drought tests, the latter timed at flowering or at seed-fill, included released varieties and breeding lines from South America, North America, South Africa and Malawi. Tests are conducted during the dry and rainy seasons and at the end of the rainy season to exploit diminishing residual moisture. Root and shoot biomass and seed yield and its components are measured.

Insect resistance--cultivars, local accessions and breeding lines are evaluated at Bunda College under natural infestations in the field. The most prevalent pests are the bean fly (*Ophiomyia* spp.), a chrysomelid and the bean beetle (*Ootheca* spp.). A total of 23 lines were screened for reaction to the bean fly, 17 of which were CIAT accessions reported to be resistant or tolerant, and six local agronomically superior selections. Early planted beans had lower adult populations. CIAT entries were most attractive to adult insects, but larval and pupal counts were relatively low. Malawi lines were generally intermediate in terms of numbers of adult flies.

Variety performance tests--the tests for grain yield were conducted at five sites throughout Malawi during the rainy period, and included eleven entries comprised of introductions, landrace selections, hybrid materials and one check variety, Nasaka.

Evaluation of intercropping systems--planting pattern tests have been carried out with both bush and climbing types. Tests were conducted at four sites with bean varieties and maize types grown singly and in association. Yield and yield components data were recorded and main and interaction effects determined.

Host/pathogen co-evolution studies--plant pathogens were sampled to determine patterns of variability and racial identity. Samples of ALS were collected from plant tissue of beans growing in the Southern Region during the rainy season. A total of 130 strains were isolated in the plant pathology laboratory at Bunda College as single spores and subsequently multiplied in culture. These 130 cultures have now been received at MSU for isozyme analysis. The cultures retained at Bunda have been race-typed using a set of ten differentials that were multiplied under irrigation at Bunda in 1989. Seeds of plants sampled for ALS were collected to establish gene-pool identity.

Isozyme and dwarf-lethal studies--isozyme analysis of 130 ALS isolates are being carried out on hyphal extracts of colonies maintained on artificial media in the laboratory at Michigan State. The isozymes are electrophoresed on horizontal starch gels. The resulting zymo-patterns will be correlated with the gene pool identity of the host plant from which each ALS isolate was taken to test the hypothesis of co-evolution. At Bunda, the virulence tests on bean gene-pool differentials will have provided data with which to support or refute the hypothesis.

In addition, a total of 675 bean accessions from the areas of Lilongwe and Dedza (Malawi) are being crossed with two cultivars of known dwarf-lethal genotype, Sierra pinto (DL_1) and Montcalm kidney (DL_2) to determine the distribution of dwarf-lethal genes in the Malawian bean gene pools.

Mitochondrial DNA RFLP analysis--mt DNA was isolated from 10 to 21 day old seedlings of 23 bean genotypes (20 from Malawi landraces, differing in "genetic distance," seed characteristics, isozyme patterns and in phaseolin patterns and three representing standard Andean and Meso-American gene-pools). The mt DNAs were digested with eight restriction endonucleoses and the fragments separated by horizontal electrophoresis in agarase gels of varying percentages. After photographing, the restriction fragments were transferred to nylon hybridization membranes where, after baking or UV crosslinking, the membranes were consecutively hybridized to three or four different probes comprising random DNA sequences of the bean mt genome.

Significant Results:

Training--Five Malawians have received graduate degrees under CRSP auspices and have returned to Bunda College, thus placing Malawi in a strong position to carry out research on beans--the major source of protein for the population. U.S. students have also received training in international agricultural research, strengthening the U.S.'s ability to conduct research in this area.

Understanding of the complex array of socio-cultural and biological factors which underpin genetic diversity in Malawian bean landraces--Studies of the social and biological social factors accounting for genetic diversity in Malawian beans were a major thrust of the first eight years of project research. Numerous presentations and publications have resulted from these studies and this information is being used in the current bean improvement program as a basis for selection of varieties for improvement purposes.

Isozyme studies in Malawian bean landraces--Studies involving 375 landrace components revealed two principal patterns of variability and several mixed patterns. The two main patterns were perfectly correlated with seed size and phaseolin type indicating these alternative allelic state patterns were gene-pool specific. This in itself was a surprising outcome for several reasons. The mixed patterns are the result of gene pool recombination, another surprise in view of the known hybrid sub- or in- viability of inter-gene pool crosses.

Diversity in Malawian beans using mitochondrial DNA cut with restriction endonucleases--This work has shown that the mt genomes of Andean and Central American gene pools are distinct from each other. Two large-seeded U.S. cultivars, however, do not follow this pattern, being comprised of mt genomes that show predominantly Central American RFLP characteristics.

Germplasm collection--Bean landraces have been collected from all major bean growing regions in Malawi. These landrace accessions are maintained at Bunda College (with duplicates at CIAT and Pullman, Washington) and are being grown out and characterized. Representing a wide range of preferred seed types, these landraces serve as a basis for the Bean Program's crop improvement efforts.

Varietal releases--The Malawian National Bean Program is in the final stages of testing four new bean varieties (three dry bean cultivars and one snap bean cultivar) for release purposes. These varieties are being tested at research sites throughout the country.

Question and Answer period: MALAWI

The seed multiplication and distribution issue, as in Tanzania, was raised. Companies will not make money on beans since farmers (small landholders) keep seed for a number of years. The artisan system is being advocated by CIAT and may be useful for CRSP projects.

A discussion of component breeding problems indicated the difficulty for the government in seed multiplication, testing and release of numerous lines. Thus, if components with genetic diversity are created as a strategy that by bulking earlier heterozygous lines (say at F_5) some diversity can be created. Outcrossing rates of 1 percent are common in Malawi--but if lines with higher outcrossing rates can be found, it was suggested that this could diversify the breeding lines. Thus, landrace cultivars with improved characteristics could be released. Further discussion on component selection raised the issue of whether landrace evolution was actually occurring. Since socio-cultural studies have highlighted the selection process made by the farmer, evolution (or co-evolution of host [pathogen] is not the only processing going on).

A question was raised on whether bush or climbing types were targeted in the project. It was stated that both types will be considered in the CRSP as it will be for the CIAT breeding program.

Farmer priorities did not have diseases/pests ranked high and this did not seem to match project priorities. The explanation to this is that farmer perceptions of yield (highest rank) have pest and disease impact mixed with total yield. A study should be done on evaluating farmer perception of disease/pest problems.

MEXICO/MICHIGAN STATE UNIVERSITY/INIFAP
Dale Harpstead and Jorge Acosta Gallegos

Improving Resistance to Environmental Stress in Beans Through Genetic Selection for Carbohydrate Partitioning

Presenters: Dale Harpstead, Eunice Foster and Jorge Acosta Gallegos

This project can be characterized as a coordinated, multifaceted effort which includes both basic and applied research. It has been designed to identify new genetic resources for drought resistance, evaluate physiological plant responses to moisture stress and to incorporate favorable plant responses into commercially acceptable varieties for the central highlands of Mexico. This is being accomplished through close coordination between field and laboratory activities in Mexico and Michigan.

Drought resistance in edible dry beans, as in other fast growing annual crops, is the product of favorable plant growth patterns, compensatory plant physiological responses, and morphological features which maximize water use efficiency. In most cases, these are directly or indirectly under genetic control. Progress has been made in the identification of superior drought resistant genotypes through extensive regional testing, utilization of induced moisture stress and the evaluation of relative growth rates. Rigorous elimination of drought susceptible genotypes coupled with aggressive genetic recombinations among selected genotypes has resulted in progress toward more acceptable varieties for commercial production albeit at a very slow rate.

Recurrent selection strategies result in continuing evaluation, plant selection, recombination and retesting procedures. In 1988 more than 2300 individual plants were selected for further testing. Seed of these was increased in a winter nursery in 1989 to be used in field plot tests in 1990. Special field nursery environments are maintained for selection against stresses caused by root rots and various foliar disease organisms.

To efficiently direct plant breeding approaches toward higher levels of drought resistance, it is necessary to have the capacity to recognize essential plant response characteristics independent of associated confounding of plant growth factors and/or environmental interactions. To achieve these goals, additional research has been directed toward basic plant physiology, storage and remobilization of photosynthate, and molecular marker patterns which could be used to describe the genetic complement of the desired plant types. Three broad categories of drought response in plants are recognized: escape, avoidance and tolerance. In an escape strategy, the life cycle of the plant is regulated to produce seed before the water supply is exhausted. Rapid growing, early maturing genotypes are the most common example of this strategy.

For bean production in the semiarid highlands of central Mexico, a drought-avoidance strategy is the principal plant breeding goal. An attempt is being made to identify a series of physiologic plant responses which operate independently or in concert to prevent or reduce the damaging effects of moisture stress. These include the maximizing of water uptake by deep and extensive root systems; minimizing water losses through stomatal control, leaf movements and leaf shedding; and cell sap osmotic adjustments which enhance short-term survival under conditions of water stress.

To identify more favorable drought avoidance responses additional emphasis is being placed on the utilization of selection indices developed in moisture-stressed and irrigated field plot environments which incorporate data from total biomass, root biomass, seed yield, maturity, N_2 fixation and growth habit measurements.

Drought tolerance in classical terms is associated with xerophytic vegetation.

Nitrogen is essential to plant growth and regrowth processes and has a high probability of involvement in plant adaptation to stress. Thus, extensive studies of nitrogen storage and remobilization have been made. In these studies, nitrogen becomes an invaluable tool inasmuch as it is vital and can be supplied to the plant as the stable isotope ^{15}N-urea which can be identified after it has been translocated and incorporated into various growth and storage organs of plants grown in controlled moisture environments.

Work is in progress to identify biochemical marker loci that can be associated with quantitative trait loci (QTLs) in drought resistant and drought susceptible bean genotypes. Isozyme marker characteristics of more than 25 INIAP drought-resistant bean genotypes and 15 drought-susceptible genotypes previously classified in the field in Mexico have been cataloged by starch gel electrophoresis. Distinct polymorphisms have been recorded for 10 of the 23 isozymes investigated. These are being further analyzed for environmental stability and heritability.

This project must consider more than grain yield per se. The market demands distinct classes of beans based on color, grain size, culinary characteristics, cooking time, etc. to name only a few. In addition, the farmers in Mexico are dependent upon bean forage for animal feed and require high levels of disease and insect resistance to protect the crop from other environmental hazards.

Future research plans call for: (1) the increased testing of genotypes identified in the recurrent selection programs, (2) increased use of selection indices, (3) evaluation of market and use acceptance of selected genotypes, (4) identification of plant chemical/physiological responses associated with drought resistance, (5) utilization of labeled nitrogen and carbon to monitor plant growth/regrowth characteristics and (6) the use of DNA analyses to complement isozyme markers to monitor drought response in selected genotypes.

Question and Answer period: MEXICO

Q: How will seed of improved varieties be produced and distributed in Mexico?

A: There are several mechanisms for seed production of improved varieties in Mexico. The national seed program maintains the basic varietal stocks and also markets seeds. Regional programs are becoming more active in bean seed production since significant regional preferences exist for bean varieties with specific color, seed size, maturity, culinary properties, etc. Regional research stations are increasing specific bean types for test marketing in their areas. The private sector also is an important factor in the bean seed market.

Q: Will seed be available outside of Mexico?

A: Mexico is an active participant in regional testing programs involving other countries and bean networks. Some discussions have actually taken place with the World Bank about producing seed in Mexico for distribution in other countries.

Q: Why is it so important to identify the specific physiological responses of genotypes in selection for drought resistance.

A: Rainfall patterns in the highland regions of cultural Mexico are highly variable. Even when early season rainfall is adequate, prolonged periods of drought (up to thirty days) are not uncommon during the growing season. Successful varieties must be able to survive these periods of moisture stress and resume growth when adequate moisture becomes available. Well-adapted varieties probably will have to employ more than one drought avoidance mechanism.

NIGERIA/UNIVERSITY OF GEORGIA/UNIVERSITY OF NIGERIA
Kay McWatters and Dickson Nnanyelugo

Appropriate Technology for Cowpea Preservation and Processing and a Study of Its Socio-Economic Impact on Rural Populations in Nigeria

Presenters: Kay McWatters, Dixon Phillips and Dickson Nnanyelugo

Milling Technology and Village Mill Installation:

Traditional wet decortication of cowpeas is time and labor intensive and produces wet seeds which must be converted to food within a few hours to avoid spoilage. The rationale of this project was to develop methodology for producing a ready-to-use flour for akara and moin-moin production. Abrasive dry milling gave low flour yields. Wetting cowpea seed to a moisture of ~25 percent followed by drying at temperatures of $\leq$ 70°C loosened the seed coat making it easy to remove by abrasive or gentle impact milling. Grinding through a 1.0 mm screen resulted in meal with excellent functional properties.

A small processing facility utilizing project milling technology has been assembled and installed at Ogbodu-Aba (near Nsukka). This village was chosen for its strong motivation and leadership. The mill building was erected largely by community effort. A heated forced-air batch dryer, seed cleaner, plastic steeping tanks, Engelberg rice dehuller, hammer mill, 3.5 kw generator, package sealer and weighing scales were provided by the project. Mill products include cowpea meal, cereal-cowpea flour blends and cowpea-based weaning food. A second village mill is located in Isiala Ngwa, Imo State, as part of a State Ministry of Health-AFRICARE Child Survival Project. This project features plots for demonstrating improved crop production, the mill which produces cowpea and maize meals as well as weaning foods, and a clinic which treats seriously malnourished children and trains mothers in nutrition and child health. Plans are being developed to "clone" this project at other locations in Imo State.

Processing/Storage Treatments Which Modify Cowpea Functionality and Nutrition:

Flatulence associated with cowpea consumption is attributed to the oligosaccharides. Germination at 25, 30 and 35°C for 12, 24, 48, and 72 hours reduced the oligosaccharide content, improved the nutritional quality and altered the functional properties of cowpea.

Cowpeas, like other legumes, develop the hard-to-cook (HTC) defect when stored at high temperature and relative humidity (RH), rendering the whole seeds uncookable, wasting fuel and compromising nutritional quality. Cowpea seeds were stored at 30, 37 and 44°C and 76, 85 and 97 percent RH for up to six weeks to investigate the reaction rate in development of the HTC defect. Accelerated storage at 37°C and 85 percent RH was also employed to produce HTC seeds for nutritional evaluation. Studies have confirmed the development of HTC at high temperature/high humidity conditions. The higher the temperature/humidity, the faster the rate of hardening. Seeds stored at -18°C or 30°C/33 percent RH did not change with time which indicates that low temperature/high humidity and high temperature/low humidity combinations can prevent development of HTC.

Cowpea Meal Products: Their Formulation and Functional/Sensory Evaluation:

Akara (fried cowpea paste) is a sensitive food system for evaluating effects of storage and process conditions on cowpea paste properties and end product quality. Under ideal conditions, cowpea paste should have good water absorption capacity, foam when whipped and have flow properties appropriate for dispensing and frying. These properties have been shown to be mainly protein-related. Storage, process and preparation conditions which produce cowpea meal and akara that compare favorably with traditionally-made products in functional, sensory and nutritional properties have been established. These conditions include storage of peas at cool (2°C) or mild (21°C) temperatures, use of moderate temperatures (50-90°C) for drying peas that have been pretreated for mechanical decortication, milling to a particle size distribution that concentrates 80-82 percent of meal particles in the 50-200 mesh range, and hydrating meal to a final paste moisture of 58-60 percent. Objective methods to characterize the texture and structure of cowpea products have also been developed and correlate well with sensory measures. Functional behavior of meal made from germinated seeds was satisfactory in preparation of akara. The flavor and texture of akara were slightly different from the ungerminated control but were not objectionable.

Nutritional and Microbiological Evaluation of Cowpea Products:

Akara made from experimental meal was evaluated for protein nutritional quality along with cowpea meal cooked by extrusion and kettle cooking/drum drying. Akara and extruded products had a significantly improved protein efficiency ratio compared to raw meal, but drum dried paste had reduced protein quality. Germination alone for 24 hour at 30°C or shorter germination at 25 or 30°C followed by incubation effectively reduced oligosaccharide content and flatulence potential of cowpeas. Germination increased thiamin, riboflavin and niacin content and improved protein digestibility of cowpeas. The mean *in vitro* protein digestibility of control cowpeas was significantly higher than that of HTC cowpeas. HTC cowpeas which were ground to flour prior to cooking as paste or by extrusion exhibited the greatest damage to protein quality. No effect on starch digestibility was detected. The nutritional quality of various blends of cowpea with cereals, animal protein and other legumes have been evaluated and shown to be acceptable.

The moisture content of cowpea seeds and meal is normally too low to support bacterial spoilage but may support growth of mycotoxigenic molds. Therefore, the potential exists for growth and production of aflatoxin by *A. flavus* and represents a health hazard. Higher quantities of aflatoxin were produced at 21 and 30°C than at 37°C on cowpea seeds, meal and onion-supplemented meal. Aflatoxin was formed at a_w as low as 0.89. Death rate of bacteria, yeasts and molds on cowpeas was more rapid at 35°C than at 2 or 21°C. Total microbial populations in cowpea paste collected from three Nigerian markets were high initially and increased after incubation. Coliform populations remained constant. Predominant bacteria consisted of *Enterobacter*, *Klebsiella* and *Lactobacillus* species; *Candida* species and *Aspergillus niger* were the predominant fungi. Sorption isotherms of various cowpea products were determined and will be useful in determining their storage stability.

Socio-Economic-Cultural Impact:

Consumption patterns, processing and storage problems and nutritional status of low-income families have been determined through surveys conducted in Nigeria.

Cowpea is consumed once a week or more by >98 percent of the respondents in rural and urban areas. Consumption is not influenced by family size, educational background, marital status or occupation. Usual forms of preparation include boiled seeds; moin-moin; akara; and mixes with yam or other tubers, rice and maize. Although as many as 96 percent of families use cowpea for infant feeding, anthropometric measurements of pre-school children showed that 13 percent were mildly malnourished. Cowpeas are inadequately stored in jute bags, tins, drums, plastic wares and earthen-ware pots. In one survey 49 percent of respondents in one survey use techniques such as camphor, pepper, ganmaline and ashes as preservatives. Processing of hydrated seeds is more often by manual than mechanical means. The major constraints on cowpea consumption are the hard-to-cook defect (42 percent of respondents), diarrhea (10 percent), indigestion (24 percent), constipation (16 percent), and dislike (8 percent). Although 99 percent of the respondents in one survey were unaware that new methods of preservation and processing of cowpeas are now available, they expressed a desire to learn and adopt these technologies.

Implications for Target Groups and Future Research Needs:

Increased cowpea consumption will improve nutritional status of Nigeria's rural and urban poor. New technologies will promote employment opportunities and increase and redistribute income. Village mills will serve as a catalyst to promote development. Cowpea-based foods, especially akara, represent potential channels for marketing cowpeas in the U.S. through institutional, fast food and supermarket sectors. Increased demand for cowpea would reverse the diminishing consumption of pulses and be an incentive for their increased production by American farmers.

The ongoing nutritional, sociological and economic impact of the CRSP village mills on villagers, especially women and children, should be evaluated over the next five years. Further research into the mechanism and importance of storage defects such as the HTC condition on reduced nutritional quality, increased fuel use and wasted cowpeas is needed. Effects of cultivar on milling technology and the functional and nutritional quality of resulting products need attention. Fermentation and germination for making new/improved cowpea products should be further investigated.

Planned Next Steps and Potential Linkages:

As this project is terminating on September 30, 1991, it will be necessary for the University of Nigeria team to seek a new source of support for pursuing the research needs mentioned above. The U.S. team has begun to seek an appropriate site for continuation of utilization research. Research needs in the new location will be identified during site visits in collaboration with scientists in those locations.

Question and Answer period: NIGERIA

Q: Would the microorganisms found in cowpea paste survive the frying process in preparation of akara?

A: This was not determined, but since the frying process is basically short-term steaming, it is assumed that spores and some vegetative cells would survive and present a potential health risk.

Q: Is aflatoxin produced on whole cowpea seeds and meal?

A: Cowpeas are not as good a substrate for aflatoxin production as corn, peanuts or rice. However, aflatoxin can be produced under certain conditions of temperature and relative humidity.

Q: Was there a problem of insect infestation during storage of cowpea meal?

A: No insect infestation of cowpea meal was observed under controlled storage conditions in the U.S. Long-term storage of cowpea meal is not anticipated and has not been studied under conditions in Nigeria.

Q: Has the problem of flatulence potential in cowpea weaning foods been addressed?

A: Data showing reduction of flatulence by decorticating, steaming and frying were collected from survey information and not from clinical studies. We believe that processes such as germination, decortication and cooking would eliminate problems associated with feeding cowpeas to infants.

Q: Has the project evaluated the milling effects of different cultivars?

A: Cultivar evaluation has not been the focus of this project up to this point. The object was to develop a successful technology using a type of cultivar already widely used and well accepted in Nigeria. We recognize the importance of examining the effects of various cultivars in the future.

Comment: There was a comment that this project should be working with the breeders.

Response: The project team believes in the importance of multidisciplinary research. However, we contend that the responsibility for initiating such cooperation lies as much with breeders as with food scientists. Further, we believe that research cooperation must begin with joint planning at the project's inception rather than as a request for analytical service later on.

SENEGAL/UNIVERSITY OF CALIFORNIA-RIVERSIDE/ISRA

A. E. Hall and Limamoulaye Cisse

A Program To Develop Improved Cowpea Cultivars, Management Methods, And Storage Practices For Semiarid Zones

Presenters: A. E. Hall and Limamoulaye Cisse

Cowpea is a subsistence food crop for families on small farms in semiarid zones of Africa, Asia and Latin America. In these semiarid zones, drought, heat, diseases and pests seriously limit cowpea production and storage. ISRA and UCR are collaborating in research to develop improved cowpea cultivars, management methods and storage practices for the semiarid zone in Senegal and other countries.

Developing Improved Cowpea Cultivars:

The overall strategy of collaboration and division of labor is that UCR has emphasized the physiology and genetics of breeding for tolerance to heat, adaptation to drought and yield potential, whereas ISRA has emphasized breeding cowpeas with resistance to bacterial blight, mosaic viruses, cowpea weevil, cowpea aphid and *Striga*. Effective cultivars for semiarid Africa would need most of these characteristics, and this requires an integration of breeding activities in the U.S. and Africa.

Heat tolerance: UCR has developed a model for heat tolerance based upon the observation that high temperatures can damage different stages of development during the reproductive period (Dh). The critical stages where cowpea is sensitive to heat are the production of peduncles (Ped.) and flowers, and the

$$\frac{\text{Grain Yield}}{\text{area}} = \text{Dh} \quad \frac{\text{Ped.}}{\text{area x day}} \times \frac{\text{Pods}}{\text{Ped.}} \times \frac{\text{Seeds}}{\text{Pod}} \times \frac{\text{Weight}}{\text{Seed}}$$

number of pods set per peduncle. It should be noted that high temperatures damage early floral bud development in bean as well. Physiological and genetic studies at UCR established that heat sensitivity during early floral development and pod set is partly due to genes involved in the phytochrome system that are "hidden" and not expressed under optimal temperatures. Diverse cowpea accessions from different countries and climatic zones, and including many important genotypes bred by IITA, were screened under field and growth chamber conditions and classified into eight groups based upon their tolerance to heat during reproductive development under long days. Cowpeas in the Sahelian and Sudanian zones of Africa are subjected to days that, initially, are longer than the critical photoperiod and subsequently become shorter. Consequently, we have now begun evaluating cowpea accessions for heat tolerance under short days using a specially designed hot glasshouse. Results from the first experiment during the fall and winter of 1990 indicated that certain cowpeas bred at UCR are heat tolerant under short as well as long days, and differences in sensitivity to heat were present under short days among photoperiod-sensitive cowpea genotypes from Senegal and other countries in the Sahelian and Sudanian zones of Africa. We have now bred cowpeas with substantial heat tolerance that are adapted to commercial production conditions in California and provided heat-tolerant germplasm to ISRA and a cowpea breeding program in Ghana.

Drought adaptation: UCR has developed a model for drought adaptation based upon the observation that drought during the reproductive stages has quantitative effects on grain yield of cowpea.

$$\frac{\text{Grain Yield}}{\text{area}} = \sum^{Dw} \frac{\text{Transpiration}}{\text{area x day}} \times \text{WUE} \times \text{HI}$$

Where Dw is the duration of flowering and pod filling. In water-limited environments, the supply of water in the root zone influences both transpiration/day and Dw and is influenced by depth of rooting. A method for screening genotypes for depth of rooting under field conditions was developed, based upon observing plant symptom response to an herbicide placed deep in the soil. This method was used by UCR to evaluate cowpea accessions and is now being used in the peanut breeding program of ISRA. Selecting and breeding for water-use-efficiency (WUE is the ratio of plant biomass production to water use) has been constrained for all crops by the difficulty in measuring WUE for large numbers of genotypes under field conditions. Research at UCR has established that measurements of the heavy carbon isotope composition of leaves, but not seeds, can be used to detect genotypic differences in WUE. One unresolved physiological problem is that genotypic differences in WUE were not associated with differences in the ratio of photosynthesis to transpiration measured on recently expanded leaves during the afternoon, whereas drought-induced changes in WUE were associated with differences in gas exchange. Genotypic differences in WUE were positively correlated with biomass production under water-limited conditions, with only small differences in water use. A crossing program has been initiated to breed cowpeas with higher WUE. Research by other scientists has established that this methodology could be effective with bean as well. Research in Australia with peanuts has indicated the necessity of parallel selection for both WUE and harvest index (HI is the ratio of grain yield to total biomass produced). We are not sure whether this is necessary with cowpea, but we have established that genotypic ranking for HI (based upon the ratio of grain yield to shoot rather than total plant biomass) is not influenced by plant density. This indicates that selection for HI in cowpea could be effective in early generations, such as the F_2, with individual plants grown at wide spacing. The duration of flowering and pod filling (Dw) has a major impact on drought adaptation and yield potential under subsistence farming conditions where multiple hand harvests of pods are practiced. We have discovered genotypes with the combination of delayed leaf senescence and abundant pod production. In field trials at UCR, one of these genotypes exhibited greater adaptation to mid-season drought than a variety with typical leaf senescence. The drought adaptation of the genotype with delayed leaf senescence was due to greater ability to recover after the drought and produce a greater second flush of pods than the variety with typical leaf senescence. Delayed leaf senescence due to genotypic differences or pod-picking was associated with the accumulation of large quantities of starch in the main stem. A rapid visual staining test for starch in the main stem late in the season may provide breeders with a screening technique for selecting genotypes with greater ability to resist mid-season drought.

Yield potential: Cowpea varieties used for irrigated production in California and for rainfed production in the Sudanian Zone of Africa could benefit from increased yield potential. Research at UCR has shown that genotypes with pods within the canopy have much greater efficiency in using light than genotypes with pods held above the canopy. Presumably this loss in efficiency is due to pods absorbing solar radiation and not using it as effectively in photosynthesis as do leaves.

Breeding for resistance to diseases: Bacterial blight and certain mosaic viruses represent major constraints to cowpea production in Africa because these diseases substantially reduce yield and are seed-borne. ISRA has established that the cultivars presently used by farmers in Senegal are susceptible to these diseases. ISRA has bred a cowpea genotype with resistance to these diseases and greater yield stability than present cultivars. This genotype is being considered for release as a new cultivar. Use of this cultivar by farmers would also reduce the extent to which seed stocks are contaminated by these diseases. The research of ISRA may be of benefit to California because UCR has recently discovered that these diseases are present at low levels in California.

Breeding for resistance to insects: Cowpea weevil can severely damage cowpea grain in storage and is one of the major constraints for the food and seed supplies of subsistence farmers in Africa. The potential new cowpea cultivar developed by ISRA was selected for resistance to cowpea weevil (in addition to the resistance to diseases described earlier). In recent years, cowpea aphid has caused substantial damage to cowpea production in Senegal and some damage to cowpea production in California. Using a seedling screening technique, ISRA has bred cowpea genotypes with resistance to cowpea aphid, but further research is needed to select the genotypes that have both strong resistance to cowpea aphid under field conditions and other desirable agronomic characters. Research at UCR has demonstrated that the California biotype of the cowpea aphid is aggressive and can overcome known sources of resistance, but we have recently discovered two genotypes with partial resistance to this cowpea aphid.

Breeding for resistance to *Striga*: The parasitic weed, Striga, is a major constraint for cowpea production in many parts of Africa. Until recently, it was thought that cowpea striga was not present in Senegal. Research by ISRA has shown, however, that cowpea striga is widely distributed in Senegal. ISRA has begun screening cowpea genotypes from the CRSP Botswana project and the IITA project in Burkina Faso to determine whether any of these genotypes have resistance to the cowpea striga present in Senegal and would be useful as parents in a breeding program.

Developing Improved Management Methods:

More than 90 percent of cowpea production in Senegal is from sole-cropped cowpeas grown in rotation with pearl millet, peanut and occasional fallows. Earlier research by ISRA has not shown any advantages to the intercropping of cowpea with pearl millet in the Sahelian Zone where most cowpeas are grown. There may be some advantage to the relay intercropping of cowpea with millet in the Sudanian Zone which is wetter than the Sahelian Zone. The project has been evaluating the hypothesis that varietal intercrops consisting of alternating rows of early-erect and medium-cycle-spreading cowpea cultivars can improve the stability of cowpea production under the harsh conditions of the Sahelian Zone. This research is being conducted by a Senegalese student who has executed field experiments in Senegal during the summer and fall, and laboratory studies and course work as part of an M.S. program at UCR during the winter and spring. The research has demonstrated significant advantages of the varietal intercrop over sole crops of the same cultivars under either infertile or slightly improved soil conditions with respect to the production of both grain and hay. This research has also shown that low soil fertility is limiting cowpea production in the Sahelian Zone of Senegal. Pods of early cowpeas are often harvested at the color-break stage in Senegal as a source of food during the period of hunger and for sale. Field studies at UCR demonstrated that longevity of the crop can be enhanced by

removing color-break pods from cultivars which otherwise tend to senesce as pods mature. In addition, these studies demonstrated that pod-picking can confer greater resistance to mid-season drought by enhancing plant survival and the ability of plants to produce more pods when the drought is ended.

Developing improved Storage Methods: ISRA has been conducting an extensive series of on-farm tests of two methods for minimizing damage to cowpea grain due to cowpea weevil during storage. These tests indicate that both methods, sealed-drum storage and treating grain in sacks with K-Othrine PP2 at 50 g/100 kg, can be effective. Socio-economic evaluations are being conducted to determine the merits, advantages and problems of these two storage methods, and the cultivars and management methods that are being evaluated in the on-farm tests.

Relevance of Technology Being Developed to Subsistence Farm Families:

The improved cowpea cultivars being developed by this project represent an improved technology of extremely low cost that is equally available to farmers with small or larger farms. The cost of producing seed of the improved cultivars is less than present cultivars because the improved cultivars are more productive per unit of input. The cultivars are self-pollinated lines and farmers can obtain seed from their own food production fields. Disease-resistant cultivars have more stable production and produce healthier seed than cultivars that are susceptible to seed-borne diseases. Cultivars with resistance to insects can be more productive and require less input of insecticides than cultivars that can be damaged by insects. Varietal intercropping can be readily adopted on small or larger farms because virtually all of the farmers producing cowpea in Senegal use animal-draft equipment for sowing and cultivation. Adequate methods for improving soil fertility are not yet available for most cowpea farmers in Senegal irrespective of farm size, but cowpea can be reasonably productive in infertile soils. The sealed-drum method for storing cowpeas favors farm families that have the capital to buy the drums, but the low cost of the K-Othrine PP2 (25 U.S. cents to store 100 kg of grain) should not constrain the use of this technology on small farms. The extensive on-farm testing and socio-economic evaluations being conducted by ISRA will help to insure that the technology being developed to improve cowpea production and storage is suitable for adoption by the vast majority of cowpea farmers in Senegal who have small farms and limited resources. For the future, progress in varietal improvement could be accelerated by increasing collaboration among ISRA, UCR and IITA, and the project is progressively increasing the level of interaction among the breeding programs.

Question and Answer period: SENEGAL

Q: What type of evidence do you have for the genetic model of heat tolerance that was presented, and would mixtures be as effective as varietal intercrops?

A: Mixtures may be less effective than varietal intercrops in Senegal for the following reasons:

a. Mixtures of erect and spreading varieties could not be as efficiently cultivated to control weeds as intercrops.

b. Separation of seeds during harvest would be more difficult with mixtures than varietal intercrops--this would make it difficult to sell the grain (mixtures are worth less in Senegal than uniform grain) or, if they had the same seed characteristics, it would make it difficult to select the proper proportions of seed for planting the following year.

Evidence for the genetic model was obtained as follows: Evidence for the ph gene is described in the literature, Pt_1 was described based upon the segregation of F_2, and backcross progeny, and individuals within F_3 families and F_3 families from several crosses. The Pt_2, Pt_3, and Pt_4 genes and their epistasis have not yet been fully elucidated but data from many crosses have been accumulated. The Hta and hbs genes were described based upon the segregation of F_2 and backcross progeny from several crosses.

Q: Is it possible that the epistasis you proposed is really due to interactions at the physiological level?

A: Yes, this is possible because the ph and pt genes appear to act through a complex phytochrome control system.

Q: How expensive are the drums used in the method for storing cowpeas, and did you use K-Othrine in the drums?

A: K-Othrine was not used in the drum treatments; they did not contain any insecticide.

The drums are completely sealed, and it is the reduction in oxygen concentration due to respiration of insects and seeds that kills the cowpea weevils.

The cost of drums does limit the number of farmers who can afford this technology, but drums are now being used by some farmers in Senegal. In contrast, the K-Othrine is very cheap at approximately 25¢ for enough to protect 100 kg of cowpea grain and widely available to farmers in Senegal.

Q: What is the evidence that carbon isotope discrimination may be useful for detecting genetopic differences in water-use efficiency in common bean?

A: Data concerning genotypic differences in carbon isotope discrimination in common bean have been obtained by Jeff White of CIAT and Mark Brick of Colorado State University in cooperation with Jim Ehleringer of the University of Utah at Salt Lake City.

Q: What were the yields of the varietal intercrops and sole crops?

A: Average grain yields of the two intercrop combinations were 897 and 918 kg/ha compared with 596, 640 and 758 kg/ha for the sole crops. The differences are reasonably reliable because they represent means over two years, two locations and two treatments with different low levels of soil fertility. The overall yield levels may appear to be low but they were obtained in extremely harsh environments in northern Senegal with low rainfall, sandy, infertile soil, many biotic pests and high temperatures. Levels of yields on farmers' fields in this region were approximately 400 kg/ha.

TANZANIA/WASHINGTON STATE UNIVERSITY/SOKOINE UNIVERSITY
Matt J. Silbernagel and James Teri

Breeding Beans (Phaseolus vulgaris L.) for Disease, Insect and Stress Resistance and Determination of Socio-Economic Impact on Smallholder Farm Families

Presenters: Matt J. Silbernagel and James Teri

Common beans (*Phaseolus vulgaris* L.) are a relatively minor crop in the state of Washington. The 1988 production of snap beans for processing, dry beans for consumption, and both dry beans and snap beans for seed had an approximate farm gate value of only $21 million. Beans rank 23rd in a list of 40 commercial crops grown state-wide which have an estimated total value of $3.67 billion. While the State of Washington has never had a state-funded bean improvement program, the USDA since 1957 has had a strong bean program at Prosser because of the regional and national importance of seed production in the arid western desert states, which maintain breeders and foundation seed stocks of the cvs needed in the mid-western and eastern bean-producing states (as well as export needs). By producing seed under rill irrigation in this hot, dry environment of Central Washington, the seed-borne diseases of anthracnose, bacterial wilt, common bacterial blight, halo blight and bacterial brown spot are held to zero tolerances. This practice of seed production in the western states (to produce disease-free seed) has been the primary means of control of the above diseases for the past fifty years. However, under these conditions, viruses (bean common mosaic virus [BCMV] and common tobacco virus [CTV]) and root rots (Fusarium, Pythium, Rhizoctonia) are major production constraints.

The Collaborative Research Support Program between Washington State University and Tanzania is deemed beneficial to the U.S. bean program (by U.S. research administrators) because this collaborative effort allowed us to focus much needed additional emphasis on bean common mosaic virus, which is important not only in the U.S. and Tanzania but worldwide. Additionally, the CRSP support has also allowed much more to be done in breeding for root rot and halo blight resistance.

Methodology and Results:

Research in the U.S. (Prosser) includes:

1. BCMV is genetically quite variable, readily aphid-transmitted and is seed-borne. Because of international movement of bean seed lots, new strains can appear almost overnight anywhere beans are grown. When these exotic new strains are able to infect previously resistant local cultivars, the results can be devastating.

   Circumstantial evidence suggests that seed lots of BCMV-susceptible bean cultivars that are produced in eastern or southern Africa by Dutch seed companies often become infected with serogroup A isolates of BCMV and eventually find their way to the commercial bean production areas of the U.S. or Europe. Because there are currently no U.S. laws restricting bean seeds, exotic BCMV isolates are not detected in commercial seed lots until economic problems develop.

   Under the Bean/Cowpea CRSP (1980-84), we produced nearly 600 hybridoma cell lines which elicit antibodies specific for one or more BCMV strains. Cell

culture supernatant were tested at that time against a panel of BCMV strains collected from around the world; this panel included only four serogroup A isolates. We selected one cell line from which we produced a monoclonal antibody (which is now available commercially) that detected all known strains of BCMV. Two additional MoAB lines were selected that are specific for the serogroup A strains. There was considerable diversity in strain specificity among the remaining 500-plus cell lines which are currently being held in liquid nitrogen storage awaiting further evaluation. It is likely that additional MoABs can be developed from this collection that will be useful in discriminating both among serogroups and possibly among the pathogroups defined on the basis of differential bean host cultivars.

2. Hundreds of hybrids have been made between U.S. and African cvs to combine desirable plant and seed characteristics with sources of resistance to the major disease problems in Africa (BCMV, rust, angular leaf spot, anthracnose, halo blight, common blight) and the U.S. (BCMV, halo blight and root rots). Further selection at Prosser and Morogoro have identified promising lines that should lead to improved cvs for both locations.

Planned Next Steps and Potential Linkages:

In addition to what is outlined above, we are well into developing an improved set of differential bean cultivars for the biological identification of strains of BCMV. These differentials will all be based on the recurrent bush bean parent, Stringless Green Refugee. A separate pair of near isogenic lines will be selected which differ for each of the seven single genes for BCMV bean host resistance (I, bc1, $bc1^2$, bc2, $bc2^2$, bc3 and the non-specific gene bc U).

Dr. John Kneseck, Department of Microbiology, Texas Woman's University, Denton, Texas and his graduate students will attempt to develop cDNA probes for each of the seven host resistance genes using our near isogenic lines. In the future, it may be possible with these probes to quickly determine which gene(s) for BCMV resistance a parental or segregating hybrid line may have, without the laborious time and space consuming efforts now required.

Being able to easily construct presently unavailable combinations of genes for BCMV resistance will also allow us to identify strains of BCMV which are presently undetectable with the now available bean host differentials.

Summary Report for Sokoine University of Agriculture:

Introduction: The common bean (*Phaseolus vulgaris*) is the most important leguminous pulse food crop in Tanzania. Annual production (FAO 1988 estimate) now stands at 240,000 metric tons from 400,000 ha. Average yields in farmers' fields stand at 600 kg/ha although potential yields of 2,000 kg/ha in farmers' fields have been demonstrated.

The major constraining factors to achieving the potential yields are lack of high yielding varieties (HYV) that are resistant or tolerant to stresses like diseases, pests and drought.

The major objective of the Bean/Cowpea CRSP in Tanzania has been to develop high yielding, widely adapted, disease and insect resistant bean cultivars for the smallholder family and to estimate the economic viability of the new cvs and their impact on women's role in the production, consumption and marketing of beans.

Methodology and results: Research in Tanzania has included the following:

1. Smallholder farm family surveys to establish baseline data on farm sizes, family farm enterprises, production statistics, selection criteria of cvs, gender issues in bean production and extension as far as reaching female-headed households is concerned--Importance of beans in the farming systems of the major bean growing regions of Tanzania has been documented including the role of women in these farming systems. Problems of female-headed households and selection criteria of bean cvs have been documented.

2. Germplasm collection, screening and improvement--The germplasm collected has been screened for superior types. Crosses made among these and other lines have been screened and superior types identified.

3. Screening segregating populations to identify lines resistant to rust, angular leaf spot (ALS), BCMV, heat and drought.

4. Agronomic and physiologic studies of beans under monoculture, intercropping and cultivar mixtures to identify superior cultural practices for beans.

5. The annual workshop reports documenting CRSP activities in Tanzania.

Implications for the small-scale farmer and for future research: The technologies being generated (i.e., HYV resistant to insect pests, diseases and other stresses, use of rock phosphate, BNF and cvs suitable for intercropping and mixtures) are ideal cheap technologies for the resource-poor, small-scale bean producers.

Earlier socio-economic research has shown the importance of women in bean production, consumption and marketing and hence the need to develop technologies which will enhance these roles. Of great concern are the female-headed households which are poorer in resources and less reached by the extension service.

Planned next steps and potential linkages: Joint studies are planned with the CIAT/SADCC bean project in screening hybrid segregants against beanfly and nematodes and in farmer participatory research. There is a joint (SUA/CIAT) supervision of a Ph.D. student from Uganda.

Question and Answer period: TANZANIA

There was a discussion on the philosophy of utilizing a single cultivar (pure line) verses mixtures of genotypes (landrace situation). About 25 percent of acreage is planted with pure lines and the remaining 75 percent is small farm acreage with mixtures predominating. Thus both strategies should be used in the project.

Seed multiplication and distribution were cited as problem areas to be addressed. Growers should be identified, seed distributed and impact should be studied. CIAT/SUA/Tanzanian government are cooperating in three ecological zones (low, middle and high altitude) for breeding line evaluation and this could be utilized for seed distribution.

A question was raised about how to handle the post harvest nutrition/cookability aspects. Although some work is being done in this area, strengthening was suggested. Similarly, post harvest storage (75 percent of the beans are used on farm) work needs to be done to deter bruchids which are the main problem.

Clarification was made on the issue of what criteria are used to discard breeding materials (i.e., pest susceptibility and lack of adaptation are top priorities).

THE ROLE OF FOOD SCIENCE AND TECHNOLOGY IN THE DELIVERY SYSTEM: UNDERSTANDING THE GAME PLAN

T. O. M. Nakayama
Department of Food Science and Technology
University of Georgia

Food science and technology has been defined as the application of the natural sciences to the processing and distribution of foods. This descriptive definition, however, does not allow for interpretations on how the various facets interact with each other and the food delivery system as a whole.

I will attempt here to give you some idea, albeit a personal view, on what the requirements of the delivery system demand and how the various CRSPs can play a part in organizing the delivery systems in developing countries.

A basic premise is that social organizations exist for the purpose of creating wealth by lessening labor required for the essentials. The organization of a family traditionally has brought specialized roles for males and females. The organization of family units into communities has further benefits of mutual protection and division of labor, which has the increased ability to simplify tasks. Even the most rudimentary tasks consist of multiple operations. If these could be separated and each family perform one task, this would result in an increase in efficiency. For instance if an apparatus were to be made of three different parts, each family could make one part and the fourth could be responsible for assembling this apparatus. Because of specialization, a greater degree of efficiency, and probably quality, would result. However, this type of communal behavior requires coordination and mutual trust depending upon whether one lives in an autocratic unit or a democratic one.

An organized society may utilize increased efficiency by engaging in the creation of further wealth. Wealth is a matter of creation by societies and is a distinct human endeavor.

In animals, one might note that herd behavior is often controlled by a single dominant individual. Similarly, many of the large projects such as pyramids, great walls and palaces were essentially created by individuals or elite groups governing the masses. On the other hand, wealth can be created in a more participatory society through what is commonly known as a democratic process. Our country is evolving toward this end.

Food is a necessary and continuing need for all peoples and, thus, it behooves any society to coordinate the food delivery system so that this need can be met with least input in order to conserve resources for other activities. The food delivery system has as its primary function the provision of food for the populace. Food is the instrument of delivery of nutrients for people. Thus, the human can be considered as an isothermal machine which requires about 2500 K calories/day and sufficient nutrients to repair itself. The energy to be utilized must be in the form of chemical bonds which can be broken and the resultant energy utilized at constant temperature. These bonds are found in biologically derived materials, both plant and animal. Thus, one can use an analogy from the Second Law of Thermodynamics and say that consumed food equals total food produced minus that lost, wasted, or used elsewhere. However, because

the process is at constant temperature, thermal considerations are not as important. During production phases of a foodstuff, also known as growing, the total amount of energy reserve increases to a maximum until the time of harvest or slaughter, as the case may be, and thereafter decreases eventually returning to standard conditions. Thus, the act of harvest is an identifiable point.

The other point to be noted is that part of the system which is analogous to entropy is constantly decreased during production. That is, random molecules of carbon dioxide, nitrogen and water are being organized into starch, protein, fat and other cellular components by the use of radiant/chemical energy. After harvest, while the total amount of food is reduced, the amount of waste is also decreased or increased depending on the circumstances. Under natural conditions, the food material spoils and returns to the original random state of molecules. On the other hand, through human intervention the amount that would be lost is decreased. The very essence of preservation is to keep food in a state which is utilizable until eaten. Thus at the point of consumption, the total amount of available food is decreased by perhaps less than half but the amount wasted is decreased also, resulting in a net increase in value. After consumption, the randomness of the molecules increases to eventually yield carbon dioxide, water and energy. Thus, harvesting and consumption are easily identifiable points in this delivery system. It is between these points that the role of food science and technology can be discerned.

Foods, while an instrument of delivery, have several facets which appeal to different senses; thus, foods are difficult to compare in simple systems such as the often heard "You can't compare apples and oranges." However, a common experience for most people is to walk into a supermarket and decide whether to buy apples or oranges. Thus, that which cannot be compared is obviously done everyday. However, what exactly are we comparing? The integrating instrument here is value. Value of anything is equal to the amount or quantity times a factor (an objective quality) times a probability of acceptance/consumption.

$$\frac{\text{Value}}{\text{costs}} = \frac{\text{quantity x quality x probability}}{\text{costs}}$$

Cost, of course, is labor and energy, but also societal cost, environmental cost, etc. This very general equation can be used to understand the role of food science and technology in the CRSPs.

"Value added" is that increase in value of a foodstuff beyond the point of harvest. This includes such things as perceived values, which impact on the probability of acceptance. Typically, value added is about twice that of the value at harvest in the U.S. In developing countries it can be as much as ten times. The purpose of an organized effort as previously stated is to create wealth. In order to create wealth, you must increase value. This consists of optimizing the ratio of the above equation by maximizing the numerators and decreasing the denominator. The probability of consumption, as you can guess, is a multiple of many probabilities such as the probability of the price being correct, the probability that the color is right, the shape is right, the taste is good, etc. As you can note, these probability and quality factors are largely socio-economic or sociological in origin while the quantity and costs are heavily technological. However, it should be noted that these factors are to be multiplied. They are not additive. Thus, one may have large values for quantity and quality and low values for cost; however, if the probability of acceptance is low, the value is low. If one were to perhaps limit quantity, then in order to

maximize value, one must raise quality and probability of acceptance. This equation, which should intimidate no one, helps us understand why, with produce such as beans and cowpeas, the quality appears to be the best when the price is the lowest--when it is the height of the season. Value is a human connotation and thus, heavily dependent on sociological factors. Today, some of the prominent factors affecting probability of acceptance include such considerations as nutritious, healthful and light which are bolstered by such terms as natural, organic and low calorie in developed countries. The probability of acceptance in developing countries is more likely to be affected by ease of cooking, low inputs for production, digestibility, familiarity, etc.

Let us trace some foodstuffs through the system. When a seed is planted, there is virtually no potential food here. However, as the crop (for instance, beans or cowpeas) matures, it is quite apparent that there is a great deal of value here. The fact that the net effect is positive with respect to value can be seen in small huts that the growers erect in fields to guard against thievery near harvest time. Once harvested, there is, of course, storage and distribution, both of which increase the value of beans and cowpeas by making them more acceptable and less prone to deterioration by insects, molds and rodents. Beans and cowpeas subjected to all of these operations have maximum value. After the beans or cowpeas are eaten, of course, the energy is expended and eventually the molecules are returned as carbon dioxide and water.

A similar scenario might be enacted for animal products which reach a maximum at slaughter and then are processed, transported, etc. and finally consumed. The animal system, of course, requires an input from plant sources to furnish the energy necessary to grow and develop. Efficiency here is about 10 to 1 in terms of energy. Sociological considerations also impact heavily. Dietary taboos, of course, render certain products with very low probabilities of acceptance, thus negating their value. Likewise, products suspected of containing undesirable chemicals lose a tremendous amount of value. Because this task of keeping the food delivery system going is a continuing one, the more efficient the system, the less resources must be spent by the society. The measure of this, of course, is the amount of disposable income used for food, which in our country is quite low. Further sociological efforts need to be expended on utilizing excess resources for constructive value increases rather than destructive ones--drugs, crime, etc.

The combination of organized effort and technological possibilities make it possible for more developed countries to transfer some of this know-how to less developed countries who are still largely in the subsistence mode. An attitude of self-sufficiency and going-it-alone is a sure road to poverty for any society.

An example of technology transfer is the use of wheat and the location of flour mills. Of the fifteen largest flour mills in the world, seven are located in countries growing virtually no wheat. In Nigeria one can see bread sold in every rural village. The acceptance of bread has formed the basis of a large industry, and efforts are underway to grow wheat. It has also rendered the country captive to the wheat producers.

But there is no doubt that without mills, the enjoyment of bread would be only for the rich in these countries. The milling of grains is a fundamental method of preparation which ranges from a mortar and pestle to ready-made flours. This operation is a part of a woman's chores at the subsistence level and man's at the industrial level. An analogous case to wheat can be made for the milling of other grains.

An index of development in any society is the worth of a woman's time. The lessening of her burdens would enable her to devote more of her time to pursuits which would enrich her life and that of her family. Societies which relegate their women to a permanent underclass are marked by stagnation.

Food science is concerned with the properties of foods and their transformations, while technology entails the application of this information for specific ends and includes food processing, etc. The closer to the consumer the delivery system comes, the higher the value and, thus, the higher the intellectual properties associated with the product. Brand names, processes, etc. are generally protected under the aegis of intellectual property by such things as patents, copyrights, show-how, know-how. Most research in land grant colleges in food science deals with properties of foods and their transformations and in a limited way with process conditions and technology--that is, process design and implementation. These latter elements are in the province of the industry which has a great stake in them. For developing countries, however, the show-how and know-how must be developed with great care. If one were to transfer the technology of the system directly to another country, that would best be done by industry since industry has the know-how to do this. I raise my contention that the place of the land grant institution is what it has traditionally been in our own country. That is, to lay the foundation information for all to use which would then be applied by the practitioners. Thus, in the training phase of the CRSPs, the principles of food science can be learned and the aspects of technological requirements known. The actual implementation of these, however, would be best left to those practitioners in the Host Countries. In this way, what is created would be sustainable technology. Many examples of inappropriate technology transfer have occurred which tend to make them instructive via the experience route. Thus, food science has a definite and indispensable role in the development of food delivery systems in developing countries. It fulfills this role by interacting in a purposeful fashion with the natural and the social sciences necessarily impacting on women in development, technological resources, natural resources and political organizations.

Question and Answer Period: Food Science and Technology in the Total Food Delivery System

Comment: Producers feel that value added to commodities by the processing, distribution and marketing of foods is overrated.

Response: This is a common feeling expressed by producers. However, in the equation for value (see page 3 of Dr. Nakayama's written summary), more effort is put in countries or situations where quantity is plentiful. Anything a consumer is willing to pay for is real value.

Q: What can the CRSP do to link more closely the concerns of consumers and producers?

A: This is a problem of communication and the need for understanding what each group needs. Food Science and Technology works between the consumer and the producer and can translate those needs.

Q: What should Food Science and Technology be doing in the CRSP?

A: The role of Food Science and Technology should be to save foodstuffs produced by decreasing waste and making food more appealing to the consumer by building in or adding value. Also, an extremely important component is the training of people and the development of human capital.

IDENTIFICATION, MAPPING AND USES OF RESTRICTION FRAGMENT LENGTH POLYMORPHISMS

Michael J. Havey
Vegetable Crops Research Unit, USDA/ARS
Department of Horticulture
University of Wisconsin

In diploid plants, two alleles reside at a given genetic locus in each individual. For morphological traits or disease resistances, the alleles are distinguished by different phenotypes such as blue versus white flower petals, resistant versus susceptible, tall versus dwarf plants, etc. If allelic variability is present at numerous genes, the physical ordering of the genes on individual chromosomes can be estimated. The relative positioning (mapping) of genetic loci is elucidated by crossing between plants possessing different alleles and studying the numbers of parental versus recombinant progeny. Alleles at loci that are closely located on the chromosomes have a greater probability to be inherited as a unit. This physical linkage of genetic loci is expressed as a greater proportion of progeny possessing the phenotype of the parents. Using classical genetic markers such as morphological traits and disease resistances, plant geneticists have developed detailed genetic maps for a few species, e.g., pea, maize and tomato. However the number of classical genetic markers are limited and, as a result, most plant species have very rudimentary genetic maps. Biochemical markers, such as isozymes, have increased the number of loci that are mappable, but the numbers of variants are still inadequate to generate detailed genetic maps of most species.

Recent advances in molecular biology have led to the discovery of a new class of genetic marker. Restriction enzymes are proteins that cut the DNA at specific sequences of either 4-, 6-, or 8-base pairs. Because the restriction enzyme recognizes a specific sequence, a mutation changing one base pair in the recognized sequence would result in the loss of the site at which the DNA is cut. Insertion or deletion of DNA between two restriction enzyme sites can also change their relative location. DNA fragment size differences between plants, breeding lines or populations due to changes in the positions of restriction enzyme sites are called restriction fragment length polymorphisms (RFLPs). RFLPs have a genetic basis and are inherited as simple Mendelian factors. Because RFLPs represent changes in the DNA of the plant, they can be detected in all tissues and at all stages of plant development. Adequate numbers of RFLPs have been identified in numerous plant species allowing for the development of genetic maps at a level of detail not possible using classical markers and isozymes, e.g., maize, tomato, rice, potato, lentil, lettuce (Bernatzky and Tanksley 1986, Helentjaris et al. 1986, Landry 1987, Bonierbale et al. 1988, McCouch 1988, Havey and Muehlbauer 1989).

Detection of RFLPs is presently expensive and technically difficult (Beckmann and Soller 1983). After digestion with a specific restriction enzyme, plant DNA is size-fractionated through an agarose gel, denatured and transferred to a supporting membrane. Unique cloned fragments (probes) of DNA from the plant are radioactively labeled, heat denatured and added to a solution surrounding the digested DNA on the supporting membrane. These probes will hybridize only to complementary sequences of DNA on the supporting membrane. Because the probe DNA is radioactive, the location of the complementary sequences can be detected by autoradiography. RFLPs are therefore identified as differences in the sizes of bands on X-ray film. The cost of identifying RFLPs will soon become less costly with the advent of new approaches, such as the polymerase chain reaction.

The genetic characteristics of RFLPs include a Mendelian mode of inheritance, co-dominance, multiple allelic forms and lack of pleiotropic effects on economically important traits (Beckmann and Soller 1983). RFLPs are useful for line identification, plant variety protection and measurement of genetic diversity (Bailey 1983, Soller and Beckmann 1983). They can provide a means of monitoring the level of heterozygosity or homozygosity in a population, analyzing quantitatively inherited traits and assisting in the introgression of useful traits in segregating populations (Beckmann and Soller 1983, Burr et al. 1983, Tanksley 1983, Helentjaris et al. 1985). Markers have been used effectively to assess genetic diversity within and between plant populations (Helentjaris et al. 1985) and to identify and select for monogenic or polygenic traits in crop improvement programs (Edwards et al. 1987, Stuber et al. 1987). RFLPs have been used to identify genes conditioning quantitatively inherited traits of economic importance in tomato, e.g., high soluble solids, water use efficiency and insect resistance (Osborn et al. 1987, Paterson et al. 1988, Nienhuis et al. 1988, Tanksley and Hewitt 1988, Martin et al. 1989). RFLP linkage maps can potentially facilitate the more efficient use of resources in a practical plant breeding program. Traits with relatively high heritabilities and which are expensive or time-consuming to evaluate may be improved by selecting for tightly linked marker loci (Beckmann and Soller 1988). Therefore, the use of RFLPs as tools in plant improvement programs is likely to expand in the future.

References

Bailey, D. C. 1983. Isozymic Variation and Plant Breeder's Rights. In S. D. Tanksley and T. J. Orton (eds.) Isozymes in Plant and Genetics and Breeding. Amsterdam: Elsevier Co.

Beckmann, J. and M. Soller. 1983. Restriction Fragment Length Polymorphisms in Genetic Improvement: Methodologies, Mapping and Costs. Theory of Applied Genetics 67:35-43.

Beckmann, J. and M. Soller. 1988. Detection of Linkage Between Marker Loci and Loci Affecting Quantitative Traits in Crosses Between Segregating Populations. Theory of Applied Genetics 76:228-236.

Bernatzky, R. and S. D. Tanksley. 1986. Toward a Saturated Linkage Map in Tomato Based on Isozymes and Random cDNA Sequences. Genetics 112:887-898.

Bonierbale, M., R. Plaisted, and S. Tanksley. 1988. RFLP Maps Based on a Common Set of Clones Reveal Modes of Chromosomal Evolution in Potato and Tomato. Genetics 120:1095-1103.

Burr, B., S. V. Evola and F. A. Burr. 1983. The Application of Restriction Fragment Length Polymorphisms to Plant Breeding. Genetic Engineering 5:45-59.

Edwards, M., C. Stuber, and J. Wendel. 1987. Molecular-Marker-Facilitated Investigations of Quantitative-Trait Loci in Maize. I. Genomic Distribution, and Types of Gene Action. Genetics 116:113-125.

Havey, M. and F. Muehlbauer. 1989. Linkages Between Restriction Fragment Length, Isozyme, and Morphological Markers in Lentil. Theory of Applied Genetics 77:395-401.

Helentjaris, T., King, G., Slocum M., Siedenstrang, C. and S. Wegman. 1985. Restriction Fragment Polymorphisms as Probes for Plant Diversity and Their Development as Tools for Applied Plant Breeding. Plant Molecular Biology 5:109-118.

Helentjaris, T., M. Slocum, S. Wright, A. Schaefer, and J. Nienhuis. 1986. Construction of Genetic Linkage Maps in Maize and Tomato Using Restriction Fragment Length Polymorphisms. Theory of Applied Genetics 72:761-769.

Landry, B., R. Kesseli, B. Farrara and R. Michelmore. 1987. A Genetic Map of Lettuce (*Lactuca sativa* L.) with Restriction Fragment Length Polymorphisms, Isozymes, Disease Resistance Genes, and Morphological Markers Genetics. 116:331-337.

Martin, B., J. Nienhuis, G. King and A. Schaefer. 1989. RFLPs Associated with Water Use Efficiency in Tomato. Science 243:1725-1728.

McCouch, S., G. Kochert, Z. Yu, Z. Wang, G. Khush, W. Coffman and S. Tanksley. 1988. Molecular Mapping of Rice Chromosomes. Theory of Applied Genetics 76:815-829.

Neinhuis, J., T. Helentjaris, M. Slocum, B. Ruggero and A. Schaefer. 1987. Restriction Fragment Length Polymorphism Analysis of Loci Associated with Insect Resistance in Tomato. Crop Science 27:797-803.

Osborn, T., D. Alexander and J. Forbes. 1987. Identification of RFLPs Linked to Genes Controlling Soluble Solids Content in Tomato Fruit. Theory of Applied Genetics 73:350-356.

Paterson, A., E. Lander, J. Hewitt, S. Peterson, S. Lincoln and S. Tanksley. 1988. Resolution of Quantitative Traits into Mendelian Factors by Using a Complete Linkage Map of Restriction Fragment Length Polymorphisms. Nature 335:721-726.

Soller, M. and J. Beckmann. 1983. Genetic Polymorphism in Varietal Identification and Genetic Improvement. Theory of Applied Genetics 67:25-33.

Stuber, C., M. Edwards and J. Wendel. 1987. Molecular-Marker-Facilitated Investigations of Quantitative Trait Loci in Maize. II. Factors Influencing Yield and its Component Traits. Crop Science 27:639-648.

Tanksley, S. 1983. Molecular Markers in Plant Breeding. Plant Molecular Biology 1:3-8.

Tanksley, S. and J. Hewitt. 1988. Use of Molecular Markers in Breeding for Soluble Solids in Tomato--A Re-examination. Theory of Applied Genetics 75:811-823.

STATUS OF BEAN RESEARCH AT CIAT: STRATEGIC OBJECTIVES FOR THE 1990s

Douglas Pachico and Julia Kornegay
Bean Program, CIAT
Cali, Colombia

During the decade of the eighties, the principal research objective of Centro Internacional de Agricultura Tropical's (CIAT) bean program was to improve bean varieties for resistance to diseases and insects. Disease resistance breeding was given the highest priority. The justification behind these decisions was based on the widespread importance of diseases throughout Latin America and Africa, the fact that most diseases are seed-borne and persist because bean farmers in the tropics usually save their own seed and due to the difficulty to control disease by non-genetic means. The bean program believed that multiple disease resistant varieties would reduce production costs and risks and thereby make bean production more profitable to both farmers and less expensive for consumers.

During the 1980s plant breeders, plant protectionists and agronomists were trained both at CIAT and within their regions. Emphasis was placed on on-farm research training with the objective to help increase national program capacity to set priorities and evaluate the new technologies. Also during this time, regional research networks were set up in both Latin America and Africa to provide the means by which scientists or different countries could collaborate on specific research problems and share their results. These research networks were guided by steering committees composed of national program leaders, who advised CIAT and the networks on the priorities for future research and training activities. Within CIAT's Bean Program, fifteen scientists are out-posted in regional network projects in Latin America and Africa, and eleven program staff are based at Headquarters in Cali, Colombia.

At the end of the 1980s, the Bean Program had consolidated its efforts in Latin America and Africa building stronger ties with national research and development systems and decentralized an increasing share of its applied research objectives to national programs within regional networks. Measurable impact was already seen in farmer's fields, with more than 50 improved varieties grown by farmers on more than 350,000 hectares. Based on these achievements, the Bean Program began the decade of the nineties with a strategic review of its changes needed to increase bean production and productivity for small-scale farmers and poor consumers of the tropics. To design the new research strategies for the 1990s, an extensive, interactive process involving CIAT scientists, external advisors and consultations with many national program leaders was initiated. Five strategic objectives were prioritized for the bean program.

Strategies for the 1990s

National programs are highly heterogeneous with different capacities and needs. Many countries have limited resources and the interaction between research, extension and farmers is weak. In general, little attention is paid to the long-term effects of current cultural practices. To deal with these problems, the first strategic objective will be the continued high priority of <u>strengthening national program capacity to improve bean productivity</u> in diverse cropping systems. The strategies to accomplish this objective are: (1) to deliver

to national programs genetic materials as parents, segregating populations or finished lines according to their needs; (2) link national programs more strongly into research networks to solve common problems and exchange results; (3) strengthen national program capacity to involve farmers in setting research priorities and technology evaluation; and (4) stimulate national programs to develop sustainable and productive crop management systems.

Specialized training, coordination with network activities and collaborative research projects are essential components in the implementation of these strategies. Technology development must be based on the realistic needs and abilities of national programs to implement and diffuse new solutions to bean production problems.

Reduce losses from pests and diseases. Although much progress has already been achieved in this area, further effort is needed to: (1) broaden the genetic base of resistance sources; (2) identify sources of resistance where lacking and incorporate the genes conditioning resistance into acceptable cultivars; and (3) develop integrated control strategies to complement genetic resistance while reducing pesticide application.

The increasing use of pesticides by small farmers in Latin America is a growing problem. Pesticide abuse is becoming more prevalent. Although multiple disease and insect resistant varieties will help alleviate this situation, it is difficult in many cases to breed resistance to all the biotic constraints present in a given production environment. The combination of resistant varieties and Integrated Pest Management (IPM) practices is needed. The development of suitable IPM practices which can be easily taught and used by small farmers is beginning, but more is needed.

The overall soil fertility in bean-based systems is declining because of expansion of beans into marginal soils, shortened fallow periods, soil erosion and limited use of fertilizer, especially in Africa. Over half of the area planted to beans is also subject to drought stress. Significant research is needed in these areas. A start was made during the 1980s to improve the efficiency of nutrient and water use by bean plants, however, significant challenges remain to be solved. To relieve nutrient and drought constraints four strategies are being pursued: (1) breed bean genotypes with improved ability to fix nitrogen; (2) identify mechanisms and develop efficient screening methods for tolerance to low phosphorous and to acid soils; (3) generate bean genotypes with improved adaptation to water stress; and (4) stimulate national program research in fertility management for bean-based cropping systems.

With the increasing availability of bean varieties with multiple disease and insect resistance there is a growing demand by national programs to increase the yield potential of beans. Little progress, however, has been made in this area, especially among the medium to large seeded types preferred in many countries. Research to tackle this problem has begun and includes: (1) placing a greater emphasis on selection for yield in the breeding nurseries; (2) exploring the genetic variation across gene pools as a means to optimize genes controlling yield; (3) attempting growth habit modifications in medium-large seeded types to produce more productive plant types; and (4) studying yield maximizing physiological traits such as canopy morphology and patterns of nitrogen uptake and partition to determine which factors can be optimized for higher yield potential.

The final strategic objective of the bean program is to improve methods for utilizing *Phaseolus* genetic resources by: (1) studying the patterns of genetic diversity to prioritize new resource acquisitions; (2) utilize biochemical markers to increase the efficiency of conventional breeding; (3) evaluate the potential for increased utilization of wild ancestors and related species for common bean improvement; (4) apply new methods for gene transfer; and (5) link biotechnology research institutes in developed countries to priority problems of beans in the tropics through advanced research network on beans.

Progress in molecular biology offers the opportunity of more efficient identification and transfer of useful genes, both within *P. vulgaris* and from related species. CIAT has a comparative advantage in identifying these genes through evaluation of its collection of *Phaseolus* genetic resources. However, the collection is too large (more than 40,000 accessions) for in depth evaluation of its materials. CIAT is in the process of forming a subset or core collection of the genetic variability present in the total collection, which will facilitate the use and evaluation of useful genes.

In the scope of this presentation, it is not possible to give the details of the specific research projects that will be done to accomplish the objectives outlined in the strategic plan for the 1990s. The challenges are great and the research that is needed will require innovative approaches to understanding and solving these problems.

Conclusion

To achieve the five strategic objectives of CIAT's bean program in the next ten years, shifts in resources will be made, and some research areas of the 1980s will be reduced to make way for the new research of the 1990s. More reliance will be made on collaboration with our national partners in Latin America and Africa and with advanced research networks, such as the CRSP, in the developed countries. The goal of increasing food availability and income to the poor by improving bean productivity requires basic, strategic and applied research. We hope that our strategic plan will stimulate CRSP scientists to shift more of their resources towards the basic and strategic research areas that are outlined in this paper. The results of this research will be beneficial not only to CIAT and our national partners by alleviating bean production constraints, but will also benefit bean farmers and agricultural science in the developed countries as well.

References

Cardona, C., J. Kornegay, C. E. Posso, F. Morales and H. Ramirez. In press. Comparative Value of Four Arcelin Variants in the Development of Dry Bean Lines Resistant to the Mexican Bean Weevil (Coleoptera: Bruchidae). Entomologia Experimentalis et Applicata.

Cardona, C., C. E. Posso, J. Kornegay, J. Valor and M. Serrano. 1989. Antibiosis Effects of Wild Dry Bean Accessions on the Mexican Bean Weevil and the Bean Weevil (Coleoptera: Bruchidae). Journal of Economic Entomology 82:310-315.

CIAT. 1989. CIAT in the 1990s: A Strategic Plan. Cali, Colombia. 58p.

CIAT. 1989. CIAT Annual Report. Bean Program, Cali, Colombia.

Kipe-Nolt, J. and H. Vargas. 1989. Components of Nitrogen Fixation in *Phaseolus vulgaris*. In S. Beebe (ed.) Current Topics in Breeding of Common Beans. Working Document No. 47. Bean Program, CIAT, Cali, Colombia, 438P.

Laing, D. R.. 1990. Incremento de la producción de granos basicos, utilizando menos insumos en agricultura sostenida. Conferencia Magistral. PCCMCA. Reunion XXXVI. El Salvador, Marzo 26, 1990. CIAT, Cali, Colombia.

Lynch, J., A. Gonzalez and J. Tohme. 1990. Variation in Characters Related to Leaf Photosynthesis in Wild and Weedy Bean Populations. Submitted to Crop Science.

Lynch, J. and J. W. White. (In preparation). Aspects of Nitrogen Use Efficiency in Common Bean and Other Grain Legumes in a Tropical Environment.

Pachico, D. and A. van Schoonhoven. 1989. A Post-Green Revolution Strategy for the Improvement of Small Farmer-grown Common Beans. Tropical Pest Management. 35:243-247.

Valasquez, J. G., P. Prada and G. Henry. 1990. Snap Bean Pests and Diseases in Sumapaz, Colombia: Their Present Status and Implications. In G. Henry and Janssen (eds.), Snap Beans in the Developing World. Proceedings of an International Conference. CIAT, Cali, Colombia, October 16-20, 1989.

White, J. W., J. Kornegay, J. Castillo, C. H. Molano, C. Cajiao and G. Tejada. 1990. Effect of Growth Habit on Yields of Large-seeded bush cultivars of common bean. In preparation for Field Crop Research.

White, J. W., J. Kornegay and C. H. Molano. 1990. Photoperiod response of flowering in snap bean germplasm. Submitted to Journal of the American Society of Horticultural Science.

Question and Answer Period: Status of Bean Research/CIAT

Q: What has been the yield stability of isogenic lines expressing the Type I growth habit vs. Type II or III growth habit?

A: On the average, Type I lines were more stable than IIs or IIIs. However, some individual lines with II or III growth habit were shown to be relatively stable in the environments measured.

Q: Have lines with a high arcelin content been tested in comprehensive nutritional studies?

A: Yes. They have been tested in several laboratories in various nutritional trials. No problems were identified. Furthermore, arcelin appears to be labile at normal cooking temperatures and times.

Q: To what degree is there acceptance by farmers and users of this improved materials traceable to CIAT germplasm.

A: Comprehensive testing is done in each area by teams of researchers from the respective areas. Data have been collected on standard parameters such as seed size and color, cooking time, hard seed formation and taste.

CURRENT STATE OF COWPEA RESEARCH FROM IITA'S PERSPECTIVE AND THE MAJOR RESEARCH NEEDS FOR THE FUTURE

S. R. Singh
Grain Legume Improvement Program
International Institute of Tropical Agriculture
Ibadan, Nigeria

Introduction

IITA launched a strategic planning study in 1986, from which was developed its Strategic Plan 1989-2000. The implementation of the long-term Strategic Plan is being carried out on a phased basis, the first phase of which is the Medium-Term Plan 1989-1993. The focus is on the smallholder African farmer or family farmers in five agroecological zones of West and Central Africa.

Cowpea is the predominant grain legume crop in most of the region, and is marketed and consumed throughout all zones. It is an important cash and food crop in the Sahel/dry savanna and is also a major grain legume in the moist savanna, transition and inland valleys. Cowpeas vary in maturity, plant type and seed characters due to the diversity in the cropping systems in the various agroecological zones. The constraints in cowpea production vary according to cropping systems and ecologies. There is need for site-specific research.

IITA's Cowpea Improvement Program

IITA has a global mandate for cowpea research in the CG system. IITA's cowpea improvement program works closely with national programs in Africa. IITA scientists participate with national scientists in the development of research plans at IITA and at national level. Joint monitoring tours and evaluation of advanced breeding lines is also undertaken. A cowpea network coordinator is based at Ouagadougou, Burkina Faso with the Scientific Technical and Research Commission of the Organization of African Unity (OAU), being funded through a grant from USAID. The coordinator is a member of the Steering Committee for the cowpea network for West and Central Africa. In addition, Research Liaison Scientists based at IITA headquarters also assist national programs in developing their cowpea research work.

IITA recently signed an agreement with the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR) to locate a team of scientists in Maputo, Mozambique to give regional support to the countries of the Southern African Development Coordination Conference (SADCC) for cowpea improvement.

The major objective of IITA's grain legume improvement program, as mentioned in the IITA Strategic Plan, is to develop varieties that are well adapted to the cereal-based farming systems of the African savannas and that meet the dual needs for grain and fodder.

Given this general objective, the main researchable issues for cowpeas in cereal mixtures include:

1. Their morphological and physiological adaptation to interplanting with cereals in a range of environments with varying lengths of growing period.

2. The identification and incorporation of multiple pest and disease resistance into adapted varieties.

3. The nitrogen economy of the cereal/legume systems in terms of biological nitrogen fixation.

4. The basis and improvement of drought tolerance in cowpeas, especially for the millet farming system of the semi-arid zone.

To accomplish IITA's strategy to improve cowpea production in the cereal-based systems, IITA recently established a research station in Kano. A cowpea breeder and physiologist based at the station will collaborate with a local institute, IAR, and Ahmadu Bello University, Samaru and with ICRISAT scientists at Kano for farming systems research in cereal systems.

Some of the specific research needs include the search for host-plant resistance to cowpea pests, which will involve three essential strategic components: (1) the refinement of existing methods and the development of new methods to identify better sources of resistance, which will require substantial research on the biology and rearing of the pests; (2) the extensive collection by the IITA Genetic Resources Unit of new germplasm, especially of wild relatives in Africa, and the intensive evaluation of both existing and new collections and of breeding materials; and (3) collaborative basic research with advanced laboratories for the study of pest biology, wide crosses, resistance mechanisms and innovative screening methods.

IITA's Interest in Collaborative Research with Advanced Laboratories

1. Biotechnology Research

   a. Interspecific hybridization in *Vigna*. IITA has identified several sources of resistance to post-flowering pests in *Vigna* species other than cowpea, *Vigna unguiculata*. So far all attempts to cross cowpea with the resistant *Vigna* have failed, interspecific hybridization in *Vigna* therefore has high priority.

   b. Embryo culture and morphogenesis. Embryo abortion before seed maturity has been consistently observed in some *Vigna* interspecific crosses. Therefore methodology needs to be developed for culture media for embryo rescue or callus culture.

   c. Gene transformation. Agrobacterium-mediated transformation systems using callus and other plant tissues need to be investigated. Further studies on CPT_1 (cowpea trypsin inhibitor gene) and BT protoxin (*Bacillus thuringiensis*) as well as novel transformation systems like DNA particle gun are warranted.

   d. Restriction fragment length polymorphism (RFLP) mapping in cowpea. We believe that RFLP mapping will greatly help us, in classical cowpea breeding in the optimization of use and management of cowpea germplasm, whereby breeders will be able to pinpoint the best accessions for crossing in the breeding program. In addition, RFLP should also assist us in determining the range of genetic diversity in the germplasm.

2. Biotic and abiotic stresses

The main research needs here are in innovative screening methods for resistance to *Striga* and post-flowering pests including cowpea storage beetle, investigation of resistance mechanisms and in identification of better sources of resistance.

Another area of need we have is in the identification of morphological and physiological traits for heat and drought tolerance.

A third area of need is in plant microbial interactions, improvement in biological nitrogen fixation.

3. Socio-economic research

Diagnostic survey of constraints and socio-economic factors underlying cowpea genetic diversity and cropping systems.

References

International Institute of Tropical Agriculture. 1988. IITA Strategic Plan 1989-2000. Ibadan, Nigeria. 108p.

International Institute of Tropical Agriculture. 1988. IITA Medium-Term Plan 1989-1993. Ibadan, Nigeria. 91p.

Singh, S. R. and Rachie, K. O. 1985. Cowpea research, production and utilization. Chichester, U.K.: John Wiley & Sons. 460p.

Grain Legume Improvement Program. 1989. Cowpea Research at IITA. Research Monograph No. 1. 19p.

Question and Answer Period: Status of Cowpea Research/IITA

Q: What is the update information on thrip resistance?

A: Four or five lines have been identified which have resistance superior to the lines in the first generation of resistance materials.

Q: Follow-up question on resistance to *Maruca*.

A: Morphopological characteristics of the plant are very important. Infestations occur first on the young, tender leaves and shoots with subsequent infestations moving to hollow plant stems. At this point the insect functions as a stem borer. Solid stem genotypes are known. This characteristic is common in wild cowpea accessions. Several changes in plant architecture have influenced the damage from this insect. The long peducules of the of the inflorescence in cultivated types are significant and most wild types have the inflorescence within the leaf canopy which increases the damage. Also a wider angle between seed pods decreased the likelihood of insect penetration.

Q: A question was raised relative to the policies for IITA established sub-programs within national research entities.

A: It is not the policy of IITA to establish funded programs at national research locations. There are, however, a few exceptions to this where it is critical to provide a level of expertise not available within the local program. One person located in Ghana was cited as an example of this special case. A more likely means of providing support to national programs would be to provide training and backstopping for teams of local researchers and thereby increase the capacity of national programs to address critical national and regional issues.

Q: What is the status of cowpea resistance to aphids?

A: Aphids are a major problem over much of the cowpea growing area of West Africa. This is true in spite of the existence of high levels of resistance in varieties adapted to the region. It is not immediately clear why there has not been a wider acceptance of aphid-resistant materials.

Q: Have regional centers (regional sub-centers of IITA) been phased out?

A: Yes. Cutbacks in funding have forced this action. The case of the regional center in Brazil was cited. As a result of these actions there has been an increase in the training of local scientists and increased program coordination between IITA and national programs.

Q: What type of cowpeas are most frequently grown in Africa; Type I or III?

A: The choice of plant growth habit varies greatly from region to region and by the ways cowpeas are used in the farmers' cropping cycle. In many cases cowpeas will be planted following more valuable crops such as corn or sorghum. It is not uncommon to find these producers selecting Type III varieties with the objective of maximizing forage production for use as animal feeds.

This discussion prompted Dr. James Oxley from the Small Ruminant CRSP to observe the significance of legume forage as an animal feed supplement during the dry season. He commented on: (1) the importance of late season production; (2) the safe storage of plants on root tops; (3) the controlled feeding of this forage as a supplement; and (4) the importance of this feed source in the reproductive cycle of animals.

Dr. Singh commented on the various bilateral projects between IITA on forage quality.

Q: Dr. Singh was asked to comment on post-harvest research in progress at IITA.

A: Numerous research and verification activities are in progress which draw heavily on practices in use in local communities. This includes the investigation of storage containers up to and including the use of old fertilizer bags, the application of oil to coat the seed, and special efforts that are in use to preserve seed stocks. An attempt is made to make accurate comparisons between low cost technologies and the technologies which may be used to protect commercial seed lots stored for food or seed purposes.

APPLYING A BENEFIT/COST APPROACH OF RATE OF RETURN ANALYSIS TO SPECIFIC CRSP PROJECTS

Lisa A. Schwartz and James F. Oehmke
Department of Agricultural Economics
Michigan State University

Overview of Evaluation of Investments in Agricultural Research

Recently, the international agricultural development community has demonstrated increased interest in assessing the returns to agricultural research and extension. In both host and donor countries, international development research is currently characterized by tight budgets and skepticism about returns to agricultural research investments. In the U.S. this financial climate has led to congressional demands for accountability, thus pressuring donor agencies to take stock of returns to ongoing projects before moving on to new initiatives. The World Bank is currently beginning a major study of its twenty-four year support of the T&V (training and visit) system of extension in developing countries. A.I.D. is funding a Michigan State University (MSU) study, in the Department of Agricultural Economics, of the use of rate of return (ROR) analysis of agricultural research projects in developing countries. This paper presents rate of return analysis as a tool to be used by researchers and administrators to facilitate both the allocation of scarce resources to research projects and to assess the returns to investment in agricultural research.

Daniels et al. (1990) review the literature on returns to research in Africa and find that quantitative studies are scarce relative to Asia and Latin America. "To date only four [ROR] studies have been identified for Africa" (Daniels et al., 1990, p.18). There is clearly a need for additional evaluative work to provide information for improving project design and implementation and to generate public sector support for agricultural research.

The latter is important because the products of research often become public goods after dissemination. That is, one person's use of an innovation, such as hybrid seed corn, cannot exclude another person from using the innovation. Furthermore, "Private firms tend to underinvest in many types of agricultural research from society's point of view because they cannot internalize many of the benefits from that research" (Norton and Davis, 1981, p.26).

From the perspective of the Collaborative Research Support Programs (CRSPs), ROR analysis provides an opportunity to evaluate and to strengthen their projects where appropriate. To this end, it is useful to generate capacity for in-house quantitative evaluation of the returns to CRSP research. This paper, which suggests guidelines for such an effort, offers a practical approach for carrying out an impact study for any given CRSP project.

Background of ROR Analysis

The first study of returns to agricultural research at a commodity level was carried out by Griliches in 1958. He calculated "the loss in net social surplus . . . [a measure of national welfare] . . . that would occur if hybrid corn were to disappear" (Norton and Davis, 1981, p.27). In his 1964 paper on the benefits of research expenditures and education of the farm labor force Griliches

concluded that such "expenditures affect the level of agricultural output significantly and that their social rate of return is quite high" (p.961). "Return" refers to the benefits which accrue: (1) to producers in the form of lower per unit costs of production and (2) to consumers in the form of lower purchasing prices for commodities.

There are various different methods used to estimate the benefits and costs which go into the calculation of the ROR. One method, developed by Schultz (1953), is to estimate the net benefits and costs associated with development and dissemination of a particular innovation(s). The benefit/cost approach yields the average annual rate of return generated by the resources invested in research. This is the approach outlined in this paper.[1]

There are other methods which separate the returns to different components of a research project. For example, the production function approach separates the effect of research from education, supply of conventional inputs or research in another geographical area (Norton and Davis, 1981). It entails the derivation of a production function including research as a variable which is then used to generate a marginal rate of return. The production function approach, first used by Griliches in 1964, requires relatively complex calculations and specific data on inputs to the production process in order to build a representative production function.

Different methods of assessing the returns to agricultural research require "different kinds of expertise and resources, especially management time; they themselves are subject to . . . [and have an impact on] . . . benefit/cost considerations" (Contant and Bottomley, 1989, p.1). Regardless of the ROR analysis method chosen, to avoid misleading results project evaluators must recognize that economic policies affecting relative prices of both farm inputs and output, subsidies and exchange rates all have an effect on the returns to agricultural research.

What is a Rate of Return?

Rate of return analysis utilizing a benefit/cost approach is a user-friendly method of assessing the returns to agricultural research projects. The concept behind the ROR is that a given investment will yield some return in the future. However, a dollar earned in the future is worth less than a dollar earned today. The ROR methodology collapses the time stream of current and future research benefits into a single measure which is easily compared to a minimum acceptable rate of return. An acceptable rate of return is based on the cost of funding; in developed countries this number is close to 10 percent. An acceptable ROR in developing countries may be higher due to inflation.

The method of calculating the rate of return using the benefit/cost approach has three components. First, the stream of benefits associated with a specific project is estimated.[2] Second, the stream of costs incurred by the project and supporting activities is estimated. Third, the estimated benefits and costs are

---

[1]For a more complete discussion of the origins of this method, see Daniels et al. (1990) and Norton and Davis (1981).

[2]The stream of benefits refers to benefits over time.

plugged into the ROR formula to determine the estimated ROR. The estimated ROR "is the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even" (Gittinger, 1982, p.329). Suggestions for carrying out the first and second components are discussed in the remainder of this paper. For details of the third component see the Appendix.

It is possible to use the ROR technique either prior to (*ex ante*) or after (*ex post*) a project has been implemented. For example, the benefit/cost approach to rate of return analysis can be used for rapid appraisal of actual project returns. Such an *ex post* evaluation was done in the CRSP Senegal impact study. The study was prepared over a period of five months using secondary data from annual reports and price data sent over a modem transfer from Senegal. Given that resources for agricultural research are relatively scarce, budget requests from research organizations can be strengthened by the inclusion of ROR estimates.

Limitations of the Benefit/Cost Approach

The rate of return as an indicator is sensitive to the estimation of benefits and costs. If the evaluator errs in assessing the benefits and costs then she will incorrectly calculate the ROR. One way to approach this task is to examine variability in rates of return under different assumptions about benefits and costs--this is called sensitivity analysis. Additionally, the method of ROR analysis chosen affects the interpretation of the ROR. The rate of return calculated using aggregate benefits and costs approach does not separate out returns to each component of the project individually. However, this method has the advantage of being relatively easy to implement and provides an evaluation of project performance in terms of economic and/or financial benefits. In order to get rates of return to individual components, the aggregate net benefits must be broken down into the benefits and costs attributable to each component.

Implementing the Benefit/Cost Approach and Tailoring it to Specific Projects

There are six steps in the process: (1) identify the key innovations and their context; (2) identify potential economic benefits and costs associated with those innovations; (3) develop an analytical framework; (4) collect data; (5) quantify benefits and costs; (6) calculate the rate of return; (7) conduct sensitivity analysis.

The first stage of an impact study is to identify the key factors which are being addressed by a given research project. In the case of the CRSP Senegal project the innovation being developed was improved cowpea varieties which, among other characteristics, have an early harvest, improved yields, resistance to drought and disease, and delayed senescence. These varieties were being developed for growth in a semi-arid climate under rain-fed agriculture where drought has been a major problem. All of these conditions were important factors related to the estimation of economic costs and benefits necessary for calculating the rate of return.

Identification of key innovations:

This first step of the process requires research goals to be broken down into specific categories. Listed below are generalized key question areas which can be used to identify relevant characteristics for consideration.

1. Seasonal factors such as length of growing season, livestock or fish production cycle, rainfed versus irrigated production and variability in food stocks.

2. Geographical factors including rainfall, elevation, slope and diversity of areas covered. Examples of additional questions are: (a) Is the innovation(s) appropriate for diverse areas or only in a specific region? (b) In the location of planned dissemination, are prices high enough to ensure returns to the investment?

3. Quality factors such as the effect of new seed varieties on the taste, caloric content and nutritive value of foods, thereby improving human health; better animal health leading to improved quality of livestock.

4. Environmental factors such as soil conservation and decreased use of chemicals.

5. Effects on transportation and storage such as resistance to storage pests or rotting.

6. Marketing, processing and infrastructural development directly related to the research project.

7. Training of staff: on-the-job, degree programs, short courses.

8. Effects on the institution building process such as increased research capacity due to infrastructural improvements and improved human capital.

9. Extension component including all dissemination activities such as radio programs, field agents, written materials, etc.

Once the relevant elements of a research project have been identified in terms of its goals and the conditions under which it functions, it is possible to proceed with the second step--identification of economic benefits and costs.[3]

Costs:

Costs are relatively easy to assess compared to benefits. The key is to identify all expenditures (both monetary and in-kind) associated with a given project.

1. Annual Research Costs such as capital, land and labor costs, personnel charges for professional and technical staff and cost of materials.

2. Duration of research (in years) is important. The length of a project is a function of:

   - complexity of the research itself: research programs which are very complex may incur higher costs because a longer period elapses before benefits are earned from increased production.

---

[3]The list of benefits and costs was developed based on Contant and Bottomley (1989) and Gittinger (1982) with additions.

- linkages to foreign research and existing domestic research programs may speed up the research project by sharing research results and the burden of funding.
- suitability and motivation of research staff (qualifications, areas of specialization, experience, incentives).
- physical research capacity.
- size and consistency of funding.

3. Costs of dissemination such as extension and the establishment of input supply channels.

4. If the new technology is costly to use, adoption and the rate of increased benefits will be slower. This is a function of:

   - financial costs to producers (are they higher with the innovation[s] and by how much?)
   - exchange rates which affect imported inputs
   - labor requirements: in terms of hours and degree of skill required
   - subsidies or taxes on inputs.

Benefits:

Benefits can be either tangible or intangible. Tangible benefits such as increased yields or livestock production or decreased storage losses are relatively easy to identify and to measure if data are available. Intangible benefits include such things as improved health, longer life, more and better job opportunities, feelings of national pride, etc. Intangible benefits may be difficult to identify and sometimes impossible to put a value on, but they should nonetheless be discussed in an impact assessment of a research program. In the Senegal impact study benefits such as improved household food security and food quality were discussed in detail although not included in the ROR analysis due to lack of data

1. Benefits related to production:

   - gross benefits (increased revenues from increased production) to producers and consumers (increased supply and lower prices)
   - increased foreign exchange earnings or savings
   - level of price supports or price controls and taxes on production which affect earnings
   - decreases in yield variability and/or price risk
   - effects on equity (gains to poor vs. rich farmers)
   - effects on food security in terms of availability and access to food
   - additional processing opportunities.

2. The ceiling on adoption or the maximum number of potential adopters:

   Adoption may be 100 percent, as it was with hybrid corn in the U.S., or far less. The adoption ceiling is particularly important when considering potential benefits prior to implementation of a research project. Factors affecting this element are similar to those considered when estimating costs of adoption:

   - farmers' access to funds for any initial investment
   - geographical and infrastructural constraints
   - education levels and age of target population
   - willingness to bear risk.

3. Length of time prior to reaching the adoption ceiling is a function of:

   - degree of "coordination between input suppliers, research, extension and output markets" affects the rate of adoption of an innovation(s) and thus the success of any given research project (Echeverria and Oehmke, 1990). This factor influences the availability, appropriateness and timeliness of credit and other inputs.
   - additional net financial benefits (gross benefits minus costs)
   - changes in required expenditures
   - technical ease or difficulty of implementation
   - changes in yield variability and/or price risk
   - farmer receptiveness to innovation and the tendency to adopt innovations in a stepwise manner rather than as a whole package
   - population pressure.

4. The longer an innovation will survive in a production system the greater the benefits society can derive from it. The lifespan of an innovation is affected by:

   - genetic and other elements of stability in the innovation
   - probability of displacement by further innovation
   - rate of pathogen mutation.

5. Benefits to human capital development can be measured in terms of monetary and non-monetary returns. The following are some factors to consider:

   - number of people trained
   - change in salary following education
   - decrease in number of foreign scientists required
   - changes in lifestyle--can be measured by surveying degree holders concerning changes in housing, leisure time, etc.

6. Intangible and indirect benefits should be listed to clarify the full effects of the research.

Data Collection Requirements

At this point of the analysis the costs and benefits have been identified but not quantified. Before moving on to steps three through six it is useful to discuss the data requirements of rate of return analysis. Quantitative techniques are only as good as the quality of data fed into them. Availability of data in developing countries is frequently a major constraint to the use of more precise evaluation techniques. However, the minimum data requirements for the average rate of return approach are relatively few compared to other methods. The actual data collection process should follow the identification of specific benefits and costs to be estimated and the development of an analysis framework to avoid wasting time collecting unnecessary data. Several considerations must be made prior to data collection such as how is it be collected, from where and by whom.

Specific types of data required for estimating tangible benefits include: prices for relevant commodities, both traditional and innovative (different seed varieties, animal breeds), yields (with and without) the innovation of plants, fish or number of animals, and area devoted to both new and traditional varieties, methods and practices.

To estimate costs, all expenditures contributing to the project, both in cash and in-kind, should be tallied. Investments in extension and research could be added up separately to distinguish between expenditures on technology generation versus transfer. Prices for traditional inputs are needed as well as costs of supporting services.

The CRSP Senegal study used secondary data from annual reports and articles as well as price data sent electronically (via modem) from ISRA (Senegalese Institute of Agricultural Research) in Senegal. The relatively easy access to price data made possible by the modem illustrates the importance of maintaining even a basic computerized and coordinated data base. Individual projects must decide what is the best method to facilitate ongoing evaluation and information transfer both inside an individual research institution and between institutions. To this end projects should establish consistent methods of data storage and selection of hardware and software in order to develop compatibility of data systems across projects, thus building a CRSP data base.

There are two main advantages to establishing a CRSP data base: (1) data would be available in a convenient form for comparative analyses of projects within one CRSP or characteristics of projects across CRSPs; and (2) the large sample of research projects available for benefit/cost analysis would allow improved insight into how different factors will affect research under diverse conditions. Of course, the benefits and costs of establishing such a data base should be estimated before implementation.

Analysis of Data

The third, fourth and fifth steps in the overall assessment process are to set up a framework for data analysis, collect the data and specifically quantify costs and benefits for the project. This analysis of data is done in order to calculate the rate of return--step six.

The process of quantifying benefits and costs involves the aggregation of data to determine net benefits. For example, the value of benefits arising from adoption of a new seed variety are assessed by calculating the area devoted to the variety and multiplying that number by the yield and their price which the variety is expected to earn, thus yielding gross returns. The costs of adoption then "consist of the costs of growing the new variety (extra fertilizer, labor, other inputs as well as the cost of improvements in services) minus the costs of growing the old variety, or other commodity previously produced on the same land" (Contant and Bottomley, 1989, p.27). The gross benefits minus the costs equal net benefits.

A technique for clarifying the process of quantifying costs and benefits is to set up a word equation which clearly delineates the changes resulting from the introduction of an innovation.[4] The following example was developed based on the CRSP Senegal impact study (Schwartz et al., 1990).

(1) <u>Changes which increase benefits</u>
[hectares planted to improved cowpeas x yield x price] - [input costs] = gross benefits

---

[4]This format used for the "word equation" is actually a partial budget.

(2) Changes which decrease benefits
[hectares planted traditionally to peanuts x yield x price] + [hectares planted traditionally to cowpeas (old varieties) x yield x price] - [traditional input costs] = opportunity cost of land

(1) - (2) = (3) net benefit of production changes

(4) Costs of research and technology transfer

(3) - (4) = (5) net benefit to all investments in cowpea research and "operation cowpea"

There are other benefits to the CRSP Senegal project which were discussed in the impact study but not included in the calculation of the rate of return due to a lack of specific data. A key element not included is the caloric and nutritional contributions of cowpeas to the diets of people in Northern Senegal. There simply were not enough data available on household consumption to include these benefits in the calculation. However, when such data are available they can be included.[5]

An additional technique for establishing an analysis framework is to set up a table with the benefits and costs and discount rates shown clearly. Data are collected based on what is needed to fill in the table. Tables can be modified relatively easily to suit availability of data. For the sixth step the data is entered into a suitable software program, such as LOTUS 1-2-3 or MSTAT, and the ROR is calculated.

Finally the seventh step, sensitivity analysis, is used in order to estimate the relative returns to investments in a research project under conditions different from those originally considered: higher or lower prices, yields, etc. As Evenson points out, it is necessary to "make some assumptions regarding the continuation of the benefit stream beyond the period of analysis" (Evenson, 1988, p.52). Sensitivity analysis is useful for approximating the effect of changes in key variables over time. Sensitivity analysis requires recalculation of benefits, costs and rates of return under different scenarios which may reflect actual situations.
For example, benefits will be different if an increase in yield is attributable 100 percent to research versus 50 percent to research and 50 percent to increased rainfall.

Application to the CRSP Senegal Impact Study

In the CRSP Senegal study there were two major elements of the project around which questions were structured. First, food security and seasonal fluctuations in food supply were considered. The factors affecting food security were identified as seasonal variations in prices and yields; variation in price across markets and geographical variation in price; and changes in the quality of food produced. The Senegal study used average prices from several varieties of cowpeas but focused on one region (Louga).

The Senegal study compared the possible combinations of benefits accruing from new innovations under differing conditions and in different seasons. It looked at how cowpeas can provide green pods for food during the period of the hungry season and early grain before the main harvest. Additionally, cowpeas can be planted in drought years when alternative crops such as peanuts failed entirely.

[5]In the case of a nutrition research project, household consumption data with and without research innovations will be the primary input into the ROR calculation.

The second major element included in the assessment of costs and benefits was the scientific training component. It was quantitatively analyzed based on the cost of education versus the cost of importing expertise and returns to training in terms of monetary and non-monetary benefits.

The benefits and costs from both research and training were entered into tables and the rate of return computed to be 63 percent, sensitivity analysis indicated that this rate of return did not change much even when the assumptions concerning benefits and costs were varied somewhat (see Schwartz et al. for details).[6] One reason for the high rate of return was the important function that short-cycle cowpeas served in the farming system of providing food during the hungry season. The benefits from the innovation represented a change from zero food under low rainfall conditions.

Conclusion

Some ROR calculations can be very complex, however the relatively simple benefit/cost approach to calculating a rate of return is user friendly in that it has minimal data requirements and can be carried out with easily accessible software such as LOTUS 1-2-3. It should be recognized that to use more complicated methods is more costly but it is also more accurate and informative. However, there is no universally perfect method for assessing returns to research and there are clear advantages to a user friendly approach with relatively limited data, funding and time requirements. The key reason for using quantitative methods for analyzing costs and benefits and calculating rates of return, based on estimates or actual data, is to assess the viability of proposed research or the value of disseminated innovations in terms of their contribution to social welfare based on economic measures.

Levels of acceptable rates of return are typically established by donor organizations funding research projects--A.I.D. uses a rate of approximately 11 percent, the World Bank uses a range of 8 percent -15 percent.[7] In considering the value of a project there are often benefits which are difficult to quantify for reasons of lack of data and/or theoretical framework. However, these elements should not be ignored. Useful impact studies must include a clear explanation of both quantifiable and non-quantifiable benefits if they are properly to assess net social benefits of research.

This paper provides an introduction to using the benefit/cost approach of rate of return analysis and provides a framework for carrying out an impact study using the ROR method. Additional resources required for the actual implementation of such a study are a computer or programmable calculator (plus manual) and some additional technical references.

---

[6]The GAUSS software package was used.

[7]These rates are based on the assumed opportunity cost of capital or the return to the next best alternative investment. As it is difficult to know the actual opportunity cost of capital, acceptable minimum rates of return are based on the cost of funding.

References

Contant, Rudolph B. and Anthony Bottomley. 1989. Manual for Methods of Priority Setting in Agricultural Research and Their Application. The Netherlands: ISNAR.

CIMMYT. 1987. From Agronomic Data to Farmer Recommendations. El Bacan, Mexico: CIMMYT.

Daniels, Lisa, Julie Howard, Mywish Maredia, James F. Oehmke and Richard Bernsten. 1990. Assessment of Agricultural Research: *Ex-Post*, *Ex-Ante*, and Needed Methodologies. East Lansing, Michigan: Michigan State University.

Evenson, Robert E. 1988. Human Capital and Agricultural Productivity Change, Proceedings of the International Conference of Agricultural Economists. IAAE. Beunos Aires, August 24-31,

Gittinger, J. Price. 1982. Economic Analysis of Agricultural Projects, 2nd edition. Baltimore: Johns Hopkins University.

Griliches, Zvi. 1964. Research Expenditures, Education, and the Aggregate Agricultural Production Function. The American Economic Review LIV(6):961 -974.

Norton, George W. and Jeffrey B. Davis. 1981. Evaluating Returns to Agricultural Research: A Review. American Journal of Agricultural Economics 63:685-699.

Ruben G Echeverria and Oehmke, James F. 1990. Sequential Evaluation of Agricultural Research, Staff Note No.90-83. Netherlands: ISNAR.

Schultz, T.W. 1953. The Economic Organization of Agriculture. New York: McGraw-Hill.

Schwartz, Lisa A., James A. Sterns and James F. Oehmke. 1990. Impact Study of the Bean/Cowpea CRSP for Senegal. East Lansing, Michigan: Michigan State University.

APPENDIX

The equation used to calculate the rate of return looks like this:

$$\sum_{t=0}^{n} \frac{B_t - C_t}{(1 + r)^t} = 0$$

To compute the IRR, solve for r. Σ indicates a summation from the beginning of the project to some future point in time (n = # of years); (B) - (C) represents the difference between benefits and costs; and $(1+r)^t$ serves to discount the stream of net benefits over time where t = time and r = the rate of return which makes the above equality hold.[8]

When aggregating the time stream of net benefits, weights can be used to attribute greater importance to returns to research which directly improve the welfare of targeted groups. For example, it may be appropriate to attach heavier weights to benefits to poorer farmers in order to take account of a desire to favor those research projects which are likely to benefit the poor (Contant and Bottomley, 1989, p.23).

---

[8]r equals the rate at which the present value of benefits equals the present value of costs. At this point, the rate of return indicates that a project is earning returns equal to the next best alternative investment.

OVERVIEW OF BEAN RESEARCH ACTIVITIES

G. S. Abawi and J. F. Weeden
Departments of Plant Pathology and Horticulture Sciences
Cornell University

The bean pathology projects have been a major component of the research program directed by George Abawi since 1972. Detailed studies have been conducted on the biology and epidemiology of several fungal and nematodal diseases of beans. The overall objective of the program is the development of integrated control measures that are effective and economical, and contribute minimally to environmental pollution. Fungal diseases investigated included web blight, white mold, Alternaria pod-flecking, Fusarium wilt, charcoal rot, and root-rots incited by species of *Rhizoctonia*, *Fusarium*, *Thielaviopsis* and *Pythium*. Nematode diseases of beans which were studied were those caused by the root-knot and lesion nematodes. Recently, bean research projects have emphasized the impact of cultural practices on disease severity, development of germplasm screening procedures, and the identification of sources of resistance to a number of bean pathogens. In cooperation with CIAT scientists and with the contribution of thesis research by two Ph.D. graduate students, several sources of bean germplasm with resistance to *Thanatephorus cucumeris* and its anamorph *Rhizoctonia solani*, *Macrophomina phaseolina*, *Fusarium oxysporum* f. sp. *phaseoli* and *Meloidogyne* spp. (root-knot nematodes) have been identified. Current research efforts include characterizing the identified resistance factors, elucidating their inheritance, determining the races of Fusarium wilt pathogen that exist in Latin America, investigating the role of root-knot nematodes in modifying the reaction of Fusarium wilt susceptible and resistant bean cultivars, and biological control of selected fungal and nematodal bean pathogens.

The research program being directed by Norman Weeden has a strong commitment to the genetics, genetic diversity, and systematics of *Phaseolus* and related genera. Allozyme polymorphism has been used to distinguish cultivars of white seeded beans and to establish genetic markers and linkages in the common bean. Several studies are currently being performed in Weeden's laboratory, including a survey of allozyme and chloroplast DNA polymorphism in African *Vigna*, RFLP mapping of the *Phaseolus* genome, analysis of the glucosephosphate isomerase genes in *Phaseolus*, and a search for genetic markers for several commercially important characters (resistance to *Macrophomina*, photoperiod genes, etc.). A relatively low variability was found among the cultivars of cowpea, but high levels of variability was found in the closely related taxa examined including the other subspecies of *Vigna unguiculata*.

The above mentioned bean research programs are only part of the overall bean research being conducted by several faculty in Plant Pathology, Horticultural Sciences, Entomology, Plant Breeding, and Vegetable Crops at Cornell on the Geneva and Ithaca campuses.

RESEARCH INTERESTS

Paul Gepts
Department of Agronomy and Range Science
University of California-Davis

The overall, long-term goal of my program is to investigate the genetics of bean species in the *Phaseolus-Vigna* complex. This research orientation combines both basic and applied research as well as field and laboratory experimentation and is intended to provide both genetic information and genetic materials to the California bean breeding program in collaboration with Dr. S. Temple. Currently, the activities of my program are organized along three research orientations:

Organization of genetic diversity in bean species:

I seek to determine how to characterize and where to find genetic diversity in the primary gene pools of principally common bean (*Phaseolus vulgaris*), but also tepary bean (*P. acutifolius*), runner bean (*P. coccineus*), lima bean (*P. lunatus*) and cowpea (*Vigna unguiculata*). Analyses of molecular markers such as seed proteins and allozymes reveal that, in all species, domestications appear to have induced a genetic bottleneck at the molecular level, indicating that wild ancestors may contain a significant store of additional variability not represented among cultivars. In certain species, cultigens resulted from multiple domestications (*P. acutifolius*, *V. unguiculata*). The multiple domestication finding is particularly significant in that both common and lima bean cultivars belong to two evolutionary divergent components of their primary gene pool (Mesoamerican vs. Andean). Results from common bean indicate that this divergence includes not only molecular markers, but also morphological traits (e.g., growth habit), and agronomic traits (e.g., disease resistance). Further analyses, in collaboration with Dr. S. Singh at CIAT, have shown that it is possible to divide the Mesoamerican and Andean components into smaller groups on the basis of phaseolin type, allozymes, morphological traits and agronomic characters (e.g., disease resistance, phenology, adaptation). Identification of these groups will help in establishing core collection within the *Phaseolus vulgaris* gene banks and help breeders select parents for crosses.

Current projects in this area include: (1) identification of hypervariable DNA markers for population genetic studies; (2) molecular evolution of phaseolin in *P. vulgaris*, *P. lunatus*, and *V. unguiculata*; (3) segregation and linkage in inter-gene pool crosses within *P. vulgaris*; (4) genetics of morphological and photo-period differences between wild and cultivated *P. vulgaris*; and (5) diversity of cpDNA and nuclear DNA sequences in *P. coccineus*.

Mapping of the common bean genome:

My objective is to establish a linkage map of the common bean genome that integrates molecular markers (principally RFLPs) and agronomic traits, including growth habit and other morphological differences distinguishing wild and cultivated types, earliness, drought and low soil phosphorus tolerance, and disease resistance (BCMV: I, anthracnose, angular leafspot, rust, and common bacterial blight). In collaboration with Dr. S. Singh (CIAT), four recombinant inbred population (RIPs) have been established that segregate for the traits mentioned. The advantage of RIPs is that they allow both quantitative and qualitative traits to be analyzed and the data can be accumulated on the same

genotypes. Based on the high levels of polymorphisms that can be detected between the parents, we expect that within two to three years we will have a complete map (average distance between markers: 20cM; numerous factors for agronomic traits located on the map). An additional project in this area involves the mapping of all known anthracnose resistance genes in collaboration with H. Bannerot and M. Dron (France).

Genetics of heat tolerance in common bean:

The objective of this research is to determine the genetic control of heat tolerance at two reproductive development stages that appear to be very susceptible to heat stress: early bud development and pod fill. Results from field and growth chamber experiments indicate that, for both stages, tolerance to heat stress involved a high number of genes with, in some cases, dominance and epistatic interactions and possibly maternal effects. For bud abortion one factor, correlated with the indeterminate growth habit, appeared to have a major effect on heat tolerance. This observation raises the possibility that California kidney cultivars, which are currently determinate, should be converted into indeterminate cultivars. Further analyses showed that both traits exhibited significant general combining ability, indicating the opportunity for gain from selection. Significant specific combining ability for bud abortion indicates that specific cross combinations rather than crosses among tolerant parents may be important for this trait.

For further information, contact P. Gepts: Department of Agronomy and Range Science, University of California, Davis, CA 95616; Phone: (916) 752-7743, 752-1703; Fax: (916) 752-4361.

RESEARCH INTERESTS

Robert L. Gilbertson
Department of Plant Pathology
University of California-Davis

One of the overall goals of my research program is the development of innovative plant disease management strategies utilizing plant disease resistance and cultural practices, with particular emphasis on plant pathogens of the common bean, *Phaseolus vulgaris*. The specific areas of research that my program emphasizes are ecology, epidemiology and plant disease resistance. To accomplish these research objectives, my research program will utilize traditional approaches as well as the more recent tools of molecular biology. Because I will be initiating my research program at the University of California beginning October 1, 1990, I will provide a synopsis of my research interests and accomplishments while at the University of Wisconsin at Madison.

Common bacterial blight:

My efforts on common bacterial blight of beans caused by *Xanthomonas campestris* pv. *phaseoli* (*Xcp*) have involved studies on plant disease resistance, ecology and epidemiology, rapid and specific detection of *Xcp*, and study of the genetic diversity of *Xcp*. I developed a new method for inoculating beans with *Xcp* that is particularly for developing countries and studied the survival of *Xcp* in bean debris in various tillage systems. In the course of this research, I discovered a pectolytic xanthomonad that colonizes bean debris but is not pathogenic to beans. To rapidly differentiate *Xcp* from other bacteria recovered from beans and bean debris, I developed a DNA probe based on plasmid DNA from *Xcp* and developed methods for application of this DNA probe to various studies of *Xcp*, including the first use of squash blot hybridization for detection of plant pathogenic bacteria in plant tissue. I have been using restriction fragment length polymorphism (RFLP) to analyze the genetic diversity in populations of *Xcp*. I plan to continue studies on the genetic diversity of *Xcp* using RFLPs and the polymerase chain reaction. Of particular interest is a repeated DNA sequence isolated from a *Xcp* plasmid that may be an insertional element. Some of my future effort will be involved in the characterization of this element and its use as a DNA probe.

Bean golden mosaic geminivirus:

The objectives of this multicomponent research project have involved the molecular characterization of bean-infecting geminiviruses from Central South America and the Caribbean, the rapid and specific detection of these viruses with DNA probes, and the development of transgenic beans with resistance to these viruses. I developed methods for isolating and cloning geminivirus DNA directly from infected plants and cloned the entire bipartite genome of three bean-infecting geminiviruses. I conclusively demonstrated that an isolate of bean golden mosaic virus (BGMV) from Brazil was genetically distinct from isolates from Central America and the Caribbean and have proposed a theory of divergent evolution to explain the origin of the distinct BGMV isolates. I developed squash and dot blot hybridization methods for rapid and specific detection of these viruses in plants and insects. With colleagues at the University of Wisconsin and Agracetus Company, Inc., we demonstrated the infectious nature of cloned geminiviral DNA in beans using electric discharge particle acceleration.

My research program at the University of California will include the continued application of molecular methods for studying the diversity of plant pathogens and continued development and application of DNA probes for detection of plant pathogens. This would include, but not be limited to, the above mentioned pathogens. I will also continue research on the influence of cultural practices on plant pathogens and plant diseases and various aspects of plant disease resistance, with emphasis on novel methods.

RESEARCH ON DRY EDIBLE (*PHASEOLUS*) BEANS

K. Grafton, J. Venette, A. Lamey, and P. McLean
Departments of Crop and Weed Sciences
and Plant Pathology
North Dakota State University

The bean breeding program has focused on developing early maturing, day-neutral, upright and disease resistant cultivars that support effective nodulating bacteria and produce seeds that meet market quality standards. Crosses among adapted and exotic germplasms provided variability from which advanced genotypes with these superior characteristics were obtained using traditional backcross, pedigree and recurrent selection schemes. Many of these are undergoing advanced field tests and some are being increased for release as new cultivars. These genotypes and others are vigorously tested for resistance to many diseases including rust, white mold, bacterial blights and BCMV. Germplasms with genes pyramided for resistance to rust were released. White mold resistance is screened in field disease nurseries, and physiological resistance has been implicated as an integral component of the field resistance through novel laboratory screening techniques. The program includes identifying genes that control rate and duration of seed fill as it relates to earlier maturity.

The pathology program deals with biology and control of fungal and bacterial pathogens. Fungicides and biocontrol agents are routinely tested for efficacy as seed treatments. Each year, fungicide sprays are evaluated for control of foliar diseases. Studies have shown that pH influences the activity of fungicides, especially copper l. oxide which, acidified, becomes significantly more effective in control.ng bacterial blight. Field and greenhouse studies have shown that nitrate and calcium fertilizers can reduce severity of white mold and bacterial diseases. An exponential inoculator was developed and successfully used to identify partial resistance to white mold in greenhouse screening tests. A seed test which quantitatively detects bacterial contamination in seed beans has been developed and is routinely used in the Seed Health Testing Laboratory.

The extension plant pathologist conducts annual grower surveys on the problems and practices in growing dry beans in North Dakota and Minnesota. The results of these surveys have had major impact on research direction and government regulation. Extension field trials have shown that banded application of fungicide improved control of white mold and reduced costs. Predictive models based on weather parameters and crop development have been tested in the control of bean rust.

Work in biotechnology has led to the regeneration of dry bean through redifferentiation of cotyledonary node nonmeristematic cells. Somaclonal variants (96) were evaluated for variation in mitochondrial DNA by digesting the DNA with restriction endonucleases, separating the fragments on agarose gel, Northern blotting and probing with cosmids containing mitochondrial DNA. No variation was seen, nor was variation observed when 250 somaclones were evaluated in field trials. A pink-seeded pinto somaclonal variant was evaluated for gene action, and results suggest the line may possess unique methods of generating the pink color. Dry bean shoot tips from embryos have been reliably micropropagated.

ASIAN GRAIN LEGUMES NETWORK

J. P. Moss
Legumes Cell Biology Unit
ICRISAT

The Asian Grain Legume Program was established with ICRISAT funding and a coordinator appointed on January 1, 1986 with a mandate to work on chickpea, pigeonpea and groundnut. Known subsequently as the Asian Grain Legumes Network (AGLN), it provides bilateral connections with ten Asian countries (Bangladesh, Indonesia, Myanmar, Nepal, Pakistan, the Peoples Republic of China, the Philippines, Sri Lanka, Thailand and Vietnam). India is also a member and has a special consultancy role. These bilateral arrangements are based on Memorandums of Understanding (MOUs) with each country, an AGLN-country coordinator in each country, and work plans agreed upon by regular review and planning meetings in each country. These plans facilitate interchange of material, staff and information between ICRISAT and each country. They also identify and support training activities at ICRISAT and in-country. In essence the AGLN supports ICRISAT's Legumes Asian regional program. The Asian Development Bank has provided support for AGLN activities in four south Asian countries and is expected to extend that support to AGLN activities in all network countries. Also, adaptive research projects involving ICRISAT input in specific countries are supported by special funding. The AGLN also facilitates strong multilateral connections among its member countries through activities such as workshops, monitoring tours and working groups. These working groups are essentially sub-networks which focus on a specific problem such as Peanut Stripe Virus or Agroclimatology. They bring together specialists from many countries who do collaborative research to solve the specific problems of the working group.

An important component of the network has been interaction with other groups active in legumes research in the region such as ACIAR, ARFSN (IRRI), AVRDC, CIDA, CGPRT, FAO/RAPA, ICARDA, IDRC, IITA, USAID and Winrock International.

The main purpose of the AGLN is to strengthen NARS through bringing its member scientists together to solve problems in member countries. The AGLN facilitates and supports the activities of its members.

EFFECT OF WATER DEFICITS ON THE GROWTH AND PHYSIOLOGY OF DRY BEAN VARIETIES

A. Nuñez-Barrios, J. T. Ritchie, A. J. M. Smucker
Department of Crop and Soil Sciences
Michigan State University

In Michigan, two contrasting dry bean varieties (seafarer and [a water stress adapted] lef-2rb) were grown in a rainout shelter facility under different water stress conditions. The timing of the stress was set at early vegetative stage and 50 percent flowering. A well irrigated control was maintained near the drained upper limit during the experiment. Plant growth measurements, neutron probe, minirhizotron camera and photosynthesis readings were made during the experiments. In both varieties, water deficits significantly diminished leaf area index and plant height. There was also evidence that the dry weight of branches was reduced much more than that of the main stems. The effect of water stress on the dry weight of leaves and branches was mainly observed in the first four nodes of the main stem. Photosynthesis rate was higher for lef-2rb, but stomatal conductances were greater for seafarer. Leaf area index reached higher values for lef-2rb giving a greater percentage of light interception and hence, greater accumulation of dry matter. Pod number was significantly affected under stress, diminishing in 82 percent and 75 percent for seafarer and lef-2rb respectively. Total seed weight was reduced by the water deficit in both varieties. A decrease of 35-40 percent was observed when the stress was imposed during the vegetative stage and 64-74 percent when imposed during flowering. Root growth was greater for lef-2rb as compared to seafarer. This difference was mainly due to the number of branches. On the other hand, the general patterns of root growth were similar. In the stress treatments, maximum rate of root number occurred at the time of pod initiation, and this was significantly greater than the control. Also higher proliferation of root branching was monitored in the stress treatments, along with higher root turnover ratios.

Greater photosynthesis rates, better patterns of light interception, and higher root branching may increase productivity under water deficit conditions. These are traits to be considered in the future research of genetic programs.

STATEMENT OF RESEARCH INTERESTS

Steven R. Temple
Extension Agronomy
University of California-Davis (UCD)

The long-range goals of my program are to identify, through agronomic evaluation and plant breeding, legume genotypes and production technology that result in safe and affordable food produced in a socially responsible manner.

During the eleven years I worked on germplasm development and bean breeding at CIAT, my focus was heavily oriented toward the following objectives: (1) closing the large gap between demonstrated physiological yield potential and farmers' yields; (2) increasing yield stability in difficult environments by incorporating combinations of key stress resistance factors into locally-preferred grain and plant types; (3) improved durability of host plant resistance to genetically variable diseases like bean rust and bean common mosaic virus (BCMV); and (4) development of breeding and selection schemes designed to retain substantial residual genetic heterogeneity in cultivars as a hedge against the demands of variable local growing conditions. During my last four years at CIAT I dedicated significant time/effort to "decentralizing" the selection and testing process away from Colombia and toward national programs.

With my move from CIAT to UCD four years ago, I assumed programmatic responsibilities for sugarbeets, oil crops and alternative crops, which left little time or mandate for legume research. During that time I planted two large nurseries of introduced *P. vulgaris* germplasm from international programs, and I evaluated the agronomic potential of winter and summer legumes (particularly the sweet white grain lupin) for California rotations. In 1989 I was assigned a statewide extension specialist role for grain legumes, including the mandate to lead the statewide field testing program for cowpeas, common and lima beans, and chickpeas.

My research is focused on the genetic improvement and breeding of common and lima beans, placing emphasis on the following:

1. Reduced dependency on external production inputs
2. Improved host plant resistance to *Lygus*
3. Reduced susceptibility to nematodes
4. Better tolerance to drought and high temperature
5. Improved nitrogen fixation
6. Better quality grain type (canning, nutrition and reduced flatulence)
7. Increased seedling vigor and competitiveness and better plant size and stature.

I am active in LISA research and contribute as a co-Principal Investigator on a large rotation systems research project that features both common bean and grain lupin as components in the transition from conventional to low input and organic production systems. I will continue to evaluate the potential of existing and novel legume germplasm to meet the new demands of more sustainable cropping systems. California has climatic diversity covering virtually the entire range of world *Phaseolus* environments. This is a challenge and an opportunity that Paul Gepts and I are addressing in the UCD legume program, which has a long tradition of serving this state and bean producers around the world with improved

varieties for a number of bean classes and species. We share the opinion that heretofore underexploited genetic diversity has the potential to contribute measurably toward the attainment of those legume improvement goals cited above.

A very important part of the applied effort to accomplish these goals depends upon close working ties with plant pathologists, entomologists and nematologists. A *Lygus* screening and selection nursery is planned for May 1990 at the Kearney A. Field Station, working with legume researchers from UC-Riverside (UCR) and UC-Berkeley (UCB) entomologist Dr. Charles Summers. Recent collaboration with UCR nematologist Phil Roberts on nematode screening will be expanded to include screening and reselection for severed bean classes. Paul Gepts and I have written a W150 IPM grant proposal with Phil Roberts of UCR and UCD nematologist Ed Caswell. Plant pathology contributed to our 1988 and 1989 work with information on the distribution and virulence of *Fusarum oxysporum* races, emphasizing chickpeas and cowpeas. In 1990 I will continue to collaborate with UCB pathologist Dr. Shirley Smith, and at UCD in the seedling disease work of Dr. Jim DeVay. The arrival of Dr. Gilbertson later this year presents many new opportunities. I feel very comfortable in this type of collaborative research after years of similar, productive work in Colombia.

Further information may be obtained by contacting Steven R. Temple, Agronomy and Range Science Department, University of California at Davis, 95616, telephone (916) 752-8216.

GENOME MAPPING IN COWPEAS WITH RFLPs

Nevin Dale Young
Department of Plant Pathology
University of Minnesota

Restriction fragment length polymorphisms (RFLPs) are a powerful, new technique for understanding and manipulating the genetics of important crops species. Using RFLPs, scientists can pinpoint the best individuals for breeding, estimate diversity in germplasm collections or uncover the map locations of polygenic traits. Molecular biologists can even use RFLPs to clone genes that underlie important traits, such as disease resistance, stress tolerance or yield. Because of its many applications, RFLP analysis is now considered an essential component for effective management of crop research and breeding programs.

Cowpeas (*Vigna unguiculata*), along with many other species of this legume genus, are important as major sources of protein for some of the world's poorest people. In some parts of Africa, for example, more than half of the plant protein in human diets is provided by cowpea. Cowpeas are moderately drought tolerant and can be grown in a wide range of environments throughout the tropics. Like all legumes, cowpeas fix nitrogen and therefore enrich the soil directly or as green manure. From a research perspective, cowpea and other *Vigna* species are ideally suited to RFLP analysis because their genomes (ensemble of chromosomes) are very small in size and simple in organization. Considering this fact, along with the importance of cowpeas in world agriculture, it is surprising that no RFLP map has yet been constructed for cowpeas of other *Vigna* species.

As part of a long-term commitment to genome mapping in *Vigna*, a group of scientists at the University of Minnesota, directed by Dr. Nevin Dale Young, has recently begun developing an RFLP map for cowpea and other *Vigna* species. This research is a first step leading to the long-range goal of using RFLPs to improve disease resistance, stress tolerance, quality and yield of cowpeas and to assist in management of germplasm collections of *Vigna* species. The immediate goal of this research effort is to map and characterize genes controlling resistance to major pathogens of cowpeas.

At the University of Minnesota, we have isolated DNA from cowpea and a wide range of *Vigna* relatives, prepared "Southern Blots" for molecular analysis and developed cloned genomic libraries as sources of "probes" for RFLP mapping. We have set up collaborative arrangements with scientists working on the classical genetics and breeding of *Vigna* at several international institutions, including the International Institute for Tropical Agriculture (IITA) in Nigeria, the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, and the Institute for Plant Breeding (IPB) in the Philippines and have also corresponded with cowpea researchers throughout the United States.

Collaborations with international agricultural research centers will make it possible to apply the RFLP map to ongoing research and breeding programs in the developing world. RFLPs can be used to determine the map location of genes controlling disease resistance, stress tolerance and important agronomic traits and thereby identify the best individuals for breeding through genotypic selection.

It is fortunate that cowpeas, a crop that is so important to international agriculture, is also so well suited for the application of modern biotechnology. An RFLP map for cowpea is an essential tool that should be an integral part of future work in this important crop species.

Discussion Group: Ethical Issues in Research

Discussion Leader: Wayne Adams

Rapporteur: Rafael Rodriguez

Three main areas were addressed.

1. Genetic resources as it refers to loss of biodiversity, exchange between researchers and countries and consequences of proprietary claims by the means of gene patenting.

   a. It was concluded that germplasm is a common good just as the air or the seas. Therefore, preservation, evaluation and exchange should be free. Respect to these countries where collections are made should be shown by sharing and respecting their regulations.

   b. Development of innovation in the form of better cultivars is of interest of all people. The cultivar patenting system works towards encouraging innovation. Free exchange is a key issue and every effort should be made to protect and stimulate it.

   c. On the other hand, we believe gene patenting works against innovation, free exchange and against authorization for further collection of biodiversity.

2. Defining research objectives, means to develop it and way of results release may touch sensitive areas.

   For example:

   - Creating dependency in use of agrochemicals which were previously not needed (including banned ones).

   - Pressure for release of not-sufficiently-evaluated cultivars or methodologies, which can result in failure with consequences of liability and discredit of CRSP researchers.

   - Studies involving humans, like in nutrition, might result in hurting social precepts, etc.

   It was concluded that since there are not two issues alike there cannot be effective regulations to control these problems. Instead, we believe ethics should be the guiding principle. But since the differences between ethical and unethical varies due to culture, professional knowledge, etc., ethics have to be defined multidisciplinarily, considering those which are involved in or affected by the research.

3. How should the CRSP define its fields of research? We should follow the CRSP Global Plan as a baseline for the definition of research priorities. The best answer is that arising from the study of the needs to be addressed by multidisciplinary teams keeping the balance of the Global Plan, the Host Country and the U.S. (funding source) defined responsibilities.

Recommendations to the CRSP:

1. Researchers need to continue the free exchange of germplasm.

2. Multidisciplinary research teams need to be utilized to address our research problems. Issues of ethics also need to be addressed by multidisciplinary teams.

Discussion Group: Biotechnology in Developing Countries

Discussion Leader: Nevin Young

Rapporteur: Paul Gepts

Dr. Young introduced the subject by reminding us that biotechnology consists of a series of techniques, including:

1. Gene cloning
2. Molecular probes: disease diagnosis, genetic characterization of host plant and pathogens or pests
3. RFLPs: genetic information on linkage, marker-based selection
4. Tissue culture: several techniques including vegetative propagation, somaclonal variation, and transformation and regeneration (transgenic plants)
5. Reproductive biology: sex changes in fishes, male sterility in plants
6. PCR (polymerase chain reaction): diagnosis, RFLPs
7. Development of vaccines
8. Information technology

Some of the potential issues regarding biotechnology in developing countries are as follows:

1. Networking between developed and developing countries
2. Education of developed and developing country scientists
3. Biosafety; social and economic implications
4. Transferability of the various techniques
5. Decision-making process: when and how to use biotechniques vs. conventional techniques
6. Biotechnology and low-input sustainable agriculture

After some discussion, the group settled on three issues:

First Issue: Decision-making process. Whether or not a problem will be solved using biotechniques, or conventional techniques, will depend on:

1. Feasibility
2. Economics: relative costs
3. Timeliness

In certain cases, a systems approach (e.g., change in cultural practices) will be more appropriate than either a biotechnique or a conventional genetic approach.

Second Issue: Networking between developing and developed countries. This is a very important but also complex issue; only two preliminary aspects were discussed within the time allotted for this discussion session.

1. Information network: There should be an information network where scientists could obtain information on what type of biotechnology research is being done, where and by whom.

2. Education: In order to promote the establishment of networks and the understanding among scientists participating in the network, there should be some type of education in two directions:

   a. Scientists involved in biotechnology in developed countries have to become aware of the possibilities or needs in LDCs

   b. Scientists from LDCs can gain an education in biotechnology which can take place in several ways: (1) formal training: Ph.D., M.S., these can be degrees devoted exclusively to biotechnology applied to developing countries (e.g., M.S. degree of the University of Brussels supported by the Belgian government) or existing degrees (e.g., genetics, plant pathology) that incorporate a biotechnology component; (2) workshops with LDC scientists (e.g., 8th Annual Symposium in Kenya on Animal Diseases organized by the Small Ruminant CRSP); and (3) faculty exchange: quarter, semester, or full-year sabbaticals.

The need for continuing education was expressed to allow LDC scientists to remain up-to-date on the latest developments in a field.

The group did not get time to discuss other topics such as the establishment and management of research networks.

Third issue: Biosafety. It is good that there are two types of recombinant DNA organisms or molecules:

1. Those used as reagents within a lab; they have usually been designed to have limited survival outside the test tube
2. Those used in field conditions: microorganisms, animals, plants

The concerns about biosafety relate to the latter class of organisms. The risks involved with those organisms need to be assessed on a case-per-case basis. For example, risks of uncontrolled gene flow may be higher with microorganisms than with plants. Among plants, this risk is higher for those plants with sympatric wild relative, etc.

Specific concerns were raised regarding biosafety regulations in LDCs:

1. How to establish regulations in LDCs
2. How to monitor for compliance
3. Large variation in the degree of expertise among LDCs
4. If a technique is determined to be safe in developed countries, is it also safe in developing countries and how do we determine this?

In addition, regulations within developed countries are not very well developed as yet (e.g., release of vaccines).

Hence, the big question from the viewpoint of CRSP (or other institutions) is: which regulations will an investigator have to follow if he/she wishes to test a genetically engineered organism in field conditions in an LDC in the absence of regulations in that country and incomplete regulations in developed countries (e.g., the U.S.)?

Recommendations to the CRSP:

1. Determine which information networks are available on biotechnology in Third World countries.

2. The decision on whether to use biotechniques vs. conventional techniques should be made by the Technical Committee (TC) with the input of other scientists as appropriate.

3. The establishment of biotechnology networks may be beyond the scope of the TC.

4. The biosafety issue is a very important one, which is, however, beyond the scope of the Bean/Cowpea CRSP and involves A.I.D, USDA, etc. It may be necessary, however, to plan ahead and come up in advance with a regulatory plan according to which recombinant DNA experiments can be conducted in LDCs.

Discussion Group: Facilitating Technology Transfer

Discussion Leader: Todo Edje

Rapporteur: Eunice Foster

1. Defined technology

   Cultivars, cultural practices, equipment, training, etc.

2. Different categories of technology transfer

   a. From farmer to researcher

   b. From researcher to farmer

   c. From developed to developing nations and vice versa including training of graduate students and transfer between scientists in developing and developed nations

   d. Among national programs at different Host Countries (HC)

3. Definition of the problem

   a. Technology isn't transferred. Not adopted; not accepted

   b. Development of inappropriate technology--technology doesn't meet needs of those who are to be the recipients of the technology

4. Implications of the problem for the CRSP

   Hampers achievement of overall CRSP mandate--Global Plan

Recommendations to the CRSP:

1. Involve farmers in development and carrying out of various aspects of project. Have constant feedback with farmer and farmer involved at all stages.

2. Important for graduate students to know that they're to work with farmers and CRSP should stress this during graduate student training.

3. Ensure that grad students work on problems that are important to the HC.

4. Maximize U.S. Principal Investigator (PI) presence in the HC. Helping PI obtain more in-depth learning about the HC.

5. Minimize turnover of the HC PIs and encourage the HC PIs to more fully understand problems of the whole country and not just the problems of their region or area.

6. Involve private sector of the HC.

7. CRSP should form stronger links, informal and otherwise, with existing extension units.

8. U.S. PIs should interact with leaders in the HC, agriculture ministry, etc., when U.S. PIs visit the HC (public relations work).

9. CRSP should utilize surveys as much as possible to gain a better understanding of the needs of the farmer and the HC before technology is developed.

10. There should be an opportunity for the HC and U.S. scientists to interact and plan at CRSP meetings such as this one.

Discussion Group: Sustainable Agriculture Systems for Grain Legumes

Discussion Leader: Dale Harpstead

Rapporteur: Don Roberts

1. Sustainable Agriculture broadly defined (*sesu latu*). The group did not spend time trying to define sustainable agriculture.

2. "System" was added to the title: Feedback Systems Between Production -- Consumption.

3. Major elements: economic/security, safety/survival, water/soil/plant considerations.

4. Emphasis must be on "consumer" (farmers). Expect U.S. component to learn from Host Country, as well as vice versa. "Discovery," not "Education."

5. Systems must be both feasible and profitable. Ask during design phase-- Is system: socially sustainable, biologically sustainable, physically sustainable, politically sustainable.

6. Long timeline needed for development and evaluation of sustainable agriculture system. Goal is to maintain high productivity over long time. Example: some systems include two or more years of fallow land.

7. Systems should accommodate changes (increase) in population pressure.

8. Sustainable agriculture systems are diffuse and not "scientific." Also much longer-term than most research projects . . . Scientists not comfortable with them.

9. Nevertheless, sustainability adds new, very important criteria for evaluating agricultural programs.

Recommendations to the CRSP:

1. Continually reassess global plan--group agreed that the seven constraints listed are still appropriate.

2. Bean/Cowpea CRSP has a credible record as to attempts to develop projects around sustainable concepts, e.g., biological control, plant breeding, etc.

3. But we could improve number 2 above, by emphasizing that farmers operate in multicropping, multifaceted system, not just production of beans or cowpeas.

   a. Incorporate biology, economics, nutrition, sociology into projects early. Encourage communication within CRSP.

   b. Encourage development of local farmer cooperatives to implement findings of sustainability after CRSP.

   c. Cross-CRSP collaboration should be actively sought. Example: Soil's input low at present.

   d. Utilize to the fullest extent, CRSP-trained cadre of scientists.

Discussion Group: Social Science Issues

Discussion Leaders: T. Edje, A. Ferguson, A. Pinchinat, L. Schwartz, J. Oehmke, A. Mkandawire, L. Bush and R. Bressani

Rapporteur: Jane Wolfson

Economic analysis is a potentially useful tool to help evaluate "return" on a project but:

- Since estimate of return is based upon quality of data estimates, economists should be involved in measurements.
- In our projects it is critical that "difficult to quantify" components such as ecological, nutritional, quality of life, cost/benefit need to be measured and included in analysis. That is our target area.

Farmers need to be included at all stages of the project--this will help with ultimate acceptability and implementation of the end product.

Big problem is how to do this. Coin method helpful with understanding farmer evaluation but limited to evaluation.

Including social scientists from the beginning of projects would seem to be helpful. It is foolish to bring them in only at the end of the process to diagnose failures. If social scientists are to be useful towards achieving project goals, they need to be included at the time of project design, implementation and evaluation.

We must realize that the reason social scientists are not included is a reflection of priority of researchers on the teams.

Since:	goals of researchers	≠	goals of farmer
	criteria of scientists	≠	farmers/consumer criteria

Specific measures need to be taken by researchers to keep them attuned to their clientele.

Mini-Panel: Bridging the Science-Farmer Gap

Presenter: Antonio M Pinchinat

Introduction

The contributions of science pervade modern daily life. In the particular case of agriculture they have led to the separation of countries on their capacity to feed their people adequately. The causes of the difference between agriculturally developed and agriculturally less-developed nations are varied. But the country's capability to marshal innovative technologies which are more productive and efficient is commonly a critical factor Thus as the number of farmers required to meet the basic food needs of the country diminishes, a larger share of the population becomes available to attend to other sectors for spurring overall national development. Technological advances in agriculture, furthermore, boost the country's competitiveness in world markets, thus fueling its economic development.

Science lays the basis for generating technology. But the process calls for a continuous flow of scientific knowledge, aptly used by informed entrepreneurs who can incorporate the knowledge into organized techniques and have access to needed materials and other resources. It is facilitated where there is motivation to act, be it political, social or economic. The so-called Green Revolution (Pinstrup-Andersen and Hazell 1985) based mostly on advances in genetics, can be cited as a classical example of turning science into technology. Its impact has been dramatic, especially where economies of scale and availability of capital are favorable.

However, the scientific advances and resulting modern technologies tend to by-pass the majority of small farmers, especially in the less developed countries where the technological development of agriculture glaringly is lagging.

Science and Technology Development in Small Countries

The concept of small countries in this context refers to those which, regardless of physical size, do not have the necessary resources (principally human and financial) to embark on full-fledged scientific studies and comprehensive in-depth research to produce new technologies. They therefore have to rely on available scientific information and techniques generated outside their borders (Pineiro 1986). Ironically, because their scientific community is small, their access to equipment, library and laboratory facilities as well as up-to-date scientific literature is marginal. For similar reason, their university system remains weak in both research and training capability. Componding these drawbacks, their private sector plays a minimal, if any, role in science and technology development.

This can be illustrated in the field of biotechnology that is expected to revolutionize agriculture (Inter-American Institute 1988).

According to a survey conducted by the Inter-American Institute for Cooperation on Agriculture, (Inter-American Institute 1989) in the twelve English-speaking countries forming the Caribbean Community (CARICOM), only one of the two

universities dealing with agricultural sciences in the region, namely the University of the West Indies, was found to offer graduate training which may be considered specialized in agrobiotechnologies. Half of the biotechnology research laboratories, which were functioning in only four of the countries, are located on the campuses of the University of the West Indies in three countries (Trinidad and Tobago, Jamaica and Barbados). Only one semi-private industry was listed as having plans to get into biotechnology (for aquaculture). These results are not surprising since the biotechnology industry requires high-level investments of capital which are beyond the reach of these small countries individually.

The sciences on which agrobiotechnology is rooted, such as botany, taxonomy, cytogenetics, physiology, biochemistry and others, are insufficiently mastered in the higher education centers or applied in the research/development institutions of the region. Similar shortcomings in technology development can be found in practically all the major agricultural fields except for a few notable innovations, particularly in zootechnology and agronomy.

As a result, these Caribbean countries in general give priority to the introduction, testing and adaptation of known technologies, over the direct generation of new ones by themselves. For the most part, though, this transfer of technologies has trickled down to them from the more developed countries of the temperate North (Western Europe and North America, principally). As such, unless properly adjusted to the local environment the agrotechnologies may be totally irrelevant to their real development needs and technical capacity or capability.

Furthermore, due to increasing privatization of science through patenting of innovations, more restrictions are being placed on open communication about and free transfer of new techniques and technologies, such as genetic engineering and improved (or otherwise valuable) crop and animal germplasm.

This growing trend in international cooperation therefore calls for innovative ways and means to facilitate access of these less developed countries and their institutions to the scientific breakthroughs, advanced techniques and relevant technologies hatched in the more developed countries or institutions.

But for that purpose the critical differences in operational opportunities between large, resource-rich and small, resource-poor farmers need to be clearly understood. Because they normally specialize in one or a few agricultural commodities and have access to the required capital and other resources, industrial-scale farmers can more readily find and adopt the technology they need than can the small-scale, subsistence farmers. These generally tend a wide range of crops or animals or both, therefore their technology needs are more varied. Due to the great diversity in their small-scale enterprises the relevant technologies needed to improve their farming systems may not have been designed. Moreover, even where available, the technology may not reach these farmers because the public extension system, typically understaffed and ill-equipped in these countries, is unable to cater to them appropriately. Also, due to unattractive cost/benefit ratios, the commercial firms which transfer technology along with the sale of their products exclude them as target customers, reducing further their access to modern technologies.

This scenario, although by necessity skeletal and simplified, pictures the Science/Farmer Gap, at least in the small countries. The gap tends to become

wider and more difficult to bridge as the situation moves from that of intensive, specialized farming systems in the ecologically less complex temperate zones to that of extensive, mixed farming systems in the ecologically more complex tropical regions such as the Caribbean.

Networking in Agricultural Research and Technology Development

In practice, technology is the bridge that leads from pure science to socio-economic development. In the developed (meaning economically richer) countries, the bridge is sustained by both the public and private sectors. In some industries such as agrobiotechnology, the private sector, motivated by profit, may even play the major development role. By contrast, in less-developed (meaning small-scale economy, poorer) countries, the job usually falls under the primary, if not almost exclusive, responsibility of the public institutions.

In allocating their scarce resources to address the needs of their different socio-economic sectors, the small countries tend to penalize agricultural science and technology development because of their relatively longer gestation period in economic or political dividends. This conflict between resources and needs has been studied by Gamble and Trigo (Gamble and Trigo 1985).

In response, networking in international cooperation has been proposed as a viable strategy to increase national research capabilities and thereby mitigate the dilemma of resource allocation in small countries such as those in the CARICOM region (Trigo 1988). It groups the relative strengths of individual countries or institutions and offers the minimum level of investments required for science and technology development without undue burden to the individual national budgets. It is a twist from the top-down cooperation mode in which the more advanced country or institution generates the scientific knowledge and hands down finished or almost-finished technology to the less-developed recipient country or institution. It can be particularly effective and efficient when it involves countries which compose a relatively homogenous region by the commonness of their technology needs and institutional structures which can facilitate horizontal/reciprocal cooperation.

Well organized and successfully functioning networks on research and technology development have been established through five horizontal/reciprocal cooperation projects administered by IICA in Central and South America (Inter-American Institute 1989). They deal with livestock and tropical or subtropical crops.

The one most directly relevant to the Bean/Cowpea Collaborative Research Support Program (CRSP) is the Cooperative Agricultural Research Program for the Andean subregion (PROCIANDINO). It works on four groups of crops: food legumes, maize, potatoes and oil seeds. The food legumes include dry beans (*Phaseolus vulgaris* L).

PROCIANDINO combines the respective comparative advantages of five participating research/development institutions, one from each of the Andean countries: Bolivia, Colombia, Ecuador, Peru and Venezuela. Each institution leads research and intra-regional technology transfer for a specific crop commodity. Each country is directly responsible for the transfer of validated technology, from the network to the local farming systems.

The network operates on national financial resources complemented with a grant from the Inter American Development Bank (IDB). By formal agreement among the

countries and IDB, institutional responsibilities are shared and committed so that the countries will continue to cooperate even when the external financial assistance is withdrawn.

The PROCIANDINO was modelled on the Cooperative Agricultural Research Program for the Southern Cone subregion (PROCISUR), grouping Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay. PROCISUR focuses on five commodities: wheat, maize, sorghum, soybean and beef cattle.

The other three projects are: (1) the Cooperative Program for the Protection and Modernization of Coffee Cultivation in Mexico, Central America, Panama and the Dominican Republic (PROMECAFE); (2) the Research Network on Animal Production Systems in Latin America (RISPAL); and (3) the Regional Network for Cocoa Technology Generation and Transfer (PROCACAO).

All are technically supported by relevant research/development institutions of excellence, including formally the International Center for International Agriculture (CIAT), the International Potato Center (CIP) and the International Maize and Wheat Improvement Center (CIMMYT).

An Approach to Bridge the Science/Farmer Gap

Bridging the science/farmer gap implies that the aspirations of farmers be heard in the generation and transfer of needed technologies, which in turn would lead to the orientation of the scientific research intended to yield them.

This approach is being tested by IICA in the multinational project "Support for the Organization and Management of Technology Generation and Transfer in the Eastern Caribbean States (Inter-American Institute 1988).

This five-year project started in June 1988. It covers IICA-member countries in the Eastern Caribbean: Antigua and Barbuda, Dominica, Grenada, St. Lucia, St. Vincent and the Grenadines and soon it will include St. Kitts-Nevis that very recently has joined IICA. Together with Montserrat, these small-island countries form the Organization of Eastern Caribbean States (OECS).

The project focuses on the following major institutional constraints, which have been identified through diagnosis of the National Agricultural Technology Development System (NATDS) in each country:

1. Unsettled national agricultural technology development policy

2. Diffused and tangled organization of the national agricultural research/extension subsystem (NARES)

3. Low managerial capability of NARES

4. Weak and low level of horizontal/reciprocal cooperation within country and among the countries in the OECS region, to access and transfer technologies

5. Scarce capitalization of scientific knowledge and advanced techniques or technologies available within and outside the region

6. Scarce capitalization of external financial resources available from the national private sector and donor agencies to support agricultural technology development (ATD), and

7. Scant participation of small farmers in guiding ATD and sharing its benefits

The project's purpose is to bridge the science/farmer gap through streamlining the functional organization and up-grading the managerial capability of the NATDS to address the identified constraints.

Its basic activities fall into three inter-related components

1. Functional organization and management of NARES

2. Availability of relevant technology and its transfer to farmers

3. Projects' design and implementation to sustain the technological development of the agricultural sector

In the OECS, applied (i.e., technology-oriented) research is mainly assigned by the Ministries of Agriculture (MOAs) to one regional structure: the Caribbean Agricultural Research and Development Institute (CARDI). So-called basic or fundamental agricultural research is left principally to the University of the West Indies that, like CARDI, is another regional organization based outside the OECS region but of which the seven countries are supporting members. Technology transfer is assumed mostly by the MOA Extension Division in each country except for a few export crop commodities (principally bananas, sugarcane and spices) which are served by private extension structures.

In this three-layered agricultural technology development and transfer system, operational interfacing is weak in practice, widening and deepening the science/farmer gap, by hampering articulation, harmonization and coordination of activities among the relevant institutions. This is reflected in science lagging to reach the farm due to scant adoption of improved technologies by farmers, even when stimulating factors such as secure markets and attractive prices are favorable to the farmers.

So far the project successfully has assisted the MOAs in

1. Defining agricultural technology policy concordant with national development goals, within the typical constraints besetting the small country resource framework

2. Streamlining the functional organization and upgrading the managerial capability of the NARES, as core subsystem of the NATDS

3. Formulating core national agricultural development programs and internally-funded projects

4. Participating in regional networks to facilitate horizontal/reciprocal cooperation in technology generation and transfer from one country to another

5. Accessing, testing, validating and transferring to target farmers relevant agrotechnologies generated outside the region

6. Identifying, formulating and implementing externally-funded investment projects to complement and strengthen the NARES core technology development projects

7. Organizing and implementing cooperative activities in technology development between the public and private (or otherwise non-government) research/development structures in the agricultural sector, and

8. Increasing the direct active participation of farmers in agricultural technology development, through consultation at the critical stages of research/extension activity planning and programming for technology generation, introduction, adaptation, validation and transfer

To bridge the science/farmer gap many non-technological conditioning factors must be considered. As much as possible some of the most critical, such as market opportunities and pricing policies, are monitored and addressed in implementing the project.

The project's outputs have contributed significantly to establish tighter planning and operational linkages among the institutional components of the NATDS, especially the MOAs (for technology validation and transfer), the research/development organizations (for technology generation or introduction testing, adaptation and validation), higher education institutions (for professional training, basic research and technology generation) and farmers (for technology validation and transfer). As a result, already known but scarcely used technologies are finding their way to the farms.

The project has been incorporated by IICA into its Plan of Joint Action for Agricultural Reactivation in Latin America and the Caribbean, endorsed by all its 32 member countries (Inter-American Institute 1989).

Like this project, the CRSPs are intended to, and effectively can, play a crucial role in bringing about the necessary institutional linkages to bridge the science/farmer gap, especially in their Host Countries, without losing sight of their priority research mandate (Havener 1984, and United States Agency for International Development 1985). The Bean/Cowpea CRSP, along with the others, justifiably boasts a remarkable record in this endeavor.

References

Pinstrup-Andersen, P. and P. B. R. Hazell. 1985. The Impact of the Green Revolution and Prospects for the Future. International Food Policy Research Institute. Food Rev Int 1(1):1-25.

Pineiro, M.E. 1986. Agricultural Production in Latin America and the Caribbean: International Organizations and Regional Programs. San Jose, Costa Rica: IICA. 11p

Inter-American Institute for Cooperation on Agriculture. 1988. Program II - Technology Generation and Transfer. Guidelines for Cooperation. Offic. Doc. Series 37 (Rev). San Jose, Costa Rica: IICA. 40 p.

Inter-American Institute for Cooperation on Agriculture. 1989. Tabulation of the Results of Survey Diagnostic of the Agrobiotechnologies in Latin America and the Caribbean. Technology Generation and Transfer Program. Internal Document (Mimeo). San Jose, Costa Rica: IICA. 17 p.

Gamble, W.K. and E. J. Trigo. 1985. Establishing Agricultural Research Policy: Problems and Alternatives for Small Countries. In Agricultural Research Policy and Organization in Small Countries. Report of a Workshop. The Hague (Netherlands): ISNAR. pp. 36-52

Trigo, E.J. 1988. Agricultural Research in the Caribbean. Some Policy and Organizational Alternatives. Misc. Pub. A1/OC-88-07. San Jose, Costa Rica: IICA. 14p.

Inter-American Institute for Cooperation on Agriculture. 1989. Annual Report 1988. San Jose, Costa Rica: IICA. (E14):152-160.

Inter-American Institute for Cooperation on Agriculture. 1988. Support for the Organization and Management of Technology Generation and Transfer in the Eastern Caribbean States Project A2882LIB0100. Internal Document. San Jose, Costa Rica: IICA/DIPROE/Program II. 40p.

Inter-American Institute for Cooperation on Agriculture. 1989. Plan of Joint Action for Agricultural Reactivation in Latin American and the Caribbean: Principal Document. San Jose, Costa Rice: IICA. 189p.

Havener, R.D. 1984. Is the Green Revolution Still Green? IAFP Working Paper Series, Pub. 8. New Jersey: Rutgers University. 18 p.

United States Agency for International Development. 1985. Guidelines for the Collaborative Research Support Programs under Title XII of the International Development and Food Assistance Act of 1975. USAID/Washington D.C.: BIFAD. Mimeo. 43 p.

Mini-Panel: Bridging the Science-Farmer Gap: Progress with On-Farm Research with Beans in Northern Tanzania

Presenter: O. T. Edje

INTRODUCTION

The objective of agricultural research in the tropics is to improve the living standard of rural people through the introduction of improved farming methods that produce higher and sustained yields. However, the rate of adoption of technologies by smallholder farmers has been generally poor (Chambers and Ghildyal, 1985). Possible reasons for disappointing rates of adoption include: the top-down approach, conducting trials on-station rather than on-farm where they may be more relevant; inappropriateness of the technology; a poor understanding of small farmers' conditions and their production goals.

For over a decade, researchers and policy makers have begun to recognize the need for more farmer involvement through a farming systems approach in the development, management, assessment and transfer of technology in participatory research, including the farmer-back-to-farmer model (Rhoades and Booth, 1982) and farmer-first-and-farmer-last model (Chambers and Ghildyal, 1985; Chambers and Jiggins, 1986).

In recognition of the role of the farmer in technology generation assessment and transfer, we in the SADCC/CIAT Regional Programme and the National Programme have worked closely with small-scale farmers in Tanzania in a partnership that we believe is liable to prove mutually valuable. The involvement of extensionists is crucial and so, too, is the strengthening of our links with the Bean/Cowpea Collaborative Research Support Program (CRSP) in which Sokoine University of Agriculture (SUA), Morogoro is the host institution. Thus, SADCC/CIAT and the CRSP are each involved in supporting different components of the national bean program in Tanzania. Linkages between our programs have improved efficiency in several instances: for example, earlier survey work in Lushoto District, by Due et al. (1985), provided us with useful information and enabled us to proceed direct to the on-farm exploratory stage of on-farm trials. Another example of collaboration with the Bean/Cowpea CRSP in Tanzania includes the conducting of joint annual workshops at SUA, where Dr. M. J. Silbernagel has been involved as U.S. Principal Investigator for the past decade.

Elsewhere in Africa, CIAT's regional programs on beans have worked in cooperation with the Bean/Cowpea CRSP in the exchange of information on bruchids between CIAT's work in Somalia and the CRSP/Cameroon project. The University of Nebraska/Dominican Republic CRSP project has identified leaf hairiness as a race non-specific resistance mechanism against rust. This information is being used both by CIAT's rust sub-project in the Ethiopian national program and in the training of post-graduate students.

The remainder of this paper will focus on our activities in Lushoto district, Tanga Regions, Tanzania, a note on which is in press (Edje et al., 1990).

Lushoto District:

Lushoto district is one of the six administrative districts in Tanga Region, Tanzania. It is situated at latitude 4° 13^1 to 4° 90^1 S and longitude 38° 12^1 to

38° 47[1] E. The topographical features of the district are the Umba plain and the Usambara mountains, which rise to an altitude of 2,200 miles above sea level; most of the agricultural activities are concentrated between 1,000-2,000 miles above sea level, in the valley bottoms and on hill slopes (Egger et al., 1980)

The pattern of agricultural production and productivity is largely dictated by the uneven and unreliable rainfall. Two main seasons may be distinguished: the long rains (*Masika*) and the short rains (*Vuli*). An intermediate rainy season in August occurs at high elevations in the West Usambaras, whereas a pronounced dry season from June to November is experienced in most parts. Mean annual rainfall ranges from about 600-2,000 mm, with large local differences. The geological base of the western Usambaras is Precambrian basement rock, consisting chiefly of gneiss and granite. Soils derived from these materials are primarily latosols. Most of the soils on the inner mountain slopes are humic nitosols and chromic luvisols. On the lower slopes, various loams and clays classified as pellic vertisols and chromic cambisols are found. Almost all soils are poor in nutrients, showing particularly pronounced deficiencies in P and K, the latosols also in Ca and Mg (Egger et al., 1980).

The population of the district is 286,069 inhabitants with a mean density of 102/km^2 and peak densities exceeding 250/km^2. Overpopulation, coupled with overstocking, have long been recognized locally as problems (Dobson, 1940). The carrying capacity of land was seen as being in danger of being exceeded (Mitchell, 1984) so threatening the sustainability of existing farming systems. Beans are an important food and cash crop in the farming systems in Lushoto district, where farm size is small (1-2 ha), and most farms are on slopes (Due et al., 1985).

On-Farm Research

An on-farm research survey on beans was conducted in 1985 by Due et al., (1985) and on-farm trials were initiated by us in Lushoto in 1987. Now a clear sequence of trials has been established, proceeding from diagnosis to determination and verification, exemplified by exploratory, on-farm variety and farmer-managed trials aimed at more farmer involvement in technology development, assessment and transfer.

Bean on-farm exploratory trials:

Exploratory trials were initiated during the *Masika* season of 1988, using the modified minus one design. The objectives of the trials were to quantify the factors limiting bean yield and to detect interactions among factors. Trial results showed that the full package (improved seed, fertilizer, disease and insect pest control) had the highest mean seed yield (1069 kg/ha) while the lowest mean yield (554 kg/ha) was obtained with farmers' practice. The results also showed that the two most important factors limiting bean yield in Lushoto were soil infertility and the lack of an improved variety. No interactions were detected.

Bean on-farm variety and farmer participatory trials:

The objectives of these trials were to evaluate the performance of six promising varieties from the national breeding program under farmers' conditions and also to obtain farmers' assessments of these materials using a range of criteria. Farmers' preferences for a variety were assessed for its production, consumption

and marketing characteristics, using both a rating scale and preference elicitation using counter methodology (Grisley and Edje, 1989). During the *Masika* season of 1988 and the *Vuli* season of 1989, the results of the on-farm variety trials showed that variety Lyamungu 85, a Calima type known previously as T23 released to commerce in 1985, was the highest yielder (1081 kg/ha). However, Diacol Calima (G 5621) was the highest yielder during the *Masika* season of 1989, with Lyamungu 85 not significantly inferior. Overall, Lyamungu 85 was rated highest by farmers for production and marketing characteristics, using both evaluation techniques.

The need to integrate farmers in the technology generating process was recognized early in our research. To this end, the regional, national and extension staff held meetings with village headmen and later with farmers to whom we explained the objectives of the on-farm variety trials and our mutual responsibilities, including input supply, land preparation, trial management and assessment. We showed the farmers seed samples of the five promising varieties, enclosed in transparent plastic strips. At the end of the meeting, we took names of farmers who were willing to collaborate in the trial. Later in the season we marked out plots in farmers' fields and requested them to prepare the sites for planting. Sowing (either in monoculture or in association with maize) was a joint exercise between the farmer and the researcher but crop management thereafter was the farmer's responsibility. During the season, we assessed the crop performance thrice at V3, R5/R6 and at harvest. The first two assessments were mostly on vigor and disease reaction while the last concentrated on yield and seed characteristics.

During the course of varietal evaluation, we observed that farmers changed their preferences depending on the stage of growth and development. At the end of the growing season, we held a meeting with all the farmers to assess the season's program and to obtain feed-back for the next one. The following points emerged:

1. Farmers said that they were glad to be involved in the selection of varieties for eventual release.

2. Farmers insisted that varieties that they had rejected should be eliminated from future trials.

3. Larger plot sizes were preferred as a rapid means of increasing the availability of acceptable elite lines.

4. Farmers wanted to form a bean cooperative as a means of increasing the availability of released lines.

In addition to the on-farm participatory research in Lushoto, two groups of ten farmers assisted by ten enumerators assessed advanced breeding materials at Selian Research Institute, Arusha and at Miegeo in the Usambara Mountains, by visual rating and counter methods. At Selian, among bush-type uniform trial entries specially sown unreplicated in large plots for the purpose of the exercise, Lyamungu 85 was the most preferred variety in terms of both production and marketing characteristics. At Miegeo, one replicate of the Lushoto bush bean variety trial was assessed. Ten farmers and ten enumerators were involved in the exercise at stage R5/R6. At harvest, only eight of the previous ten farmers took part, but the absent farmers were represented by family members. Lyamungu 85 was ranked first at R5/R6 and second at harvest, in both methods of assessment. From later discussion with the farmers, it was learned that this change in ranking

arose from their attention to vigor and disease reaction at the first assessment and seed characteristics and yield at the second. It was also indicated that rankings might change again following a culinary test. Points that emerged during discussion are being taken into account in the design of next year's trials.

Farmer-managed trials

The objective of this trial was to enable farmers to compare improved practices with their own cultivation practices on-farm using a variety selected from the on-farm variety trials as a component of the improved package. Farmers were selected, issued inputs and requested to sow beans in either association or in monoculture. During the 1989 *Masika* season, the mean yield of beans obtained by 17 farmers using improved technology was 1186 kg/ha as compared to 545 kg/ha for the farmer's practice, an increase of 118 percent.

Pilot Scheme of On-Farm Seed Production

Inadequate availability of seeds of released cultivars is one of the main constraints to seed production in many developing countries. For example, Lyamungu 85 was officially released in Tanzania in 1985. However, certified seed production did not begin until 1989, and seed of this cultivar is not yet widely available. In view of this, we are developing a pilot scheme for on-farm seed production. Using a village saturation approach, we have issued 2-3 kg of Lyamungu 85 to farmers who have been registered to sow the seed and return the same weight of clean seed at the end of the season. The results have been encouraging and this scheme is being extended to other districts (Hai in Kilimanjaro and Arumeru in Arusha regions) of Tanzania. Using another approach, by allowing farmers to retain and plant whatever they like from the on-farm variety trial, two farmers in Lushoto district have been able to multiply enough seeds within two seasons to plant one and one-half hectares of beans from an initial amount of 2 kg.

Concluding Remarks

Effective on-farm research is necessarily collaborative. Our activities in Lushoto district, where we were able to build upon the survey results from the Bean/Cowpea CRSP, began with the assistance of the German-financed Soil Erosion Control and Agroforestry Project (SECAP), whose expertise promised to complement our commodity bias. In the absence of any national research station serving the western Usambara mountains, bean research became established directly through the existing extension system whose staff are now becoming increasingly involved with us in the conduct of bean trials on-farm. A small trial site has been made available to the national bean research program by a community development center for longer term and larger trials than can be conducted on-farm, and local farmers are becoming closely involved both in trial design, management and in participation in the variety selection process.

A network of on-farm research with beans is now firmly established in Lushoto district, which is a major area of production in Tanzania. Diagnosis of production constraints is proceeding, and the spread of more productive and acceptable cultivars is gathering momentum. We believe that the direct participation of extensionists and farmers with national bean researchers is likely to bridge the gap between science and the farmer and provide a means by which agricultural change may lead to local impact in a sustainable manner.

References

Chambers, R. and B. P. Ghildyal. 1985. Agricultural Research for Resource-Poor Farmers: The Farmer-First-and-Last Model. Agricultural Administration 20, 1-30.

Chambers, R. and J. Jiggins. 1986. Agricultural Research for Resource-Poor Farmers: A Parsimonious Paradigm. IDS Discussion Paper 22. Brighton: IDS, University of Sussex.

Dobson, E. B. 1940. Land Tenure of the Wasambaa. Tanganyika Notes and Records 10, 1-27.

Due, J. M., J. Rugambisa, N. Tilahun and R. Schwartz. 1985. Beans (*Phaseolus vulgaris*) in the Farming Systems in Tanga, Tanzania. Department of Agricultural Economics, University of Illinois at Urbana, Champaign, Illinois, USA and Department of Rural Economy, Soloine University of Agriculture, Morogoro, Tanzania.

Edje, O. T., J. Maimu, O. S. Mbuya, P. Ndakidemi, C. S. Mushi and D. J. Allen. 1990. Progress in On-Farm Research with Beans in Lushoto District, Tanga Region Tanzania. A Rep. Bean Improvement Cooperative 33 (in press).

Egger, K., J. Huljus, O. Pompl and D. Prinz. 1980. Soil Erosion, Control and Afforestation in the West Usambaras (Phase 1): Feasibility study. GTZ, Gottingen, September, 1980.

Grisley, W. and O. T. Edje. 1989. Preference Elicitation Using the "Counter" Methodology. Centro International de Agricultura Tropical (Mimeo 16pp).

Mitchell, A. J. B. 1984. Human Carrying Capacity in Existing Farming Systems. In Hawksworth, D. L. (ed.) Advancing Agricultural Production in Africa, Commenwealth Agricultural Bureaux. Farnham Royal. pp. 361-366.

Rhoades, R. E. and R. H. Booth. 1982. Farmer-Back-to-Farmer: A Model for Generating Acceptable Agricultural Technology. Agricultural Administration 11, 127-137.

SUMMARY

The Bean/Cowpea CRSP convened an international research meeting at Michigan State University in the spring of 1990. The focus of the presentations and discussion sessions revolved around how collaborative research could further resolve important constraints in bean and cowpea production and utilization. Lively interactions followed the presentations by each of the speakers. The mini-panel and small discussion groups debated many important research and administrative issues. The participants were asked to help identify the collaborative research projects which would be most important for addressing major production and utilization constraints in bean and cowpea production and utilization into the next decade. The technologies to be generated, it was determined, would need to be: (1) technically feasible; (2) economically viable; (3) socially sound; and (4) environmentally appropriate

The group discussions addressed issues involving:

1. New biotechnology networks

2. Biosafety

3. Inter- and intra-CRSPing collaboration

4. Genetic resource preservation

5. Research ethics

6. Former involvement in research agendas

7. Private sector involvement

8. Sustainable agriculture

Some of the recommendations include:

1. Increase farmer involvement in the development and implementation of the projects

2. Increase involvement of the private sector in the research program

3. Expand understanding of the farmers' complex farming systems

4. Encourage cross-CRSP collaboration

5. Utilize multidisciplinary teams to address ethical issues in research

6. Maintain the free exchange of germplasm

In addition to the current CRSP research projects, the following new research areas were identified as important for the Bean/Cowpea CRSP when additional funds become available:

1. Increased biotechnology addressing disease and insect resistance

2. Increased germplasm collection, evaluation and utilization

3. More integrated pest management systems (IPM)

4. Expanded research on insect-transmitted viruses, especially white fly

5. Concentrated food nutrition/utilization issues

6. Seed multiplication

7. Changes in economic and social policies that impact beans and cowpeas (food policy)

8. Soil conservation management

This information is being utilized by the Technical Committee, Board of Directors and the Management Office of the Bean/Cowpea CRSP in developing the five-year extension proposal (1992-1997).

AGENDA

BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)
U.S. and HOST COUNTRY PRINCIPAL INVESTIGATORS' RESEARCH MEETING

University Place Holiday Inn
East Lansing, Michigan
April 30 - May 3, 1990

Sunday, April 29, 1990

6:30--8:00	REGISTRATION	

Monday, April 30, 1990

8:00--8:10	INTRODUCTION	Barnes-McConnell
8:10--8:25	WELCOME	Anderson
8:25--9:10	CRSP COUNCIL PRESENTATION AND INTRODUCTION OF CRSP DIRECTORS	Barnes-McConnell and Rowntree
9:10--9:35	PRESENTATION OF THE GLOBAL PLAN	Freed
9:35--9:50	ROLE OF THE TECHNICAL COMMITTEE AND PROJECT INTRODUCTIONS	Murdock
9:50-10:00	BREAK	
10:00-10:30	PROJECT PRESENTATION: **Tanzania** *Breeding Beans (Phaseolus vulgaris L.) for Disease, Insect and Stress Resistance and Determination of Socioeconomic Impact on Smallholder Farm Families*	Project Team
10:30-10:50	DISCUSSION	
10:50-10:55	CHANGE OVER	
10:55-11:25	PROJECT PRESENTATION: **Malawi** *Bean Improvement and Host Pathogen Co-Adaptation in Malawi, A Secondary Center of Diversity*	Project Team
11:25-11:45	DISCUSSION	
11:45--1:15	LUNCH	
1:15--1:20	RECONVENE/NOTICES	
1:20--1:50	PROJECT PRESENTATION: **Dominican Republic (UNL)** *Biology, Epidemiology, Genetics and Breeding for Resistance to Pathogens of Beans with Emphasis on Those Causing Bacterial and Rust Diseases*	Project Team
1:50--2:10	DISCUSSION	
2:10--2:15	CHANGE OVER	
2:15--2:45	PROJECT PRESENTATION: **Honduras** *Improvement of Bean Production in Honduras Through Breeding for Multiple Disease Resistance*	Project Team
2:45--3:05	DISCUSSION	

3:05--3:15	BREAK	
3:15--3:45	PROJECT PRESENTATION: **Mexico** *Improving Resistance to Environmental Stress in Beans Through Genetic Selection for Carbohydrate Partitioning, Water Use Efficiency and Efficiency of Biological Nitrogen Fixation*	Project Team
3:45--4:05	DISCUSSION	
4:05--4:10	CHANGE OVER	
4:10--4:40	PROJECT PRESENTATION: **Guatemala** *Agronomic and Genetic Aspects of Bean Yield and Adaptation*	Project Team
4:40--5:00	DISCUSSION	
5:00	ADJOURN	
6:30--7:00	CASH BAR	
7:00--9:00	BANQUET	

Tuesday, May 1, 1990

8:00--8:05	RECONVENE/NOTICES	
8:05--8:35	PROJECT PRESENTATION: **INCAP** *Improvement of Dry Bean Nutritional Quality and Acceptability*	Project Team
8:35--8:55	DISCUSSION	
8:55--9:00	CHANGE OVER	
9:00--9:30	PROJECT PRESENTATION: **Nigeria** *Appropriate Technology for Cowpea Preservation and Processing and a Study of Its Socioeconomic Impact on Rural Populations in Nigeria*	Project Team
9:30--9:50	DISCUSSION	
9:50-10:00	BREAK	
10:00-10:50	PRESENTATION AND DISCUSSION: FOOD SCIENCE AND TECHNOLOGY IN THE TOTAL FOOD DELIVERY SYSTEM	Nakayama
10:50-10:55	CHANGE OVER	
10:55-11:25	PROJECT PRESENTATION: **Brazil** *Insect Pathogens in Cowpea Pest Management Systems for Developing Nations*	Project Team
11:25-11:45	DISCUSSION	
11:45--1:15	LUNCH	
1:15--1:45	PROJECT PRESENTATION: **Senegal** *A Program to Develop Improved Cowpea Cultivars, Management Methods and Storage Practices for emiarid Zones*	Project Team
1:45--2:05	DISCUSSION	
2:05--2:10	CHANGE OVER	

2:10--2:40	PROJECT PRESENTATION: **Cameroon** *Preservation of Postharvest Cowpeas by Subsistence Farmers in Cameroon*	Project Team
2:40--3:00	DISCUSSION	
3:00--3:10	BREAK	
3:10--3:40	PROJECT PRESENTATION: **Dominican Republic (UWI)** *Molecular Approaches for Control of Bean Golden Mosaic Virus*	Project Team
3:40--4:00	DISCUSSION	
4:00--4:05	CHANGE OVER	
4:05--5:00	PRESENTATION AND DISCUSSION: EXPLOITING NEW BIOTECHNOLOGY FOR CRSP RESEARCH	Havey
6:30--9:00	DINNER RECEPTION, home of Pat Barnes-McConnell 517 Belmonte Circle, East Lansing	

Wednesday, May 2, 1990

8:00--8:05	RECONVENE/NOTICES	
8:05--8:35	PROJECT PRESENTATION: **Ecuador** *Improving the Productivity of Phaseolus Beans Under Conditions of Low-Input Agriculture Through Genetic Selection of Host Cultivars and Rhizobium Strains for Enhanced Symbiotic Efficiency*	Project Team
8:35--8:55	DISCUSSION	
8:55--9:00	CHANGE OVER	
9:00--9:50	PRESENTATION AND DISCUSSION: STATUS OF BEAN RESEARCH/CIAT	Pachico
9:50-10:00	BREAK	
10:00-10:50	PRESENTATION AND DISCUSSION: STATUS OF COWPEA RESEARCH/IITA	Singh
10:50-10-55	CHANGE OVER	
10:55 11:45	MINI-PANEL: BRIDGING THE GAP--SCIENCE, THE FARMER AND HER TECHNOLOGY	Edje, Ferguson and Pinchinat
11:45--1:15	LUNCH	
1:15--2:05	PRESENTATION AND DISCUSSION: SOCIO-ECONOMIC IMPACT ASSESSMENT	Schwartz and Oehmke
2:05--2:10	CHANGE OVER	
2:10--3:00	MINI-PANEL: MONITORING SOCIO-CULTURAL AND NUTRITIONAL IMPACT	R. Mkandawire, Bush and Bressani
3:00--3:10	BREAK	

3:10--5:00	SMALL GROUP DISCUSSIONS:	
	(1) Ethical Issues in Research: Germplasm Exchange	Adams
	(2) Biotechnology in Developing Countries	Young
	(3) Facilitating Technology Transfer	Edje
	(4) Designing Research for Sustainable Agriculture	Paul
5:00	ADJOURN	
	DINNER - On your own	

Thursday, May 3, 1990

8:00--8:10	RECONVENE/NOTICES	
8:10--9:10	LOOKING TO THE FUTURE--REVIEW OF THE GLOBAL PLAN GROUP EXERCISE: (1) Identify missing research areas (2) Prioritize research needs	Barnes-McConnell and Freed
9:10--9:30	GROUP EXERCISE: CROSS PROJECT/CROSS CRSP RESEARCH IDENTIFICATION	Yohe
9:30--9:50	PRESENTATION AND DISCUSSION: MAKING USE OF BUY-INS--MECHANISMS AND OPPORTUNITIES	Bengry and Barnes-McConnell
9:50-11:00	SESSION SUMMARIES. REPORTS AND DISCUSSIONS	Rapporteurs
11:00-12:00	IDENTIFICATION OF NEXT STEPS AND WRAP-UP	Barnes-McConnell, Freed and Yohe
12:00	MEETING ADJOURNS	

* * * * *

AUXILIARY MEETINGS:

Malawi Team and PI Candidate Teams: Convenor, Ferguson	- Sunday, 8:00 p.m.
Bean/Cowpea CRSP Technical Committee: Convenor, Murdock	
With Malawi Team and Individual PI Candidate Team	- Monday Lunch/Abawi - Tuesday Breakfast/Gepts 7:00 a.m. - Tuesday Lunch/Grafton
Business Meetings	- Wednesday, 6:00 p.m. - Thursday, 1:00 p.m. - Friday, 8:00 a.m.
Social Scientists: Convenor, Ferguson	- Wednesday, Lunch/11:45
CRSP Council	
Business Meetings: Convenor Yohe	- Tuesday, Lunch/11:45 - Wednesday, Lunch/11:45 - Thursday, 3:00 p.m.
With Socio-Economists: Convenor, Barnes-McConnell	- Wednesday, 6:00 p.m.
With TC Chairs: Convenor, Yohe	- Thursday, 1:00 p.m.

Appendix A

AN OVERVIEW OF THE FUTURE FOR THE CRSPs

William R. Furtick
Agency Director for Food and Agriculture
U.S. Agency for International Development

There is a pressing need to better finance and expand the successful Collaborative Research Support Projects (CRSPs). The CRSP model has received widespread commendation and is recognized for its success in developing mutually beneficial collaborative research between U.S. and overseas institutions. They have been able to attract the best and brightest U.S. faculty into collaborative international research because of the mutual interest and benefits involved. The CRSPs have trained a large number of overseas students who have carried out graduate programs that were relevant to their countries needs and at the same time trained a large number of U.S. students, often in partnership with the overseas students. This has greatly increased the pool of U.S. advanced degree holders with relevant overseas experience and interest. They will help provide the future staff needed to internationalize the curriculum and perspective of U.S. universities. The major problem has been progressive underfunding by the federal government. The states have increased their already overmatched contributions. Many of the developing countries have contributed as much or more than the U.S. government in cash and in kind. This said, how do we better finance, expand the coverage and broaden the mandate of the CRSP system? These are the crucial issues that a CRSP Council should address. If they are not addressed successfully, the money spent to bring the interested parties together to form a Council will be largely wasted. This paper is intended to layout a series of options of how a CRSP Council could be the driving force to accomplish these objectives.

We are meeting at a time of unparalleled change in world events. All you have to do is turn on the television to witness the close of the "Cold War." It is a time where the optimist can revel in the future, listen to the discussions on the magnitude of defense cuts, and participate in the growing realization by governments, universities and the populace at large that we are part of an integrated global economy. We must actively join this global community. A pessimist can dwell on our seeming inability to cope with social problems such as drugs, AIDS, homelessness, poverty, crumbling infrastructure, deteriorating educational system and mounting federal and trade deficits. We can view the glass as half empty or half full. I will take the latter and hope you will join me in exploring ways we can finish filling our national glass. To do this, we will have to stop waiting for someone else to turn on the faucet and start doing it ourselves.

The CRSPs are quality products which can be marketed and sold. When industry has a good product to sell, it invests part of its returns into product promotion to leverage expanded sales. It also invests in product improvement to maintain and expand sales. Modern industry also merges to capitalize on the economies and efficiencies of scale. Let's apply these same analogies to the CRSPs. By merging into a larger unit through an aggressively managed Council, we can both better promote our product and improve it to be even more competitive. Given this scenario, what could an aggressively managed CRSP Council do?

A presentation to the Organizational Meeting of the Collaborative Research Support Projects Council, Washington, DC November 30, 1989

MEANS TO WIDEN THE SUPPORT BASE

For the last two years I have urged CRSP management to stop focusing on what funds might come from A.I.D. next year and start actively seeking outside support to expand their resources. In my view, each CRSP should become the focal point of U.S. efforts to establish a comprehensive network for overseas collaboration in their designated field of expertise. This will require a searching examination of what the opportunities and needs are in the CRSP mandated domain and who the global leaders are in this field, including developing country institutions, public and private institutions in industrialized countries, and various U.S. agencies and international organizations. These form the basis of an informal network that can be joined together as a collaborative community to effectively resolve the constraints hindering further development of the commodity or factor involved in each CRSP. Each CRSP needs to analyze the scope of the problems, prioritize needs, and identify the primary institutions and scientists that form this part of the global research system. This should include determining those who also should become part of the system. This leads to the question of how can the needs identified by financed? In my view, A.I.D. should provide seed money to foster this entrepreneurial undertaking to find the needed resources for a comprehensive attack on the priority problems.

SOURCES OF FINANCIAL RESOURCES

A variety of financial resources can be carefully cultivated. These include various federal agencies such as USDA, NSF, and EPA to start with. Where commodities are involved, the private sector including the commodities groups themselves should be canvassed. For example, the soy bean growers are in the process of establishing an increase in their check-off system that creates a cess against each bushel of soybeans produced. This new scheme will bring in a significant amount of revenue, part of which will be earmarked for research. There is every potential to promote similar funding methods by the other major commodity organizations. Today more than ever before there is an acute awareness by each commodity group that extraordinary measure must be implemented to keep U.S. agriculture competitive. Indeed the time is right to promote new innovations by the producers themselves.

During 1990 there will be a comprehensive reassessment of the international research roles for both USDA and A.I.D. through the reauthorization of the five-year Farm Bill and the revamping of the Foreign Assistance Act. This period of change offers an auspicious opportunity for a CRSP Council to form new coalitions, mobilize greater program support, and ensure that their interests are fully incorporated into these long-term legislative changes and appropriations. One of the most potent political constituencies of the day is the environmental community and its associated Private Voluntary Organizations (PVOs). Their major concerns center around ecological issues, particularly sustainable agriculture. These are issues in which most of the CRSPs have significant contributions to make. They could easily form a mutually beneficial coalition with these environmental groups to influence the appropriation and legislative process.

In today's world, A.I.D. is a relatively small contributor within the donor community. The largest aid expenditures are by the World Bank, the regional development banks and other bilateral donors, particularly the Japanese. Some of the CRSPs have already formed partnership with our Canadian friends to the north, but none have aggressively pursued our affluent neighbors across the pacific or sought funding from the multitude of foundations and other donor sources.

There is little evidence that the broad benefits provided by the CRSPs to domestic agriculture have been fully communicated and acknowledged at the individual state levels. There is every justification for increased support for CRSP activities by state legislatures. Current resources could be allocated from the Experiment Stations from both state and federal sources to the CRSP system. University research faculties have been notoriously inept at using effective public awareness methodologies to promote their needs by highlighting their contributions to domestic interests.

There has been much discussion of the new "debt-for-development" initiatives. In the foreseeable future nearly 3 trillion dollars worth of developing country debt will have to be recycled by one means or another. Innovative uses of local currency must become an everyday skill within the development community. A CRSP Council should become not only a partner in this effort but a leader. This includes not only recycling of debt but using local currencies generated through Public Law 480 and other local currency resources flowing from various A.I.D. and other government programs.

AN ACTION AGENDA FOR A CRSP COUNCIL

The individual CRSPs have been immobilized by holding their finger in the dike like the proverbial Dutch boy; yet in aggregate they could be an enormously potent force. While A.I.D. is already investing nearly $18 million/year in the CRSPs, there has been considerable discussion lately with the Regional Bureaus about the buy-in process in general and on how the budget of the individual Missions can be more fully tapped by the CRSPs. Not only A.I.D. but most of the other multilateral and bilateral donors are decentralizing decision-making authority to the country level. It is very difficult to operate long distance marketing even though use of mailing techniques might be improved. It is an overwhelming task for each CRSP to market their programs to a sprawling worldwide set of customers; however, a Council could bring together the aggregate resources to the point where each traveler abroad takes not only their individual sales kit but a portfolio of products that are accompanied by carefully developed promotional literature by the CRSP Council. The same is true of developing continuing contacts with the other donors, agencies, Congress, and other sources of potential support as outlined earlier in the paper. To be effective, a CRSP Council will undoubtedly need representation in Washington with adequate travel funds and the requisite communication skills to act as the focal point for the promotion and public awareness efforts of the entire CRSP system. The cost of such an effort would be nominal for each CRSP while the return on investment would be enormous. It is recommended that pursuits be made to join forces with the International Fund for Agricultural Research for this purpose.

In addition to efforts to expand the support base as outlined already, the CRSP Council should begin to develop a comprehensive methodology for linking the individual CRSPs into the broader global research system. This effort would start by linking into other A.I.D. centrally financed projects including the International Agricultural Research Centers (IARCs). After these initial efforts, linkages would be expanded to include the USDA and other relevant federal agency programs and then broadened to network with other institutions in other industrial countries. Lastly, the linkages must include the private sector in the U.S. and abroad.

EXPANSION OF THE CRSP SYSTEM

The CRSP model has been a highly successful experimant; however, as has been discussed in this meeting, there actually is no single CRSP model. Every CRSP has developed unique characteristics and thus we have a number of derivations from an overall model. It is time that we determine how the successful CRSP model and experience can be broadened to cover other major needs beyond pure research. Some of the comparative advantages of the CRSPs are that they are truly collaborative in mode, provide a long term sustained effort, and they utilize the most able participants from all the partners involved. I feel the same basic principles could be developed into "institution building" CRSPs, whether they be developing faculties of agriculture in developing countries or national research systems. We have moved beyond the era in which the long term resident expatriate mode is viable. Most of the institutions in developing countries now have a significant cadre of staff trained in the best institutions in industrialized countries. What is needed today is a partnership in which the best and the brightest on both sides work together to improve the overall efficiency and maintain cutting edge research and training performance. The U.S. universities are in a headlong rush towards internationalization and desperately need the contact skills and interaction with the overseas institutions to satisfy their own international agenda. On the same basis, the overseas universities need the continuing dialogue and interaction with their American counterparts. This lays the basis for long-term CRSP type relationships which would be mutually beneficial and should be mutually financed.

The same principals apply to technology transfer. At one time the U.S. was the dominant source of agricultural technology development; however, now the U.S. has less than 10 percent of the global scientist years in agricultural research and we are fast becoming a huge importer of overseas technology. Thus, technology transfer is equally important to U.S. interests as it is to our overseas partners. This then opens opportunities for "technology transfer" CRSPs that can be an expansion of current CRSPs to include technology transfer or one that deals with technology transfer alone. These technology transfer efforts need to more closely involve the private sector in partnerships, in addition to a university based transfer program.

NEW PARTNERSHIPS WITH THE PRIVATE SECTOR AND COMMODITY GROUPS

If the U.S. is to remain competitive in an expanding global agricultural economy, the collaborative linkages developed by the CRSPs must be extended to the U.S. private sector, the largest segment of agricultural research in the U.S. These linkages must further extend to the commodity and other farm groups. To effect such partnerships each major commodity or other specialized interest area such as pest management, soil and water management, aquatic resources, etc. should be developed as CRSP partnerships to orchestrate a global collaborative effort in research and development. The current CRSP network is only a start in this direction. Many of the major commodities in the U.S., such as corn, wheat, soybeans, and rice, are not covered by CRSP programs.

To initiate these partnerships I suggest that the current CRSPs, through the CRSP Council, systematically convene a series of major conferences for the interested parties by commodity group or other interest area. These should include the private sector research community, the commodity groups, the input suppliers, commodity traders, and other vested interests in concert with the representatives of Congress, the Administration, state legislatures, etc. The purpose would be

to develop a comprehensive collaborative research network for each commodity or factor, designed to ensure that the U.S. is fully linked into the global system for its own self interest in order to remain competitive. The U.S. will need immediate access to all the technology being developed abroad, which is now the majority in most research area. Unless we think ambitiously in this regard, the U.S. will suffer the consequences of inaction. Therefore, in closing I threw out the challenge in stating that the opportunities are infinite and the time is right because we are in the midst of a period of dynamic change. If we don't seize the opportunity today, we may never have another chance. We are at a crossroads where history can record us as heroes or as complacent villains of the tragedy that led to the demise of American agricultural preeminence. The choice therefore, ladies and gentlemen, is up to you. May the holidays be a period of happy reflection and the new year a time of dynamic action.

Appendix B

CRSP BUY-INS AND ALTERNATE MEANS FOR PARTICIPATION OF CRSP INSTITUTIONS IN A.I.D. PROJECTS

1. Buy-Ins and Basic Ordering Agreements (BOAs)

To implement buy-ins to CRSP projects, A.I.D. has established Basic Ordering Agreements (BOAs) to act as a companion instrument to the CRSP grant. The BOA permits the acquisition of (contracting for) services from institutions participating in a CRSP project which are complementary to the activities being conducted by such institutions under the CRSP grant, and are therefore included in the statement of work and subject to the terms and conditions set forth in the BOA. This has several significant implications:

(a) Is a Contract the Appropriate Instrument? A contract, such as a delivery order under the BOA, is used when a U.S. A.I.D. Mission wishes to procure the services of a participating institution for its own benefit or to implement its own project (or a portion thereof). Further discussion is provided below on the difference between a contractual relationship and an assistance relationship such as is established under a grant or cooperative agreement. At the least, the Mission must write a contractable statement of work which expresses its needs and prepare A.I.D.'s illustrative budget. If the Mission needs assistance with this, the S&T/AGR project officer can help, often with input from the participating institution(s).

(b) Is the Buy-In Activity Within the BOA Statement of Work? A BOA is not intended to be a means of acquiring services from a CRSP institution which are unrelated to the statement of work set forth in the BOA.

(c) Are the Buy-In Services Being Provided by "Outside" Subcontractors? The authority which permits A.I.D. to acquire services noncompetitively under the BOA is based on the "essential research capability" of the participating institutions. Thus, use of institutions other than those participating in the CRSP project is an abuse of the noncompetitive contracting authority, and would suggest that the buy-in activities are not within the statement of work of the BOA.

(d) Is the Buy-In Activity Consistent with Other Terms and Conditions of the BOA? A BOA delivery order for a buy-in must be issued before the estimated completion date of the BOA (which is the same as the CRSP grant) and cannot extend beyond 120 days from the estimated completion date of the BOA. There is a $25,000 minimum amount for any delivery order (buy-in). There is a cumulative dollar ceiling for delivery orders (buy-ins) in each BOA. These and other terms and conditions of the BOA may be constraints to using the BOA.

2. Alternate means for Participation of CRSP Institutions in A.I.D. Projects

Because of the above limitations on the use of the BOA, there are likely to be occasions when a buy-in (delivery order) under the BOA is inappropriate. However, this does not necessarily mean that there is no opportunity for involvement of CRSP institutions in the activities being contemplated by the Mission. If, in fact, a contractual relationship is appropriate, the Mission can use its own contracting authority and award its own discrete contract. This may

require competition, or a separate waiver of competition may be approved in the Mission. For short-term services, Missions have authority, if approved at a level above the Mission Contracting Officer, to use other than full and open competition procedures for Mission-issued contracts less than $100,000. The Title XII selection procedure, while competitive, may also be appropriate for acquiring the necessary services. However, in many cases, a grant or a cooperative agreement, rather than a contract, may be appropriate. Thus, an understanding of the differences between acquisition (contract) and assistance (grant or cooperative agreement) is essential. While this is somewhat theoretical and esoteric in nature, attached hereto are copies of the following guidance and handbook material:

(a) Attachment 1 - Chapter 25, A.I.D. Handbook 1, Supplement B. This reflects A.I.D. policy on the choice of implementation instrument, and summarizes the differences between a contract, a grant, and a cooperative agreement.

(b) Attachment 2 - Excerpts from A.I.D. Project Officers' Guidebook (June 1980). This provides further discussion on the differences between a contract, a grant, and a cooperative agreement.

(c) Attachment 3 - Paragraph 1B, A.I.D. Handbook 13. This provides a good discussion on the differences between a contract and an assistance instrument (grant of cooperative agreement).

(d) Attachment 4 - Chapter 6, A.I.D. Handbook 13. This provides a discussion on the differences between a grant and a cooperative agreement (both of which are assistance instruments). The appropriate type of assistance instrument is dependent on the nature and extent of A.I.D. involvement in the program being funded and supported by the assistance instrument. This attachment also describes examples of cooperative agreement, as opposed to a grant in which A.I.D. would have no substantial involvement. Note Appendix 6B, which describes use of cooperative agreements for the collaborative assistance method (CAM).

In summation, a contract is used for the acquisition of goods or services from the contractor for the direct benefit or use of the U.S. or Host Country government. In contrast, an assistance instrument is used for the transfer of funds (or other things of value) by A.I.D. to the recipient in order to accomplish a public purpose of support or stimulation. A grant is the appropriate form of assistance instrument when A.I.D. will not have substantial involvement in the program, while a cooperative agreement is the correct form of assistance instrument when A.I.D. will be substantially involved.

A contract is used to acquire goods or services to implement an A.I.D. project (or portion thereof) at A.I.D.'s direction, whereas an assistance instrument is used to support what is essentially the recipient's program with no A.I.D. operational control over either the overall performance of the project or of the specific work and the manner in which it is performed. Use of an assistance instrument does not imply that A.I.D. or the Host Country does not benefit from the program; in fact, a proposal for an assistance instrument would not be funded if it did not fall within a Mission's development strategy. Rather, an assistance instrument implies a mutuality of interest and benefit. This is consistent with the mandate of state universities such as the CRSP institutions, because it is presumed that the university would not be involved if the program did not offer some benefit to the state or to the U.S. This is also consistent with Title XII and the CRSP Guidelines, which acknowledge that agricultural research is of benefit to the Host Country as well as the U.S.

It is recognized that the foregoing guidance is far from definitive, and there are bound to be situations which do not fall neatly into a specific category. The CAM is an example, because CAM can be implemented under a cooperative agreement or under a contract. The determining factors are the nature of the intended relationship and the degree of A.I.D. involvement and control, and in the final analysis, there is no substitute for the judgment and discretion of the contract, grant, or agreement officer.

Thus, the fact that an assistance instrument may be funded under an A.I.D. project (including a bilateral project) does not, in itself, mean that the implementation instrument must be a contract. Similarly, the choice of instrument is not a function of the type of organization to which the instrument will be awarded.

Notwithstanding the questionable situations, there are clearly instances where an assistance relationship, rather than a contractual relationship, is both appropriate and intended. In many cases, a cooperative agreement could alleviate any Mission concerns about lack of Mission input under assistance instruments, although care must be taken to avoid A.I.D. involvement which is so substantial as to constitute a contract.

If an assistance relationship is appropriate, competition requirements are not as rigid as they are for contracts. Included herewith as Attachment 5 is a copy of Chapter 2 of A.I.D. Handbook 13, which describes the requirements for selection of recipients for assistance instruments. Note especially paragraphs 2B.3. and 2B.4. which describe exceptions to competition and justifications therefore. It is also important to note that the A.I.D. project officer must submit the justification to the grant (or agreement) officer. If the grant (or agreement) officer agrees with the justification, a noncompetitive award of an assistance instrument may then be made.

If a Mission does not have a professional grant (or agreement) officer, the Mission Director or Principal A.I.D. Officer has the authority to act as a grant (or agreement) officer for cooperative agreements not exceeding $100,000 and for grants not exceeding $5,000,000. If the amount of the grant or cooperative agreement is in excess of such authority, an ad hoc delegation of authority may be requested by the Mission from MS/PPE/PE in A.I.D./Washington.

Like the CRSP grant and BOA, a Mission-issued contract or assistance instrument would be made to a given university and not to a specific entity within the university. Thus, it would be at the university's discretion as to whether the CRSP management office or management entity (ME) would be designated by the university as the responsible entity within the university. Similarly, a Mission-issued contract or assistance instrument could be awarded to the university acting as the ME under the CRSP grant and BOA, or to the participating institution(s) which will actually implement the project.

Appendix C

PARTICIPANTS REGISTERED AS OF APRIL 27, 1990

George Abawi
Dept. of Plant Pathology
Cornell University
Geneva, NY 14456

Jorge Acosta, INIFAP
Apartado Postal 20
Babellon, AGS 20260, MEXICO

Wayne Adams, Prof. Emeritus
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

James Anderson, Dean
Ag. & Natural Resources
Michigan State University
East Lansing, MI 48824

Raj Bahadur
Dept. of Biology
Mississippi Valley St. Univ.
Itta Bena, MS 38941

Judith B. Balderston
Nutrition CRSP
641 Alvarado Road
Univ. of Calif.-Berkeley
Berkeley, CA 94705

Pat Barnes-McConnell
Bean/Cowpea CRSP
200 International Center
Michigan State University
East Lansing, MI 48824

Mark J. Bassett
IFAS, Vegetable Crops
1255 Fifield Hall
University of Florida
Gainesville, FL 32611-0514

Ted Batterson
Pond Dyn/Aquaculture CRSP
Fisheries & Wildlife
Michigan State University
East Lansing, MI 48824

James S. Beaver
Dept. of Agronomy & Soils
University of Puerto Rico
Mayaguez, PR 00708

Sue Bengry
Bean/Cowpea CRSP
200 International Center
Michigan State University
East Lansing, MI 48824

Gustavo Bernal
INIAP
Casilla Postal 340
Quito, ECUADOR

Larry R. Beuchat
Food Sci. & Technology
Univ. of Georgia Ag.
Experiment Station
Griffin, GA 30223-1797

Duncan Boughton
Dept. of Agricultural Econ.
Michigan State University
East Lansing, MI 48824

Ricardo Bressani
INCAP
Carretera Roosevelt Zona 11
Guatemala City, GUATEMALA

Stuart Callison
BIFAD
Room 600, State Annex 2
Washington, DC 20523-0219

Oyette Chambliss
Dept. of Horticulture
Purdue University
West Lafayette, IN 47907

Limamoulaye Cisse
Dept. of Crop Production
ISRA, BP 3120
Dakar, SENEGAL

Ndiaga Cisse
Dept. of Crop Production
CNRA, BP 53
Bambey, SENEGAL

Dermot P. Coyne
Dept. of Horticulture
University of Nebraska
Lincoln, NE 68593-0724

David Cummins, Director
Peanut CRSP
University of Georgia
Griffin, GA 30223-1797

Todo Edje
SADCC/CIAT
Regional Bean Program
Arusha, TANZANIA

Hillary Egna
Pond Dyn/Aquaculture CRSP
Oregon State University
Corvallis, OR 97331-1641

Carol Engle
Pond Dyn/Aquaculture CRSP
Univ. of Ark-Pine Bluff
Pine Bluff, AK 71601

Anne Ferguson
Bean/Cowpea CRSP
200 International Center
Michigan State University
East Lansing, MI 48824

Russell D. Freed
Bean/Cowpea CRSP
200 International Center
Michigan State University
East Lansing, MI 48824

Elizabeth Garcia
Food Sci, Human Nutrition
Washington State Univ.
Pullman, WA 99164-6376

Paul Gepts
Agronomy & Range Science
University of California
Davis, CA 95616

Robert Gilbertson
Dept. of Plant Pathology
University of Wisconsin
Madison, WI 53706

Kenneth Grafton
Dept. of Crop & Weed Sci.
N. Dakota State Univ.
Fargo, ND 58105

Peter Graham
Dept. of Soil Science
University of Minnesota
St. Paul, MN 55108

Thurman Grove
A.I.D.
420C, SA-18
Washington, DC 20523

Tony Hall
Botany & Plant Sci. Dept.
University of California
Riverside, CA 92521

Roger G. Hanson
Soil Management CRSP
N. Carolina State University
Raleigh, NC 27695--7113

Dale Harpstead
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

Michael Havey
USDA/ARS, Horticulture
University of Wisconsin
Madison, WI 53706

Harvey Hortik
AID/S&T/AGR/AP
420C, SA-18
Washington, DC 20523

George Hosfield
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

James E. Hunter
Cornell University
NYS Ag. Experiment Station
Geneva, NY 14456

Donald Isleib, Director
IIA
324 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Fred Johnson
BIFAD/A.I.D.
Room 600, State Annex 2
Washington, DC 20523-0219

Jim Kelly
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

Avanelle Kirksey
Nutrition CRSP
Dept. of Foods & Nutrition
Purdue University
West Lafayette, IN 47907

Laurie Kitch
Purdue University
Entomology Dept.
West Lafayette, IN 47907

Henk Knipscheer
Winrock International
Pete Jean Mountain
Morrilton, AR 72110

Julia Kornegay
CIAT
A.A. 6713
Cali, COLOMBIA

Bernard Kupfuma
Agronomy Institute
P.O. Box 8100, Causeway
Harare, ZIMBABWE

H. Arthur Lamey
Dept. of Plant Pathology
N. Dakota State University
Fargo, ND 58105

Robert Mabagala
1573K Spartan Village
East Lansing, MI 48823

Mercy Mafuleka
1403-I Spartan Village
East Lansing, MI 48823

Douglas P. Maxwell
Dept. of Plant Pathology
University of Wisconsin
Madison, WI 53706

Wayne McLaughlin
Biotechnology Center
Univ. of the West Indies
Mona, Kingston 6, JAMAICA

Cal McNabb
Pond Dyn/Aquaculture CRSP
Fisheries & Wildlife
Michigan State University
East Lansing, MI 48824

Kay H. McWatters
Food Sci. & Technology
University of Georgia
Griffin, GA 30223

Alex Mkandawire
P.O. Box 219
Bunda College of Agr.
Lilongwe, MALAWI

Richard Mkandawire
Rural Sociology
Bunda College of Agr.
Lilongwe, MALAWI

J.P. Moss
ICRISAT
Patancheru Andhra
Pradesh 502 324
INDIA

Larry Murdock
Purdue University
Entomology Department
West Lafayette, IN 47907

T. O. M. Nakayama
Food Sci. & Technology
University of Georgia
Griffin, GA 30223

Dickson Nnanyelugo
Home Sci. & Nutrition
University of Nigeria
Nsukka, NIGERIA

Georges Ntoukam
Entomology Dept.
Purdue University
West Lafayette, IN 47907

Abelardo Nunez
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

James W. Oxley
Small Ruminant CRSP
University of California
Davis, CA 95616

Jim Paterson
103 Pesticide Research Ctr
Michigan State University
East Lansing, MI 48823

Eldor Paul
Dept. of Crop & Soil Sci.
Michigan State University
East Lansing, MI 48824

R. Dixon Phillips
Food Sci. & Technology
University of Georgia
Griffin, GA 30223

Antonio Pinchinat
IICA, P.O. Box 1223
Castries, St. Lucia, WEST INDIES

Wisdom Plahar
Food Sci, Human Nutrition
Washington State University
Pullman, WA 99164-4015

Joe C. Purcell
Peanut CRSP
University of Georgia
Griffin, GA 30223-1797

Eliane Dias Quintela
CNPAF/EMBRAPA
Caixa Postal 179
Goiania 74.000 Goias, BRAZIL

Donald W. Roberts
Boyce Thompson Institute
Cornell University
Ithaca, NY 14853

John Robins
6707 55th Street Ct. W.
Tacoma, WA 98467

Rafael Rodriguez
ICTA, Avenida La Reforma 8-60
Apartado Postal 231-A Zona 9
Guatemala City, GUATEMALA

Juan Carlos Rosas
Dept. of Agronomy & Soils
University of Puerto Rico
Mayaguez, PR 00708

John Rowntree
Fisheries Stck Asmn't CRSP
University of Maryland
College Park, MD 20742

Freddy Saladin Garcia
SEA/CESDA
Apartado postal No. 24
San Cristobal, DOMINICAN REPUBLIC

Richard Shade
Purdue University
Dept. of Entomology
West Lafayette, IN 47907

Bharat Singh
Peanut CRSP
University of Georgia
Griffin, GA 30223

Shiv Singh
IITA:PMB 5320
Ibadan, NIGERIA

Idah Sithole
Plant Biology Building
Michigan State University
East Lansing, MI 48823

James R. Steadman
Dept. of Plant Pathology
University of Nebraska
Lincoln, NE 68583-0722

Barry Swanson
Food Sci, Human Nutrition
Washington State Univ.
Pullman, WA 99164-6376

Steven R. Temple
Agronomy & Range Science
University of California
Davis, CA 95616

James M. Teri
Dept. of Crop Science
Sokoine Univ. of Agr.
Box 3005
Morogoro, TANZANIA

Mark Uebersax
Food Sci, Human Nutrition
Michigan State University
East Lansing, MI 48824

Donald H. Wallace
Plant Breeding Dept.
Cornell University
Ithaca, NY 14853-1902

Gerald C. Wheelock
Peanut CRSP
Alabama A&M University
Normal, AL 35762

Jane Wolfson
Purdue University
Dept. of Entomology
West Lafayette, IN 47907

John Yohe
Sorghum/Millet CRSP
University of Nebraska
Lincoln, NE 68583-0723

Nevin Dale Young
Dept. of Plant Pathology
University of Minnesota
Minneapolis, MN 55455

Bonnie Zell
Bean/Cowpea CRSP
Michigan State University
East Lansing, MI 48824

Appendix D

THE GLOBAL PLAN OF THE BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

INTRODUCTION

The CRSP stimulates and supports commodity-related research collaboration among AID, the U.S. Land-Grant university community (with limited contributions from the U.S. Department of Agriculture), private institutes, Host Country (HC) institutions and International Agricultural Research Centers. These aggressive collaborative efforts are to focus on persistent constraints to bean and cowpea production and utilization. This plan presents the organization of the research and management efforts designed to address specific constraints in representative agro-ecological areas of the world where beans and cowpeas are grown. The network of bean and cowpea scientists established by this CRSP will make accessible to interested programs in the U.S. and HCs expertise for problem-solving throughout the developing world.

Program Goal

The Bean/Cowpea CRSP makes available to the international agricultural research and development system a new avenue to the U.S. agricultural research network. In so doing, this CRSP is expected to make important contributions to the resolution of difficult and persistent problems associated with bean and cowpea production and utilization in areas of the world where they are important commodities.

The grant document puts forward the following goal of the Bean/Cowpea CRSP:

> The goal of this program is to make a significant contribution to improving the living conditions of small farm producers in LDCs and increasing availability of low cost nutritious foodstuffs in the marketplace for the rural and urban poor.

Program Purpose

The grant document further identifies the following purpose of the CRSP:

> The purpose of this program is to organize and mobilize financial and human resources necessary for mounting a major multi-institutional U.S.-LDC collaborative effort of research and training related to bean and cowpea production and consumption by:
>
> (1) Linking institutions having common interests in organized programs of research on this CRSP;
>
> (2) Mobilizing and coordinating the research talent from eligible institutions to ameliorate world food, nutrition, and poverty problems by research in the priority area of this CRSP; and by
>
> (3) Achieving optimum collaboration and information exchange on this CRSP with AID Missions, International Research Centers and LDC Institutions.

CONSTRAINT ELEMENTS

Through visits to Host Countries, communications with official HC representatives and exploration of available documentation, the major constraints to bean and cowpea availability were identified. This information was documented in the resulting state-of-the-art publication (Adams, M. W. 1984. Beans--Cowpeas: Production Constraints and National Programs. East Lansing, MI: Michigan State University, Bean/Cowpea CRSP Management Office). Its early draft became the basis for the development of projects in representative regions.

The researchable constraints identified were as follows:

1. Limitations due to insects
2. Limitations due to diseases
3. Plant response limitations
4. Limitations of the physical environment
5. Production-consumption economics, farming systems, socio-cultural factors
6. Storage, food preparation, nutrition and health
7. Education, training and research capability

ARTICLES OF THE GLOBAL PLAN

Through the collaborative project activity, HC as well as U.S. professionals are to be strengthened in their ability to address the constraints by forming productive professional relationships with one another. As first enunciated by the founders of this CRSP, the specific contributions appropriate from these U.S./HC teams are clear.

1. We must address, collaboratively with LDC scientists, the problems of insect and disease control. We may, in the short term, have to rely upon judicious use of non-persistent pesticides and upon novel means of applying them (for example, pyrethrums and ultra-low volume spraying); but for the longer term, we must rely on an integrated pest management system which includes breeding pest resistant cultivars, protective farming practices and biological rather than expensive and toxic chemical control systems.

2. We must support the evolution of sustainable and more productive systems. The evolving systems must maintain biodiversity, and their adaptation to the variety of conditions on small farms, utilizing breeding for higher yields and through improved mixed cropping management.

3. We must address the problem of inefficient nitrogen fixation. In order to escape the tyranny of the spiralling costs of plant nutrients, we can investigate the development of more efficient cultivars as well as nitrogen-fixing bacteria and the evolution of more appropriate farming techniques.

4. We must work to overcome problems of drought, through breeding more drought resistant cultivars and the development of farming systems that are efficient and conserving in their use of water.

5. We must work toward better nutritive value and digestibility of the food constituents of beans and cowpeas, through breeding and use Food Science research to identify and study traits, important to improve acceptability and nutrient quality.

6. We must work to overcome or minimize the problem of hard seeds and long-cooking time in beans and cowpeas, through both breeding and the use of simple storage or processing tactics, in order to reduce cooking time and fuel requirements.

7. We must promote the creation or operation of seed multiplication programs in order to reach the small farmers with seeds of improved cultivars that are not only genetically superior but that are of sound physical quality and free of seed-borne diseases. The issues of seed availability and credit to women for seed purchases must also be addressed.

8. We must help evolve methods of storage and of food preparation that conserve the full value of the dry grains without insect depredation, fungal infestation and that permit retention of full nutritive capability of these grains (or other plant parts, as applicable) when made ready for consumption. There must be no marked alteration in the grains that detracts from their acceptance and safety as food.

9. We must be cognizant of the interacting and sometimes contradictory results of various technological interventions. We must, therefore, carry out production/consumption-oriented research with socio-economic analysis to assess the acceptability and agro-economic feasibility of proposed interventions. Marketing studies should determine whether improvements, in terms of greater real gain to the farmer, can be made in the system.

10. We must give substantive consideration to major components of the farming system and especially the human components. We must become sensitive to and knowledgeable about the unique and multiple roles played by women, men and children in developing countries as they affect production and utilization of beans and/or cowpeas.

11. We must attempt to maintain an acceptable ecology by encouraging all collaborators to look specifically at the relationship of their research to the agronomic, social and cultural context of the small farm family. Researchers will have to assess the potential of their research for increasing or lessening the frequently over-whelming burden of daily living for such families, an assessment which will suggest the level of acceptance that can be anticipated.

12. We must address a serious problem of research personnel availability by supporting the training of indigenous professional and technical personnel. Trainees at all levels, including post-graduate students, will need to be supported in order to help build a supply of skilled individuals, both men and women, who can conduct useful and needed research and demonstration work with beans and cowpeas.

13. We must facilitate the institution building and development of collaborative relationships, not only between U.S. and Host Country scientists, but cross-nationally among LDC scientists themselves, and among U.S. scientists as well. The resulting networks will address the major constraints in cowpea and bean production and utilization.

14. We must facilitate the introduction of biotechnology where appropriate to the relief of constraints of beans and cowpeas.

COMMODITY ELEMENTS

It was determined that *Phaseolus vulgaris* and *Vigna unguiculata* would be the focus of this program. Although there are other legumes to which research could make an important contribution, these two were considered the most critical ones worldwide and the ones for which research expertise was most available in the U.S.

GEOGRAPHIC ELEMENT

Because sensitivity to daylength, temperature and rainfall patterns are important in the adaptation of beans and cowpeas, countries providing a range of agro-ecological conditions were chosen for the research. In addition to the U.S., the Host Countries currently participating in this CRSP are:

AFRICA		LATIN AMERICA	
Cameroon	Senegal	Brazil	Guatemala
Malawi	Tanzania	Dominican Republic	Honduras
Nigeria		Ecuador	Mexico

Collaborating with the programs in these African and Latin American nations are the following U.S. institutions:

Boyce Thompson Institute, Ithaca, New York
Cornell University, Ithaca, New York
Michigan State University, East Lansing, Michigan
Purdue University, West Lafayette, Indiana
University of California, Davis, California
University of California, Riverside, California
University of Georgia, Griffin, Georgia
University of Minnesota, St. Paul, Minnesota
University of Nebraska, Lincoln, Nebraska
University of Puerto Rico, Mayagüez, Puerto Rico
University of Wisconsin, Madison, Wisconsin
Washington State University, Pullman, Washington

SERVICE ELEMENTS

A major goal of the program is to improve the well being of small-scale farmers in developing countries through increasing their capacity to produce, utilize and market beans and cowpeas. In many contexts, meeting this goal requires that special attention be paid to women's roles in agriculture. In Africa especially, women often bear the primary responsibility for the production of legumes and other food crops consumed by their families.

Directing research to meet the needs of women and other small-scale farmers requires a multidisciplinary approach involving social and biological scientists, nutritionists, food technologists and others. This multidisciplinary research process frequently yields results which not only benefit developing countries but also find application in U.S. agriculture.

PROJECT ELEMENTS

The CRSP is divided into individual, but coordinated, projects organized to carry out research on constraints in the countries representative of where these constraints are important and where the expertise to collaborate exists. Each project is organized under the management of a U.S. lead institution with a U.S. Principal Investigator (PI) to lead the conduct of the joint research in the constraint area. In the HCs, a counterpart PI is named to be responsible for project collaboration and Host Country activities. The present projects of the CRSP are as follow:

Title of Project	Host Country	U.S. PI/HC PI
Biocontrol of Insects in Cowpea-Management Systems in Africa	Brazil	Don Roberts/Eliane Quintela
Preservation of Postharvest Cowpeas by Low Resource Farmers in Cameroon	Cameroon	Larry Murdock/Zachee Boli
Breeding for Resistance to Pathogens of Beans, with Emphasis on Bacterial Blight and Rust	Dominican Republic	Dermot Coyne/Freddy Saladin
Molecular Approaches for the Control of Bean Golden Mosaic and Other Viruses	Dominican Republic	Doug Maxwell/Freddy Saladin
Improving the Symbiotic Nitrogen Fixation of Cultivars of *Phaseolus vulgaris* Under Low Resource Conditions in Ecuador	Ecuador	Peter Graham/Gustavo Bernal
Genetics, Physiology and Agronomy of Bean Adaptation and Yield	Guatemala	Don Wallace/Raphael Rodriguez
Strategies for Breeding Beans with Enhanced Disease Resistance	Honduras	Jim Beaver/Juan Carlos Rosas
Greater Tolerance to Drought		
Improving the Protein Digestibility, Acceptability and Other Nutritional Qualities of Dry Beans Through Food Science and Breeding	INCAP	Barry Swanson/Ricardo Bressani
Bean Improvement, Genetic Diversity and Host/Pathogen Co-adaptation in Malawi	Malawi	Paul Gepts/Alex Mkandawire

Title of Project	Host Country	U.S. PI/HC PI
Breeding Beans for Yield, Adaptation and Nitrogen-Fixation Capacity under Conditions of Limited Moisture	Mexico	Dale Harpstead/Jorgé Acosta
Appropriate Technology for Cowpea Preservation and Processing and a Study of Its Socio-Economic Impact on Rural Populations in Nigeria	Nigeria	Kay McWatters/Dickson Nnanyelugo
Development of Improved Cowpea Varieties, Management Methods and Storage Practices for Semiarid Regions	Senegal	Tony Hall/Limamoulaye Cisse
Breeding High-Yielding Bean Varieties Resistant to Diseases and Insects and an Assessment of their Socio-Economic Impact	Tanzania	Matt Silbernagel/James Teri

POLICY ELEMENTS

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./HC Distribution of Funds

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

(1) To insure CRSP focus on the solution of Host Country problems rather than on the maintenance of existing research programs of U.S. institutions and

(2) To nourish a climate of collaboration and partnership between the U.S. and Host Country PIs.

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

One-hundred 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 Contribution 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 HC institutions through the training of HC nationals, a critical resource necessary for successful long-term research. To achieve this goal, CRSP projects are to give emphasis to the training of Host Country persons over the training of U.S. persons. This policy adopts a Host Country 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. Bean/Cowpea CRSP 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 ongoing 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.

CONCLUSION

While the constraints identified in this Global Plan are important country-specific issues, they exist throughout the world wherever beans and cowpeas are grown. By distributing research attention to these constraints across the agro-ecological zones represented by the CRSP countries, principles are elucidated which have application throughout the legume-producing world. Research collaboration, therefore, can be of great benefit to many countries. In particular, CRSP research collaboration has demonstrated that there is as much specifically for the U.S. to learn and gain from traditional settings as there is for modern research to contribute in return. Through partnerships the CRSP supports regional contributions from all participating national programs which in turn increases their integration into the thus expanded international agricultural research community.

Appendix E

THE BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

MANAGEMENT ENTITY
Michigan State University

MANAGEMENT OFFICE
200 International Center
East Lansing, Michigan 48824

Dr. Pat Barnes-McConnell, Director
Dr. Russell Freed, Deputy Director
Dr. Anne Ferguson, WID Specialist
Ms. Sue Tengry, Administrative Officer
Ms. Bonnie Zell, Program Secretary

MANAGEMENT ENTITY REP.
Dr. Donald Isleib, Director
Institute of International Agriculture
324 Agriculture Hall
Michigan State University
East Lansing, MI 48824

A.I.D. PROGRAM OFFICER
Dr. Harvey Hortik
A.I.D./S&T/AGR/AP
Room 420C, SA-18
Washington, DC 20523

BIFAD CONTACT
Mr. W. Fred Johnson
BIFAD
A.I.D.
Room 600, State Annex 2
Washington, DC 20523-0219

BEAN/COWPEA CRSP FY 90 TECHNICAL COMMITTEE

Dr. Larry Murdock (Chair)
Professor and Coordinator, RIISP
Department of Entomology
Entomology Hall, S. University Drive
Purdue University
West Lafayette, IN 47907

Dr. Larry R. Beuchat
Dept. of Food Science and Technology
1109 Experiment Street
University of Georgia
Agricultural Experiment Station
Griffin, GA 30223-1797

Dr. Peter H. Graham
Department of Soil Science
University of Minnesota
256 Borlaug Hall
1991 Upper Buford Circle
St. Paul, MN 55108

Dr. Douglas Pachico
Coordinator, Bean Program
CIAT
Apartado Aereo 6713
Cali, COLOMBIA

Dr. Douglas P. Maxwell (Secretary)
Professor and Chair
Department of Plant Pathology
University of Wisconsin
284 Russell Labs
1630 Linden Drive
Madison, WI 53706

Dr. Matt J. Silbernagel
USDA/SEA/AR
Irrigated Agricultural Research and Extension Center
P.O. Box 30, Bunn Rd
Prosser, WA 99350

Dr. James Tera
Sokoine University of Agriculture
Box 3005 Subpost Office, Chuo Kikuu
Morogoro, TANZANIA

Dr. Shiv R. Singh
IITA Nigeria
c/o Mrs. Maureen Larkin
L. W. Lambourn and Co.
Carolyn House, 26 Dingwall Road
Croydon CR9 3EE ENGLAND

BEAN/COWPEA CRSP FY 90 EXTERNAL EVALUATION PANEL (EEP)

Dr. Clarence Gray, III (Outgoing Chair)
Professor Emeritus
International Extension and
International Studies
Virginia Polytechnic Institute and
State University
Office: 9945 Great Oaks Way
Fairfax, VA 22030

Dr. Jack Robins (Incoming Chair)
6707 55th St., Ct. W.
Tacoma, WA 98467

Dr. Kenneth Rachie
13 Coronado Trace
Hot Springs Village, AR 71909

Dr. Edna McBreen, Director
Office of International Programs
West Virginia University
Morgantown, WV 26506

Dr. Art Siedler
Department of Food Science
College of Agriculture
University of Illinois
Urbana, IL 61801

CRSP DIRECTORS

Dr. Pat Barnes-McConnell, Director
Bean/Cowpea CRSP
200 International Center
Michigan State University
East Lansing, MI 48824-1035

Ms. Hillary Egna, Director
Pond Dynamics/Aquaculture CRSP
Office of International Research and
Development
400 Snell Hall
Oregon State University
Corvallis, OR 97331

Dr. John Rowntree, Director
Fisheries Stock Assessment CRSP
International Programs
2331 Computer Space Science Building
University of Maryland
College Park, MD 20742

Dr. J. W. Oxley, Program Director
Small Ruminant CRSP
University of California
Davis, CA 95616

Dr. Nell Kirksey, Director
Nutrition CRSP
Department of Foods and Nutrition
Purdue University
West Lafayette, IN 47907

Dr. Roger Hanson, Director
Soil Management CRSP
Department of Soil Science
North Carolina State University
Raleigh, NC 27695-7113

Dr. David Cummins, Director
Peanut CRSP
University of Georgia
Georgia Experiment Station
Griffin, GA 30223-1797

Dr. John Yohe, Director
Sorghum/Millet CRSP
International Programs
University of Nebraska
Lincoln, NE 68583-0723

BEAN/COWPEA CRSP U.S. INSTITUTIONAL REPRESENTATIVES

Dr. C. Eugene Allen
Acting Vice President
Agriculture, Forestry and Home Economics
201 Coffey Hall
University of Minnesota
1420 Eckles Avenue
St. Paul, MN 55108

Dr. James H. Anderson, Dean
College of Agriculture
and Natural Resources
104 Agriculture Hall
Michigan State University
East Lansing, MI 48824

Dr. Louis J. Boyd
Coordinator of International Agriculture
201 Conner Hall
Cedar Street
University of Georgia
Athens, GA 30602

Dr. Carlos Cruz, Director
Department of Crop Protection
College of Agricultural Sciences
University of Puerto Rico
Pinero Annex 313
Mayagüez, PR 00708

Dr. James E. Hunter, Associate Director
NYS Agricultural Experiment Station
Cornell University
P. O. Box 462, West North Street
Geneva, NY 14456

Dr. Dennis Oldenstadt[4]
Associate Director
Agricultural Research Center
403 Hulbert Hall
Wilson Road
Washington State University
Pullman, WA 99164-6240

Dr. Eldor A. Paul, Chair[1]
Department of Crop and Soil Sciences
286 Plant and Soil Sciences Building
Michigan State University
East Lansing, MI 48824

Dr. Kenneth Shapiro
Associate Dean and Director of
International Programs
240 Agriculture Hall
1450 Linden Drive
University of Wisconsin
Madison, WI 53706

Dr. D. Woods Thomas, Director[2]
International Programs in Agriculture
26 Agricultural Administration Bldg.
Purdue University
West Lafayette, IN 47907
(317) 494-8466

Dr. Dale Vanderholm, Associate Dean[3]
Agricultural Research Division
109 Agricultural Hall
University of Nebraska-Lincoln
Lincoln, NE 68583-0704

Dr. Seymour Van Gundy, Associate Dean[2]
College of Natural and Agricultural
Sciences
University of California-Riverside
1140 Batchelor Hall
Riverside, CA 92501

UN-OFFICIAL:

Dr. Ralph Hardy, President
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853

[1]*Permanent member on Board of Directors representing Dean Anderson of MSU*
[2]*Member FY 90 Board of Directors*
[3]*Secretary of FY 90 Board of Directors*
[4]*Chair of FY 90 Board of Directors*

BEAN/COWPEA CRSP HOST COUNTRY INSTITUTIONAL REPRESENTATIVES

Dr. Jacob Ayuk-Takem, Director
Institute de Recherches Agricoles
c/o Ron Levin
Yaounde ID
Department of State
Washington, DC 20520 (CAMEROON)

Dr. Manilo Castillo
Gerente en Funciones
ICTA
Guatemala City, GUATEMALA

Dr. Brown Chimphamba, Principal
Bunda College of Agriculture
University of Malawi
P. O. Box 219
Lilongwe, MALAWI

Mr. Salomon Cohen, Chief
Planning and Development Unit
INCAP
Guatemala City, GUATEMALA

Dr. Mohammed El Habib Ly
Le Directeur General
Institute Senegalais De Recherches
Agricoles
Boite Postale 3120
Dakar, SENEGAL

Dr. Luis Carlos Fierro
INIFAP
Apartado Postal #186
34000 Durango
Durango, MEXICO

Dr. A. B. Lwoga, Vice-Chancellor
Sokoine University of Agriculture
Department of Crop Science
Morogoro, TANZANIA

Dr. Simon Malo, Director
Escuela Agricola Panamericana
P.O. Box 93
Tegucigalpa, HONDURAS

Dr. Thomas Ndubizu
Dean of Agriculture
University of Nigeria
Nsukka, NIGERIA

Ing. Agr. Raphael Perez Duverge
Director de Deprtmento de
Investigaciones Agropecuaria
Secretary de Estado Agricultura
Santo Domingo, DOMINICAN REPUBLIC

Dr. Luis Stone
Chief Adj. Tecnico
EMBRAPA/CNPAF
Caixa Postal 179
Goiania, Goias 74.000
BRAZIL

INIAP/Ecuador
(Representative not yet named)

BEAN/COWPEA CRSP U.S. PRINCIPAL INVESTIGATORS

Dr. M. Wayne Adams (Acting)
Department of Crop and Soil Sciences
384D Plant and Soil Sciences Building
Michigan State University
East Lansing, MI 48824

Dr. James Beaver
Department of Agronomy
University of Puerto Rico
College of Agricultural Sciences
Pinero 221
Mayagüez, PR 00708

Dr. Dermot Coyne
Department of Horticulture
386 Plant Sciences, East Campus
University of Nebraska
Lincoln, NE 68583

Dr. Peter Graham
Department of Soil Sciences
256 Borlaug Hall
University of Minnesota
St. Paul, MN 55108

Dr. A. E. Hall
Department of Botany and Plant Sciences
4133 Batchelor Hall
University of California-Riverside
Riverside, CA 92521

Dr. Dale Harpstead
Department of Crop and Soil Sciences
A384 Plant and Soil Sciences Building
Michigan State University
East Lansing, MI 48824

Dr. Douglas Maxwell, Chair
Department of Plant Pathology
1630 Linden Drive
University of Wisconsin-Madison
Madison, WI 53706

Ms. Kay McWatters
Department of Food Science
Woodruff Drive at Hwy 3
University of Georgia
Griffin, GA 30223-1797

Dr. Larry Murdock
Department of Entomology
ARB 111, Entomology Hall
Purdue University
West Lafayette, IN 47907

Dr. Donald Roberts
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853-1081

Dr. Matt J. Silbernagel
USDA/SEA/AR
Irrigated Agricultural Research
and Extension Center
P.O. Box 30
Prosser, WA 99350

Dr. Barry Swanson
Food Science and Human Nutrition
106 FSHN Building
Washington State University
Pullman, WA 99164-6376

Dr. Donald Wallace
Plant Breeding Department
Cornell University
Ithaca, NY 14853

BEAN/COWPEA CRSP HOST COUNTRY PRINCIPAL INVESTIGATORS

Dr. Jorge Acosta
INIFAP
Apartado Postal 20
Babellon, Aguascalientes 20260
MEXICO

Mr. Zachee Boli Baboule
Chef de Centre
IRA
Maroua, CAMEROON

Ing. Gustavo Bernal
INIAP
Casilla Postal 340
Quito, ECUADOR

Dr. Ricardo Bressani, Chief
Division of Agriculture and Food Science
INCAP
Calzada Roosevelt Zonall
Apartado Postal 1188
Guatemala City, GUATEMALA

Mr. Limamoulaye Cisse
ISRA
Rue de Thiong x Valmy
BP 3120
Dakar, SENEGAL

Dr. A. B. C. Mkandawire
Department of Crop Production
Bunda College of Agriculture
P. O. Box 219
Lilongwe, MALAWI

Mr. Dickson Nnanyelugo
Department of Home Science and Nutrition
University of Nigeria
Nsukka, NIGERIA

Ms. Eliane Quintela
CNPAF/EMBRAPA
Caixa Postal 179
Goiania, Goias 74.000
BRAZIL

Dr. Rafael Rodriguez
ICTA
Avenida La Reforma 8-60
Apartado Postal 231-A Zona 9
Guatemala City, GUATEMALA

Dr. Juan Carlos Rosas
Escuela Agricola Panamericana
Apartado 93
Tegucigalpa, HONDURAS

Ing. Agron. Freddy Saladin
CESDA
Box 24
San Cristobal, DOMINICAN REPUBLIC

Dr. James M. Teri
Department of Crop Science
Sokoine University of Agriculture
Box 3005 Subpost Office, Chuo Kikuu
Morogoro, TANZANIA