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MIDCOURSE 2000 RESEARCHERS MEETING
OF THE
BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM

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THE BEAN/COWPEA COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

An international community of persons,
institutions, agencies and governments committed
to collectively strengthening health and nutrition in
developing countries by improving the availability
and utilization of beans and cowpeas

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These Proceedings are dedicated to
Dr. Patricia W. Barnes-McConnell
for distinguished service to the Bean/Cowpea CRSP

All work is as seed sown; it grows and spreads, and sows itself anew .
Thomas Carlyle

Dr. Patricia Barnes-McConnell, Professor, Department of Resource Development, College of Agriculture and Natural Resources, Michigan State University, has provided distinguished leadership to the Bean/Cowpea Collaborative Research Support Program from its inception. She contributed to the formulation of the initial vision of the program by serving as the Assistant Planning Coordinator for Development of the Bean/Cowpea CRSP in 1979-80. As a social scientist with an interest in the impact of international development on women, she participated in the Malaŵi project during the early years with Dr. M. Wayne Adams. In 1981, she was appointed as Deputy Director of the Bean/Cowpea CRSP while at the same time providing leadership in the capacity of Director (1981-83) to the expanding Women in International Development Program at MSU. Dr. Barnes-McConnell assumed the CRSP Director role in 1983 and remained in that position for nearly 17 years. On June 1, 2000, she began her consulting year at MSU, during which time she will be focusing on writing about the successes and impacts of the Bean/Cowpea CRSP over the past 20 years.

Under Dr. Barnes-McConnell's leadership, the Bean/Cowpea CRSP has not wavered from its mandate of strengthening health and nutrition in developing countries by improving the availability and utilization of beans and cowpeas. During the past 20 years, a total of 14 institutions in Latin America, the Caribbean, and in West and East Africa, plus 16 U.S. institutions have participated in collaborative research and training activities as part of the CRSP community. To date, approximately 475 students have participated in degree training programs with full or partial support from the CRSP. When the Bean/Cowpea CRSP completes its current extension in FY 2002, nearly $60 million will have been obligated to the Bean/Cowpea CRSP by the U.S. Agency for International Development.

Dr. Barnes-McConnell's contributions to the success of the Bean/Cowpea CRSP were best summed up by a CRSP trainee and current HC Principal Investigator. "Dr. Pat Barnes-McConnell is an extremely wonderful person who expertly led this CRSP to new heights each year of its existence. We all (HC CRSP scientists) loved to work with her. As CRSP graduates, we regarded her as our mother too. We wish her a retirement with many more years of joy to her family."

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FORWARD

The Bean/Cowpea Collaborative Research Support Program (CRSP) convened a *Midcourse 2000 Meeting* of its Principal Investigators and Regional Facilitators at the Kellogg Center on the Michigan State University campus in East Lansing, Michigan, on April 9 to 14, 2000. Scientists involved in bean and cowpea research, representing regional projects in West Africa, East Africa and Latin America/Caribbean, were in attendance. This meeting was important because it represented the only opportunity for all the Principal Investigators from the three continents to come together during the current FY 1997-2002 Extension period of the Bean/Cowpea CRSP. Primary objectives of the meeting included reporting and sharing of significant research and training achievements and impacts involving bean and cowpea, and planning for the next phase of the Bean/Cowpea CRSP (FY 2002-07).

At the onset of the current phase, it was recognized that efforts to find solutions to the problems associated with the burgeoning world population, including insufficient food availability, malnutrition, poverty and environmental degradation, were stymied by the lack of multi-disciplinary research. Research involving input and collaboration by scientists with diverse expertise at both the planning and execution stages was necessary to address effectively the complex problems confronting the developing countries of Africa and Latin America.

Recognizing this necessity, the Bean/Cowpea CRSP implemented a new regionalized structure for the extension phase (1997). Teams of U.S. and Host Country (HC) scientists and partner institutions were convened to integrate their resources and to work in a collaborative and comprehensive manner to overcome major constraints identified within their respective regions. Three Regional Teams, each with a specific bean or cowpea focus and with collaborating U.S. scientists were organized: West Africa (Cameroon, Ghana, Sénégal), cowpea; East Africa (Malaŵi, Tanzania), bean; Latin America/Caribbean (Costa Rica, Dominican Republic, Ecuador, Honduras, México), bean.

Constraints were identified for each Regional Project, with target impacts to be achieved as a result of the five-year research and training activities. The seven constraint categories which were established and serve as a framework for defining research needs include: (1) insufficient natural resource management and production technologies, (2) limited storage options, (3) insufficient utilization research for improved nutrition, (4) processing and value-added products, (5) socioeconomic research insufficiently integrated with production and utilization research, (6) insufficient cadre of trained personnel, (7) insufficient extension services supporting beans or cowpeas in the region, and (8) insufficient collaboration between research and extension. The Research Profiles (FY 1997-2002) for each of the three regional projects are included in Appendix A of this Proceedings. The expectation is that the new knowledge generated and innovative technologies developed will have impact throughout the respective regions, beyond the borders of the CRSP HCs.

A second unique feature of the current five-year extension of the Bean/Cowpea CRSP was a commitment to multi-disciplinary approaches to overcome regional constraints. Each year, the multi-disciplinary teams of U.S. and HC scientists participating in individual Regional Projects come together to review research progress, to strategize, and to plan integrative research activities that will effectively achieve the target impacts. There is a strong conviction that multidisciplinary approaches to research result in greater innovation; more rapid resolution of technological, social and environmental problems, the development of more contextually appropriate technologies, and greater accountability for the achievement of the societal objectives (i.e., reduction in poverty, malnutrition, and environmental degradation) in developing countries. In addition, there are important over-arching issues that needed to be integrated into many of the research activities with a biological or production focus. Issues such as improving income-generating opportunities and access to resources for women, improving the nutrition of children and expectant mothers, and improving the general quality of life in rural communities can most effectively be addressed in the context of multidisciplinary research teams.

Since the Bean/Cowpea CRSP is in the third year of a five-year extension, and the twentieth year since its inception, this *Midcourse Meeting* provided an opportunity for Principal Investigators and Regional Facilitators to share with the community of CRSP scientists their major research achievements and documented impacts. Each Regional Project Team was allotted one-half of a day for individual scientists to present oral reports of their research and training achievements. This *Proceedings* contains the transcripts of those oral reports.

Readers of these *Proceedings* are encouraged to review and assess for themselves the progress and success of Bean/Cowpea CRSP scientists in addressing the constraints which are the focus of the current five-year extension of the program. It is my hope that you will find these scientific achievements to be exciting, thought provoking, and of benefit to your individual scientific research endeavors and/or efforts in international agriculture development. I also hope you will be impressed with the overall commitment of Bean/Cowpea scientists to making a positive difference not only to the U.S. bean and cowpea industries, but also in the developing countries of Africa, Latin America and the Caribbean.

The Bean/Cowpea CRSP was honored by the presence of Dr. Charles Laughlin, Administrator of USDA/CSREES, who presented the Keynote Speech during the Welcome and Opening Session of the Meeting on Sunday evening, April 9, 2000. As a previous Institutional Representative from the University of Georgia from 1984 to 1988, he has been a strong supporter of this program and of the other CRSPs.

This *Proceedings* is being dedicated to Dr. Patricia (Pat) W. Barnes-McConnell, who retired as Director of the Bean/Cowpea CRSP on May 31, 2000, after nearly 17 years of dedicated service in that role. She had been involved in the Bean/Cowpea CRSP from its inception, serving as Assistant Planning Coordinator for Development of the Bean/Cowpea CRSP in 1979-80. Her vision, leadership, management of the program, advocacy, and tireless effort have contributed to the innumerable research achievements and extensive training of approximately 380 Host Country students receiving B.S., M.S. and Ph.D. degrees of the Bean/Cowpea CRSP over the years. The current Bean/Cowpea CRSP Principal Investigators from Africa and Latin America/Caribbean expressed their thanks to Dr. Pat Barnes-McConnell during the final session of the meeting, Friday morning, April 14, 2000, and presented her with numerous gifts from their respective countries. A dedication to Dr. Barnes-McConnell is included in these *Proceedings*.

Ms. Sue Bengry, the Administrative Officer of the Bean/Cowpea CRSP, was also recognized by the Principal Investigators for her dedicated service in the Management Office. She will be retiring from Michigan State University on December 31, 2000. Gifts were presented by Dr. Dick Phillips and Dr. Sam Sefa-Dedeh to Sue on behalf of the PIs during the final session of the meeting as an expression of their sincere gratitude for her competent fiscal management of the Bean/Cowpea CRSP grant and the many years of providing friendly supportive services to CRSP scientists.

As current Director, I want to acknowledge the contributions of the following individuals in making the *Midcourse 2000 Meeting* a success: Milissa Moryc, preparation of the *Program*, conference notebook, and the current *Proceedings*; Sue Bengry, arrangement of travel and hotel accommodations for all attendees, scheduling of meeting facilities and coordination of activities; Diane Ruonavaara, advice and assistance in the organization of the planning activities during the meeting; and Pat Barnes-McConnell, confidence and support.

Irvin E. Widders
Bean/Cowpea CRSP, Director

WEST AFRICA REGIONAL PROJECT

MANAGING INSECT PESTS OF COWPEA IN THE FIELD; FARMER FIELD SCHOOLS

A. B. Salifu, Savannah Agricultural Research Institute (SARI), Tamale, Ghana; B. Merle Shepard, Clemson University, Charleston, South Carolina, U.S.A.; M. Owusu-Akyaw, Crops Research Institute (CRI), Kumasi, Ghana; J. V. K Afun, CRI, Ghana; M. Abudulai, SARI/Clemson University

Presented by A. B. Salifu

In West Africa, a significant proportion of cowpeas produced by farmers is lost to insect and disease pests, particularly the former. Sustainable pest management strategies are required to minimize pre-harvest loss, enhance sustainable production, and improve the nutrition of millions of West Africans whose diets are predominately cereals. Integrated pest management (IPM) is one such strategy for solving cowpea field pests problems. For the field IPM component of the CRSP West Africa Regional Project, IPM is a flexible approach that deploys a variety of sustainable pest control methods. The result is increased value for the farmers and practices supportive of the environment. The techniques used for crop protection in IPM may integrate traditional crop management practices with practices improved or newly generated by formal research—such as resistant crop varieties, biopesticides and, in some instances, chemical pesticides.

The following report provides highlights from the HC/U.S. field IPM team's achievements in providing this kind of IPM product. For this flexible approach, the farmer has been center stage with considerable attention given to the local context—agroecological needs, availability and affordability of the various alternatives. The Cowpea Action Research Sites (CARS) and Training of Trainers/Farmer Field School (TOT/FFS) activities provide an opportunity to work with the farmers to analyze the whole farm environment and make informed decisions regarding an array of management options.

There have been a number of achievements and impacts. One such achievement is the reassessment of cowpea insect pests with studies to determine the location-specific economic importance of components of the complex including the pest-natural enemy dynamics.

Cowpea insect pest hot spots and areas of predominance have been identified and mapped out to aid in the development of location-specific management recommendations. In North Ghana for example, *Maruca vitrata* damage is most significant in areas where maize is a major component of the farming system. In areas where sorghum and millet are cropped extensively, pod sucking bugs occur much earlier in cowpea pod development. In Charleston, South Carolina, cowpea studies to assess the impact of insecticides on parasitism and predation on eggs of the pest *Leptoglossus phyllopus* showed that parasitism was generally low early in the season, increasing over the season in the pod filling stage.

A second achievement involved the screening for sources of resistance in both indigenous and exotic germplasm. Resistant cultivars play a valuable role in the evolution of farmer-friendly pest management options for smallholder farms. Screening cowpea germplasm, especially indigenous landraces, is one way of identifying insect-resistance for agronomically desirable cultivars and subsequently diversifying the genetic base. Much effort has been devoted to looking for sources of resistance in cowpea germplasm assembled from South Carolina and West Africa. The focus of the resistance screening studies has been on sources of thrips resistance and of late, resistance to pod sucking bugs. The following have been identified in our resistance screening program: Two thrips-resistant cowpea accessions, all indigenous accessions—*Sanzi sanbili, BUN 22* at SARI and *Sanzi sanbili, IND91-08* at CRI. Also at CRI *Ex-Adidome* was identified as resistant to aphids. Materials from South Carolina that consistently supported significantly fewer thrips in comparison with susceptible checks included V-701 PI227829, V-666 Kiawah and Bettergro. The identified indigenous accessions are now widely used in our various programs as sources for resistance breeding.

A third achievement was the determination of minimum insecticide regimes required for producing an economic crop of cowpea. Farmers generally conceded that cowpeas cannot be produced economically without recourse to insecticides. Indeed, some farmers now equate cowpea production with pesticide use.

Hence, initial efforts at developing component technology in support of an IPM strategy were geared at minimizing the number of sprays. The studies revealed that two sprays, timed at pre-flowering and podding stages respectively, gave the highest returns on investment. The results varied, depending on location. One spray was intended. However, in some areas, one spray applied at full flowering gave the highest yield, but there were problems of seed quality; in other areas, one spray applied at podding gave the least yield, but with better quality of seed.

A fourth achievement evolved from the evaluation of botanical insecticides with special reference to neem—*Azadirachta indica*—and development of a farmer/participatory neem-based management strategy for managing cowpea pests. Farm-level methods for extracting and applying neem against all of the major insect pests of cowpeas have been developed by the field IPM team. Studies at CRI showed that aqueous neem leaf extract was effective against thrips and pod sucking bugs. At SARI, a neem-based insect management strategy was developed and widely tested with farmers. Neem treatments were as good as a commonly used insecticide in all test plots. Neem is now a major component of the overall IPM strategy.

Critical to this team's IPM perspective was the adaptation or development as well as the dissemination of strategies for participatory IPM especially Cowpea Action Research Sites (CARS) and Farmer Field Schools (FFS). In the context of providing real solutions to farmers' real problems, a pragmatic IPM should involve a process that enables farmers to develop solutions to their own cowpea pest problems and make appropriate decisions through "learning by doing." CARS is a field-based activity that involves a variety of stakeholders—farmers, researchers, extension workers—coming together to discuss constraints and needs among themselves as they pertain to economic and ecological cowpea production. Information derived from the CARS feed into TOT/FFS activities. As a result of CARS and TOT/FFS activities, 321 farmers and 165 extension workers have been trained with outcomes including:

- Optimal use of natural enemies as a means of *reducing pesticide use* on cowpeas, improved skills of extension workers and farmers in *crop production* and *field observation*
- Increased knowledge of extension workers and farmers in *production* and *protection*
- Induced ecological thinking as basis for *sustainable* production and protection of cowpeas
- Increased and sustained farmer *crop yields* and *income*

Here is an example of an IPM strategy employed in TOT/FFS (Crop Management Trials): Select good variety–*Bengpla*; Choose good seed–*Conduct seed viability test*; Prepare land properly–*Use bullock traction*; Manage water–*Rain-fed*; Adopt good sowing method–*2 seeds/hill in line*; Ensure good plant density–*0.6m spacing*; Ensure fertility of soil–*Zero input (instead use manure for compound farms)*; Weed on time–*Weed twice*; Apply suitable biopesticide–*Neem leaf/seed extract*; Apply suitable pyrethroid–*None or once at peak flowering*; Spray plots on time–*Two times at preflowering, podding*; Choose good spray dose–*Neem leaf extract @ 40 percent w/v or neem seed extract @ 30 percent w/v*; Harvest on time–*At 50 percent pod drying*.

<u>Publications</u>
None reported

MANAGING INSECT PESTS OF COWPEA IN STORAGE

G. Ntoukam, Institut de la Recherche Agronomique pour le Developpement (IRAD), Maroua, Cameroon; L. L. Murdock and R. E. Shade, Purdue University, West Lafayette, Indiana, U.S.A.; L. W. Kitch, Food and Agriculture Organization (FAO), Zimbabwe; C. Endondo, B. Ousmane, and J. Wolfson, IRAD, Cameroon

Presented by Georges Ntoukam

The Bean/Cowpea CRSP West Africa Regional Project activities in Cameroon focus on insect-caused losses of cowpea grain in storage, a constraint to the availability of cowpea as food throughout the region and in many other areas of the world. The strategy in Cameroon is to devise a variety of simple, affordable, and practical technologies to reduce these losses. CRSP training to assist IRAD in building a Cameroon research team has been important for addressing cowpea storage and production problems.

The primary insect pest causing losses to stored cowpeas in West Africa is the cowpea weevil, *Callosobruchus maculatus*. Infestations begin in the field at low levels. After the crop is placed in storage, the insect population continues to grow until there is an obvious, severe infestation. Another bruchid pest of cowpea is *Bruchidius atrolineatus*. This insect causes losses primarily around harvest time, and does not reproduce in storage.

A number of technologies have been generated from CRSP research and are in use. Exposing threshed cowpeas to solar radiation on a simple solar heater developed at Purdue and tested/improved in Cameroon can kill, within minutes, resident infestations of cowpea weevil in grain. This technique makes use of cheap and widely available plastic sheeting and offers promise as a tool for use by low resource farmers and storers of cowpea. It has already undergone testing and extension in Cameroon and in many countries, namely, Burkina Faso, Mali, Nigeria, Chad, Benin, Ghana and Zimbabwe in West Africa region. Storage bulletins written in English, French and Fulfulde as well as a training film have been developed.

Three 50 kg capacity plastic bags placed one inside the other can provide effective airtight conditions. This storage method is widely used in Cameroon and many countries in West Africa. Another version of airtight storage developed at ISRA in Sénégal is the drum storage, which is spread to farmers all over West Africa.

Storage of cowpea grain in ash will arrest an initiated infestation, although it does not immediately kill insects already living within the cowpeas. However, the insects do fail to reproduce and will eventually die. The CRSP ash research lead to the development of practical protocols and recommendations for cowpea producers and users about how best to make use of ash to prevent cowpeas (e.g., particle size, portion, mixing method).

Breeding to combine seed and pod resistance is another tool to reduce losses. Screening for pod resistance to cowpea weevil has revealed several high-yielding IITA lines with high pod resistance; also, five local lines appear to be highly resistant. We have recognized that a promising long-term goal for improving cowpea preservation would be to produce cowpea types with combined seed and pod resistance. Two cowpea lines of that order were developed and tested in our breeding program (LORI NIEBE and CRSP NIEBE). A sweet cowpea variety has also been identified: 24-125 B (see paper by Larry Murdock). This sweet cowpea is currently undergoing food technology testing at Purdue University and at the University of Ghana, and germplasm carrying the sweet trait has been distributed to Ghana and Sénégal for initial testing and integration into their breeding program.

Insecticides, especially the dust form and the gas forms, are recommended for short-term storage. The products such as Actellic 2 percent or Actellic Super and Phostoxin gas are very helpful to the farmer punctually. However, insecticides are expensive and may not be available in all areas. Phostoxin is a fumigant that can kill humans and animals. Farmers are encouraged to check with their extension agents for information about the use of these and other insecticides and fumigants.

Recommendations on these storage technologies are finding acceptance among cowpea farmers in Cameroon and in the West Africa region; two lines of cowpeas adapted to the region have been released by IRAD/CRSP to farmers of the region and are finding acceptance. The project catalyzes the entry of Bean/Cowpea CRSP technologies into southern and eastern Africa, including the extension of storage technologies, supports preliminary studies of the economic potential of cowpeas in the region, and facilitates the widespread testing of West Africa varieties. An new linkage with FAO has been forged.

Progress toward the goal of developing a strong IRAD cowpea team has resulted in:

1. Completion of M.S. degree in plant breeding at Purdue University by Boukar Ousmane and Chevalier Endondo in agronomy.

2. On-going Ph.D. training of Boukar Ousmane in plant breeding at Purdue University.

3. Training of technicians, NGO personnel, missionaries and extension farmers in the West Africa region by Dr. Ntoukam, a CRSP scientist in Cameroon.

Publications
None reported

FUTURE OF COWPEA BIOTECHNOLOGY AND "SWEET COWPEAS"

L. L. Murdock and S. S. Nielsen, Purdue University, West Lafayette, Indiana, U.S.A.; G. Ntoukam, Institut de la Recherche Agronomique et Developpement (IRAD), Maroua, Cameroon

Presented by Larry L. Murdock

Cowpea suffers heavily from insects, both in the field, as well as, when the grain is stored after harvest. Conventional insecticides are not the answer to the insect problems. In Africa, where the need for insect management is great, many cowpea growers can't obtain insecticides, can't afford them, don't have the necessary equipment, or don't know how to apply them properly.

Traditional host plant resistance—the development and deployment of cultivars carrying genes that condition resistance to the insect pests—while effective in controlling some insects, has proven to be of little value against certain other insect pests of cowpea. The traditional approach to developing resistant lines requires that the genome of the crop plant include genes for resistance to the pests. To find these genes, teams of entomologists and plant breeders screen accessions of the plant until sources of resistance are discovered. The resistance traits are then transferred into desirable cultivars by a process of breeding and selection. Unfortunately, the genome of cowpea seems to be devoid of the necessary resistance genes to several major insect pests, blocking the use of this approach. IITA, among other organizations, has carried out extensive screening of cowpea germplasm for resistance to cowpea pod borer, thrips, pod-sucking bugs, and weevil. At best, weak sources of resistance have been found, if at all.

One promising avenue to introducing new sources of insect resistance into cowpea involves genetic transformation, using resistance genes taken from other plants that may not be easy to cross with cowpea or that may even come from bacteria or fungi. Three fundamental problems have to be solved to do this: (1) resistance genes have to be discovered that would, if transferred into cowpea, impart insect resistance; (2) germ-line cells of cowpea plants must have the resistance gene introduced into them and stably incorporated into the nuclear DNA—this usually involves the use of Agrobacterium tumefaciens or accelerated micro particles (the gene "gun"); and (3) plants must be regenerated from the intact transformed cells.

The current state of the art is as follows: (1) genes are available that would impart a high degree of resistance to at least two insect pests of cowpea—*Bacillus thuringiensis* crystal toxin (*Bt*), effective against *Maruca testulalis* (legume pod borer), and α-*amylase inhibitor*, effective against the cowpea bruchid Callosobruchus maculatus (Shade et al, 1994); (2) cowpea cells have been transformed with foreign genes, but thus far no one has successfully transformed germ-line cells; and (3) methods have been developed that allow cowpea plants to be regenerated from cowpea tissues or clusters of cowpea cells (Kononowicz et al., 1993).

There have been claims made at public meetings that success has been achieved in genetic transformation of cowpea. But to our knowledge no one has published a report in the refereed scientific literature that has been validated by another laboratory independently and thus is, so far, an unsubstantiated claim. Even so, the technology of genetic transformation is rapidly evolving, and the successful genetic transformation of cowpea will undoubtedly be achieved soon. CRSP researchers recognized the importance of this work.

One recent outcome of the CRSP research in Cameroon is the discovery of a sweet-tasting cowpea line by Cameroonian farmers. Since 1991, the IRAD/Purdue/CRSP cowpea breeding program in Cameroon has sought to introduce cowpea weevil resistance into cultivars well adapted to the agro ecology and farmers' preferences in northern Cameroon (see paper by Georges Ntoukam). In the course of this work, a total of 149 expert farmers, men and women, in two different areas of northern Cameroon, in two different years (1994 and 1995), evaluated 216 lines to assist the breeder in selecting highly desirable lines. They were asked to identify the lines they liked the best, and tell us why they liked them. One particular line, 24-125B, was highly preferred. They said it "tasted good" or "had a sweet taste." Similar responses to this line were obtained in subsequent years. It was real, it was repeated, it was consistent from year to year, and from place to place. Cameroonian growers LIKED this cowpea because of its taste. Chemical analyses of the "sweet" line at Purdue revealed that it contained at least twice as much sucrose as ordinary non-sweet lines. Subsequently, a "triangular taste test" was carried out in the facilities of the Food Science Department at Purdue to determine if American consumers also liked the taste of the sweet line. The results were clear and significant: Most panelists correctly identified the sweet line and many of them voluntarily commented on its pleasant or sweet flavor.

Given the objective evidence that line 24-125B is actually sweet because of its elevated level of sucrose and that American and African consumers prefer it, plans to develop this trait further and make it widely available to growers and consumers are now being implemented. These include: (1) surveys in the U.S.A. and Africa to identify potential market niches; (2) studies of the processing characteristics of 24-125B; (3) further characterization of the chemical and nutritional characteristics of the sweet line; (4) characterization of the genetic basis and biochemical mechanism of high sucrose accumulation; (5) production of high-quality seed for sharing with colleagues in the U.S.A. and Africa; (6) development of a simple, rapid, and cheap technique for evaluating sucrose levels in individual seeds, for use by breeders; and (7) evaluating the performance of the line in new sites in the U.S.A. and several African countries.

Since "24-125B" is a name only breeders could love, it has been decided to refer to this line in the future as "Sweet Sue," a name that not only reflects the sweet taste of the seed, but also honors the manifold and lasting contributions to the CRSP of its Administrative Officer at Michigan State University, Mrs. Sue Bengry.

Publications

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BREEDING COWPEAS FOR THE SAVANNAH ZONE AND RESISTANCE TO INSECT PESTS

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M. Owusu-Akyaw, Crops Research Institute (CRI), Kumasi, Ghana;
A. E. Hall, University of California, Riverside, California, U.S.A.

Presented by K. O. Marfo[1]

Cowpeas are among the most important food legumes in terms of the area under cultivation and contribution to human and animal diets in the savanna ecology.

The savanna ecology stretches between latitudes 08°03'N and 11°0'N with annual rainfall ranging between 700 and 1200mm. Notwithstanding the importance of cowpeas in this ecology, the productivity of the crop is beset with numerous biotic and non-biological stresses leading to very low yields at the farmers' level.

The non-biological stresses include poor fertility of the soils, erratic rainfall distributions and in some instances high night temperatures, with the latter resulting in heavy floral abscission. Among the biological stresses, insect pests are the most important. Because of the relatively high rainfall received in some parts of the savanna, fungal, bacterial and viral diseases are prevalent. This paper addresses some of the efforts being made to develop cowpea varieties buffered against these yield reducing factors, emphasizing resistance to insect pests.

Based on problems identified at the farm level during research planning sessions held with stakeholders in cowpea production, the following strategies are utilized in the breeding program by the Bean/Cowpea CRSP team in northern Ghana.

1. A breeding nursery is employed where germplasm from various sources, especially the University of California, Riverside, IITA and RENACO are assembled for initial evaluations and subsequent deployment of specific traits into the genetic background of existing cultivars.

2. Multilocational evaluations are carried out of breeding materials from the nursery, that have stabilized performance, as well as other materials with proven high performance. High grain and haulm yields, N fixing abilities, resistances to the various yield reducing factors are evaluated at multi-locations on-station at four sites representing the constituents of agro ecologies in the savanna zone. The test sites are: Damongo (woodland savanna), Nyankpala (Guinea savanna), Wa (an ecotone between Sudan and Guinea savanna ecologies) and Manga (Sudan savanna).

On-farm tests are also carried out in collaboration with the extension staff of the Ministry of Food and Agriculture (MoFA) and Non-Governmental Organizations (NGOs) that work in agriculture. A few high performing lines (usually not more than four), which are accompanied by the farmers' varieties as checks, are extensively evaluated on farmers' fields.

Based on the agronomic desirability, yield stability, organoleptic and other proximate composition tests, the desired materials are proposed for release to the National Varietal Release Committee in Ghana. The committee visits the crop on the field during early podding and at the fully matured stages to enable them to make a decision.

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[1]Shortly after the presentation of this paper, Dr. K. O. Marfo was tragically killed in a plane crash in Ghana. The Bean/Cowpea CRSP community joins the family in mourning the loss of this fine scientist and wonderful human being.

Two heat tolerant cowpea lines have recently been approved for release by the National Varietal Release Committee of Ghana.

Current status of the research of this team is as follows:

1. Insect hot spots have been identified and mapped out to assist in location specific recommendations for cowpea insect control in the Southern Guinea Savanna areas of Ghana.

2. Aphid resistant (Ex-Adidome) thrip resistant (Sanzi-sanbili, and Bun 91-08), extra-earliness (<50 days to maturity combined with resistance to thrips) which are all landraces have been identified and are being extensively used as sources of resistance in the breeding programs.

3. Utilizing Bun-22 as a source of earliness and resistance to thrips, a number of promising lines developed are now being tested on station and on farmers' fields in the northern Guinea and Sudan ecologies.

4. Two cowpea lines possessing acceptable seed qualities in addition to high grain and haulm yields with a heat tolerance background, ITP-148-1 and Sul 518-2, have been released for cultivation in the northern Guinea and Sudan Savanna ecologies.

5. Breeder and Foundation Seeds are being made available in sufficient quantities for Certified Seed Production.

<u>Publications</u>
None reported

BREEDING COWPEA FOR THE SAHELIAN ZONE AND RESISTANCE TO STRIGA AND DISEASES

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Presented by Ndiaga Cissé

The Sahelian zone has been characterized in the past two decades by erratic and low rainfall (200-400 mm). Consequently, drought adaptation has been an important breeding objective for the Bean/Cowpea CRSP Sénégal/University of California, Riverside team. In this zone, the most important diseases are bacterial blight and viruses. Bacterial blight (*Xanthomonas vignicola*) causes severe damage to cowpeas, while the most frequent virus disease encountered is Aphid borne mosaic virus. Annual loss caused by these two diseases in Sénégal have been estimated at 40 percent and 20 percent respectively on susceptible varieties (Gaikwad, 1988). The parasitic weed, *Striga gesnerioides,* attacks cowpeas particularly in the semiarid regions of West and Central Africa with a mean yield loss of 30 percent (Aggarwal et al., 1989).

Because of the difficulty in breeding cultivars for dry environments through physiological processes, progress in drought adaptation in cowpeas has mainly been achieved by yield testing advanced lines over several years and locations (Hall, 1997). Highly adapted local varieties such as ; 58-57, TN88-63, Suvita 2, have been used in breeding programs to generate new lines. Selection for early or medium maturity with semi-erect and indeterminate plant type have been useful where terminal and/or intermittent drought occur during the vegetative stages. Superior adaptation to drought has thus been evaluated as higher grain yield with low variability in semiarid environments.

Bacterial blight is endemic to the semiarid environment of West Africa and local adapted varieties usually have high resistance. The importance of the disease has appeared with the massive introduction of susceptible varieties such as CB5 that have other characteristics which are considered important for improved production. Artificial inoculation techniques have been developed to facilitate breeding for resistance.

Several virus diseases occur in the Sahelian zone. The most prevalent is the cowpea aphid borne virus (CAbMV). The varieties B21and CB5 combine resistance to multiple viruses (CAbMV, SBMV, CYMV, CMoV).

The most important source of resistance to Striga in semiarid West Africa are B301 and IT82D-849. These two lines are resistant to 4 of the 5 races of the parasite found in these areas. The genotypes 58-57 and IT81D-994 are resistant to the fifth race found in Zakpota, Benin (Singh et al., 1997). Complete resistance to all five have been sought in recombinants of the race differential varieties.

Important achievements have been generated by the research from this team. The cowpea varieties Mouride and Mélakh, developed by the ISRA/CRSP research, are largely diffused in Sénégal. In the production season 1999/2000, these two varieties represented 79 percent and 60 percent respectively of the foundation and certified seeds distributed. These varieties have been introduced in InterCRSP yield trials and extension programs in West and Central Africa by World Vision International.

Mouride is a medium maturing cultivar adapted to the semiarid zones of the Sahel with resistance to CAbMV, bacterial blight, Striga and bruchids. Striga resistance has been obtained from the line IT81D-1137 identified in Burkina Faso along with 58-57. However, the latter is sensitive to Striga in Sénégal where it originates, indicating that in the two countries different Striga races prevail.

Mélakh is an indeterminate early variety, adapted to the short rainy season of the Sahel. It has resistance to CAbMV, bacterial blight and aphids. It is largely consumed and commercialized as fresh beans because of its long pods.

Combining drought adaptation with resistance to the different biotic constraints in individual varieties has become the major breeding objective. Because of farmer and consumer preference, the focus also has been on large-seeded varieties with white, red or black speckled color.

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BREEDING COWPEA FOR CALIFORNIA AND AFRICA, RESISTANCE TO NEMATODES, HEAT AND DROUGHT, AND COWPEA MAPPING

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Presented by Anthony Hall

Progress has been made in developing a genetic-linkage map for cowpea to enhance the efficiency of breeding. UCR bred a set of F_8 recombinant inbred lines (RILs) from a cross that combines many traits of importance to both Africa and California, IT84S-2049 x 524B (CB3 x CB5). In collaboration with Paul Gepts at UC Davis and others, these lines have been screened for DNA polymorphisms and a DNA linkage map has been developed (Menéndez et al. 1997). Since then, in collaboration with several scientists, the parents and RILs have been screened for many useful traits, some of which have been mapped including: resistance to root-knot nematode (*Rk* gene), Fusarium wilt (race 3), several virus diseases (BlCMV, SBMV, CPSMV and CPMV), Striga (races 1 and 3 using a linked marker) and chilling at emergence (a dehydrin protein). DNA markers are being sought for specific resistance traits so that marker-assisted selection can be conducted which would enhance the efficiency of breeding.

A new cowpea variety, California Blackeye No.27 (CB27), has been developed (Ehlers et al. 2000a). Certified Seed of CB27 should be available in California in 2001. CB27 has resistance to a broader range of root-knot nematodes than current California varieties, enhancing yield and increasing sustainability by improving soil conditions for subsequent crops. CB27 has resistance to races 3 and 4 of Fusarium wilt, whereas current California varieties only have resistance to race 3 (CB46 and CB88) or have no resistance (CB5). CB27 is the first cowpea variety with heat tolerance and has produced greater yields than current varieties in California environments where hot weather occurs at flowering. CB27 has high harvest index and is compact requiring narrower row spacing (51 to 76cm) than CB5 (76 to 102cm). CB27 has excellent canning quality, a moderate sucrose content and bright white seed that may make it attractive for the dry blackeye bean package trade. Marketing tests are being conducted with California growers to determine the relative prices and ease of sale of CB27 compared with CB46.

The broader nematode resistance of CB27 is due to its having both the *Rk* gene and a recessive helper gene, *rk3* from TVu4552 (Ehlers et al. 2000b). Stronger resistance is available as the Rk^2 gene from IT84S-2049 and maybe IT84S-2246 (Roberts et al. 1997). UCR is breeding dry grain and cover crop varieties with the Rk^2 gene and also has found strong resistance to root-knot nematode in IT92KD-370, IT89KD-288 and some other lines. UCR is conducting genetic studies combined with pouch test and field screening for nematode resistance to see if even stronger resistance than is provided by the Rk^2 gene can be obtained by combining Rk^2 and *rk3* and possibly other resistance genes.

Six genetically similar pairs of lines were evaluated that either have or do not have heat-tolerance genes. Studies were conducted in eight California environments with contrasting temperatures, but similar high levels of solar radiation and optimal management (Ismail and Hall 1998). In the cooler environments, the heat-tolerant and heat-susceptible lines had similar high grain yields. In the hotter environments, grain yields of the heat-susceptible lines decreased substantially; whereas the heat-tolerant lines exhibited less decrease and produced about 400 kg/ha greater grain yields than the heat-susceptible lines by maintaining higher pod set. In contrast, in six field trials conducted by SARI in Ghana and ISRA in Sénégal, the heat-tolerant and heat-susceptible lines had similar grain yields; even though the Sahelian environments were very hot. Glasshouse studies indicate that differences in day length may explain the contrasting results obtained in California and Africa (Ehlers and Hall 1998). The heat-tolerant lines developed by the UCR breeding program were effective in both long and short days. However, the heat-susceptible lines from UCR only exhibited reductions in grain yield under long-day conditions and not under the short days that can be encountered in Africa. UCR also discovered that a few lines bred by selecting for grain yield in hot parts of Africa (e.g., Mouride selected in the Sahelian zone of Sénégal and some IITA lines selected in the Savanna zone of northern Nigeria) have heat tolerance that was effective under short-day but not long-day conditions. The low elevation desert of California provides an extremely hot field environment where very effective screening for heat tolerance can be done in irrigated nurseries. Breeding programs in most other parts of the world, however, do not have field nurseries that are effective for heat-tolerance screening. UCR and ISRA are evaluating a laboratory screening method for heat tolerance based upon electrolyte leakage from leaf disks that may be more effective in Africa than selecting based solely on grain yield (Ismail and Hall 2000).

Different types of drought adaptation are needed in West Africa. ISRA developed Mouride (see paper by Ndiaga Cissé), a medium cycle (about 70 days) variety that consistently produced greater grain yields than other varieties in many trials in Sénégal with mid-season and late-season droughts. Mouride was bred by selecting for grain yield over many locations and years. ISRA also developed Mélakh, a shorter cycle variety (about 65 days to maturity) that has been very effective in Sénégal when the rainy season was short but distinct (Cissé et al. 1997). However, early cowpea varieties usually are sensitive to droughts occurring at flowering. UCR has shown that this problem can be reduced by combining earliness with a delayed-leaf-senescence (DLS) gene that enables the plants to survive the flowering-stage drought and then produce another set of flowers and pods. The yield penalty that the DLS trait imposes on first flush yield under well-watered conditions has been evaluated, using four sets of genetic lines that were selected to either have or not have the DLS and heat-tolerance traits (Ismail et al. 2000). The DLS trait reduced first flush yield by only 9 percent (about 300 kg/ha). This indicates the DLS trait is useful because it has the potential to enhance the second flush yield by up to 2000 kg/ha. A shuttle breeding program conducted by UCR and ISRA is developing an early DLS cowpea for adaptation to dry zones. The objective is to breed a variety for Africa with the ability to produce 2000 kg/ha in 60 days and an additional 1000 kg/ha in a second flush by 100 days after sowing. UCR crossed Mouride with 8517, which has earliness and DLS, and selected the lines with these traits. ISRA made selections between and within these lines for expression of earliness and DLS in Sénégal (Hall et al. 1997b) and resistance to bacterial blight and cowpea aphid-borne mosaic virus. UCR crossed the ISRA selections with Mélakh and selected for earliness and DLS in California. The selected lines now should be evaluated in the Savanna zone and the parts of the Sahelian zone that have a growing season of at least 100 days.

Cowpea breeding in California is giving major emphasis to breeding dry grain cowpea varieties with sufficient resistance to lygus bug and cowpea aphid that they can be grown without using insecticides (Hall et al. 1997a, Ehlers and Hall 1997). UCR has discovered sources of moderate resistance to lygus and the California biotype of cowpea aphid and is breeding to incorporate these resistances. In addition, these varieties will have broad-based resistance to root-knot nematodes and Fusarium wilt, and in some cases chilling tolerance at emergence, heat tolerance at flowering and DLS for double-flush production. In California, the double-flush production system pioneered by UCR has produced grain yields as high as 8000 kg/ha in a 150 day growing season.

In addition, UCR is breeding a spreading, photo period-sensitive cowpea variety with strong resistance to root knot nematodes. This type of cowpea variety would replace an erect medium cycle variety (Iron Clay) that is being used as a rotation green-manure crop by some U.S. organic vegetable producers. The new variety should be more effective than Iron Clay in enhancing soil fertility, controlling weeds and suppressing nematode pests. UCR is collaborating with the University of the Yucatan to develop a similar spreading, photo period-sensitive cowpea variety for use as an intercrop in tropical maize/squash systems to enhance soil fertility, control weeds and provide fresh southern peas for food. A similar type of cowpea variety is needed in Sénégal to provide hay and dry grain and enhance soil fertility.

UCR has a minor program developing cowpea varieties with dry grain that is all-white or green or sweet. Consumer demands for these special varieties have not yet been established. UCR has bred cowpea lines with all-white grain for potential use in flour products. Following the pioneering work of R. L. Fery, USDA, UCR is developing cowpea lines with both the green cotyledon and the green testa genes. These lines would be grown as a dry grain crop but the dry grains would be rehydrated for use in frozen vegetable products. UCR has made populations from crosses between the sweet line from Cameroon, 24-125B, and CB27, Mélakh and Sul 518-2. These populations will be used to determine the potential for increasing sweetness by breeding. Tests are needed to determine whether consumers detect differences in taste in food dishes made from sweet and normal cowpeas that could influence varietal acceptance.

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PROCESSING AND EVALUATION STRATEGIES TO INCREASE COWPEA UTILIZATION

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Presented by R. Dixon Phillips

There are three major components in increasing cowpea utilization. These components are basically the same in West Africa and the U.S. and are:

1. To discover and transfer to consumers information on the health and nutrition promoting qualities of cowpeas,

2. To develop specific cowpea-based foods and ingredients,

3. To develop mechanisms for incorporating cowpeas and cowpea-based ingredients into foods and the diet.

Much of the cowpea crop is consumed as traditional whole-seed-based dishes. However, by processing cowpeas there can be a major increase in their utilization. It is the individual-to-small cooperative range of processing on which the Ghana/University of Georgia team has concentrated its efforts. In preserving seeds against loss to pests, care must be taken with grain to be stored for food being especially careful to exclude the use of toxic pesticides. It was discovered that steaming cowpea seeds followed by solar drying destroys all stages of cowpea weevil and prevented re-infestation for extended periods. Steaming may be practiced on any scale from a kilogram in Ghanaian steaming baskets to continuous, industrial-scale steaming boxes. The central part of our processing strategy has been to convert cowpeas into useful intermediates. Traditional cowpea processing begins with soaking the seeds, after which they can be further treated in a variety of ways. Although not commonly used with legumes, germination or malting of the seeds produces interesting changes in chemical composition. Soaked seeds can be immediately decorticated by plate milling and floating off the seed coats or they may be lightly wetted, re-dried and then the seed coats and eyes removed (decorticated) by abrasive or plate milling and aspirating the seed coats. The cleaned cotyledons are then hammer milled into flours or meals at various particle sizes. In the U.S., unpigmented seeds can be milled whole, saving effort and expense, and resulting in a desirable higher fiber product for food ingredient use (see paper by Anthony Hall). At this stage, either wet cowpea dough or dry flour can be combined with a variety of other commodities, cereals, oilseeds, starchy roots and tubers, plantain, which have been suitably preprocessed to form a very wide range of composite foods.

Many of the traditional Ghanaian foods that have been fortified with cowpea are customarily made of cereals or other starchy products, and most are fermented with naturally occurring lactobacteria and other microorganisms. The focus has been on where in the process, cowpea may be introduced, how much can be used, and whether it can also undergo fermentation all without undue modification of expected flavor, aroma, texture, and keeping properties. Both these products and the processes for making them have been extended, as appropriate, to individuals, village cooperatives, and at the small-scale manufacturing level by a number of vectors (see paper by Sam Sefa-Dedeh). Cowpea flakes have been provided for use in treating acutely malnourished children in studies at the Princess Marie Louise Children's Hospital in Accra, and have been shown to be enthusiastically received and effective in reversing malnutrition. Fortified fermented corn dough has been both provided to malnourished children in study-villages and the process for making it and other fortified products taught to villagers after the construction of processing plants in a cooperative venture between the CRSP, the Hunger Project-Ghana, and the villagers themselves. Consultation on weaning food design and manufacturing has been provided to existing village cooperatives. Cowpea flours have been combined with wheat for studies on the appearance, texture and flavor of yeast-raised breads, and chemically leavened muffins and cookies as well as unleavened tortillas.

Extrusion cooking is an extremely versatile process that, by subjecting raw cereal and legume flours to a unique combination of high temperature, shear, and pressure for a few seconds is capable of completely cooking and sterilizing the resulting product. Products range from precooked weaning foods to expanded snacks and beyond. Extruders range from simple models costing about the same as a pickup truck to very sophisticated ones costing in the neighborhood of a million dollars. We have extensively studied the use of extrusion cooking along with computer optimization/least costing to design a number of weaning foods containing significant levels of cowpea flour combined with wheat, sorghum, maize, millet, peanut, soybean and sesame. Low-cost extrusion has been used to make some of these products and a more sophisticated machine used to study processing parameters. Research is now beginning to look at extrusion technology for making nutritious convenience/snack foods for older children and adults.

These processing schemes have been developed with constant evaluation of the products and processes. The food industry wants to know how the new ingredients and products may be incorporated into its operation , and consumers must feel that the food will meet their expectations for convenience, flavor, nutrition, and safety at an affordable price. These attributes generate perceived value which control products' success in the market place. The cooking rate of cowpea seeds is being measured in response to cultivar and growth conditions as well as storage conditions, and pre-processing treatments like steaming/drying and germination. The viscosity of hydrated foods is important both to sensory quality and, in the case of weaning foods, to the nutrient density potential. The team's research has shown that extrusion of weaning food mixtures in the presence of a-amylase reduces its viscosity during cooking and at serving temperature, meaning that more nutrient can be packed into every spoonful. Electron microscopy has been useful in investigating the cellular mechanisms of both the hard-to-cook defect following storage and insect resistance following hydrothermal treatment. Texture is one of the most important attributes of foods, and we use the Instron to measure the amount of force and energy necessary to compress and shear foods—similar to chewing it—in response to storage and processing. Chemical and nutritional properties of cowpea-based foods determine both sensory quality and efficacy in meeting nutritional needs. Routinely, the gross composition of cowpea varieties and the foods made from them is determined. Protein quality is measured by amino acid profile and a novel approach to predicting protein quality has been developed from what the team calls Amino Acid Availability Corrected Amino Acid Score. Processing may also affect the content and bioavailability of cowpea carbohydrates. While extrusion has been shown to greatly increase the digestibility of starch as well as protein, germination has less effect. On the other hand, the research has shown that germination reduces both the oligosaccharide content and the flatulence that is produced by these undigestible sugars. Cowpeas are a significant source of some vitamins, although fortification with others is necessary in products like weaning foods. The same is true of minerals. Germination actually results in modest increases in some of the B vitamins. The availability of amino acids, starch and micronutrients depends on the content of antinutritional compounds, of which cowpeas contain several.

Research on cowpea food safety includes studies into the microbiological safety of cowpeas and foods made from them. Although not a particularly good host for *Aspergillus* in nature, very high levels of aflatoxin can be produced on cowpea under laboratory conditions. Of more concern are the pathogenic bacteria that are common to foods and water in developing countries. Surveys of cowpea pastes in markets have shown an appreciable level of coliforms, although these would presumably be destroyed during the frying process. The lactic fermentation process that is popular in Ghana may offer real protection against pathogens both by lowering the pH below optimal growth levels and by producing bacterosins.

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COWPEA USE IN IMPROVING HUMAN NUTRITION

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Presented by Sam Sefa-Dedeh

Protein energy malnutrition, deficiencies of micro-nutrients such as vitamin A, iron, iodine and zinc are of concern in Africa. Grain legumes such as cowpeas *Vigna unguiculata* Walp have been identified as important in addressing protein energy malnutrition. They are a major source of protein and vitamin B in the diet (see paper by R. D. Phillips) but their use for infant feeding is not widely practiced. This paper reports on research on cowpea conducted by the Ghana/University of Georgia team to improve human nutrition, with special reference to children.

A three-pronged approach has been taken to promote the use of cowpea to improve human nutrition. The three activities are:

- Product/process development and evaluation
- Introduction of target groups to cowpea products
- The involvement of micro-small-and-medium-scale enterprises.

Product/process development and evaluation is the first activity emphasized. Mothers and women from rural communities were interviewed and their perceptions regarding infant feeding practices, weaning foods and the use of cowpeas recorded and analyzed.

The majority of mothers (78 percent) indicated that the most important weaning food for children is a porridge based on fermented maize dough. The mothers further indicated that the problems associated with cowpea consumption include diarrhea, indigestion and flatulence. To increase cowpea consumption as a weaning food, the removal of hulls is an important operation to address these problems. A simple method was developed which involved tempering of the seeds, drying (50°C), dehulling, hull separation and milling.

Due to the poor protein content of maize, the traditional maize-based weaning food cannot address protein malnutrition unless it is fortified. A cowpea-fortified fermented maize dough was developed taking into account energy density, convenience, consumer acceptability, cost, shelf stability and safety. The product was found to be highly acceptable and the fortification improved the protein content and nutritional quality.

Microbiological evaluation of the cowpea-fortified fermented maize dough showed that addition of 20 percent cowpea did not affect the performance of the fermenting microorganisms of the maize dough.

Cowpea flakes were developed from dehulled, steamed cowpea flour. The flour was made into a dough and drum-dried into flakes. This 100 percent cowpea product was found to be acceptable by the mothers, children and hospital staff at the Princess Marie Louise Hospital in Accra. The majority of mothers (56 percent) added the cowpea flakes into porridge, others (36 percent) presented it as a snack. The ease, convenience and high nutritive value and acceptability drew the attention of the nurses and physicians. Large quantities packaged as 20g samples were prepared which were used as a feeding supplement for the hospital's malnourished children.

The second activity emphasized was the introduction of cowpea products to target groups. Training workshops were held in rural communities to introduce the product concept and technology in the context of previously identified need. In three communities, nutritional intervention studies were conducted using the cowpea-fortified fermented maize product. Through the Hunger Project-Ghana, the community of Awutu Kwaman was assisted in constructing a food-processing facility. Training focused on:

- Sensitization to health and nutrition
- Processing of cowpea-fortified maize dough
- A six-month intervention and monitoring

Intervention involved feeding of the 106 preschool children in the community with cowpea-fortified fermented maize dough porridge. Anthropometric measurement such as weight, height and mid-upper arm circumference were monitored. Marked improvements in the nutritional status of the children were demonstrated.

The efficacy of the cowpea-fortified product was recognized by all the people in the community as evidenced in the improved health of the children. Following the intervention, three women agreed to provide, on a commercial basis, the product for the community. In addition, the women extended the product and technology to nearby communities including an orphanage.

Another intervention involved the determination of the efficacy of iron-fortified, cowpea-based weaning foods in improving iron nutrition of children. The intervention study involved two peri-urban communities, Otinibi and Danfa, in the Ga District of the Greater Accra Region. Fermented maize-cowpea flour (80 percent maize, 20 percent cowpea) was prepared, dried in the oven and fortified with 10.7mg Fe/100 flour using ferrous fumarate. It was observed that the children fed iron-fortified maize-cowpea flour showed decreased anemia at the end of the intervention period. The cowpea-fortified fermented maize flour was found to be a good vehicle for improving the iron nutrition of children.

Encouragement of cowpea-related micro-small-and-medium-scale enterprises (MSMEs) was the third activity emphasized. In Ghana, the micro-small-and-medium-scale enterprises convert the bulk of agricultural commodities into intermediate and final products. One company, Ermack Foods, has been trained by CRSP researchers in the process for making dehydrated cowpea-fortified fermented maize flour. Preliminary consumer testing of the product has shown a very high interest. The company is planning to invest in the production of this product for the Ghanaian and foreign markets.

From this overall approach, it is apparent that cowpea is an important legume for improving the nutrition of the population. Targeting the nutrition of the child through the development and production of foods based on, or fortified by cowpea is an achievable option for resource-poor rural populations.

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FIELD SCHOOL AND INSECT PEST MANAGEMENT EVALUATIONS

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Presented by Brenda Vander Mey

Farmer Field Schools (FFS), and Training of Trainers (TOT) are modalities used to facilitate active, participatory non-formal education in real-world settings. Both situate all actors—farmers, extensionists, researchers, or volunteers—as both learners and teachers. The Schools involve hands-on learning which is experiential and discovery-based. Undergirding this non-formal learning is a systems approach to farms and farming. It is well documented that FFS, in contrast to traditional extension methods, is the most successful modality for Integrated Pest Management (IPM) learning, adaption and adoption (Stoetzer, 1997). Participants learn, for instance, plant growth requirements, soil preparation, pest-predator relationships, which insects are pests versus which are beneficial, timely weeding and timely planting. FFSs are focused on farmers as the primary clientele and TOTs are designed to equip extensionists, crop protection personnel, and others with the knowledge and skills needed to work with farmers within FFSs and facilitate farmer feedback to researchers.

FFS and TOT are the methods used to implement Integrated Pest Management on cowpea by the Ghana/Clemson team. These methods were modeled after the very successful FFSs established in Indonesia (Wiradmadya and Kusmayadi, 1996). Upwards of 1.5 million Southeast Asian farmers have been empowered through FFSs since the mid-1980s.

FFS and TOT in Ghana focus on small-scale farmers based on the assumption that sustainable development at the macro level is predicated upon sustainable development at the micro level. Participatory, sustainable development is being advocated by Ghana’s government. IPM is being promoted as economically and environmentally sound throughout the world. Participatory IPM, such as that which is achieved through field schools, is “central to sustainability” (Vander Mey, 1999, p. 41). In addition, field school principles and practices are consistent with the key tenets of participatory development (see Atwood, 1993).

Longitudinal evaluation studies are important to confidently declare the impacts of field schools. With this in mind, the Clemson/Ghana team developed an instrument to tap qualitative and quantitative indicators of impact. The outcomes of field schools are supposed to include changes in knowledge, farming practices, and chemical use and handling practices. Other outcomes include higher yields, decreased inputs, increased profits, more healthful farming ecosystems, and improved family health through consumption of cowpea. Indicators of positive impact include safer handling of chemicals, decreased chemical use, bodily protection when using chemicals, the ability to differentiate beneficial and pest insects, and increased use of cowpea as a table food and as a weaning food. Over time, field schools also are supposed to broaden decision making ability, empower farmers, and have spillover effects into other aspects of participants’ lives.

An initial follow up of one TOT and two FFSs occurred in Ghana during February and March, 1999. The TOT had been held at Wa, August-October, 1997. The FFSs had occurred May-July, 1998, at Damongo and Tampei-Kukuo, respectively. The schools had a total of 69 participants, 28 of whom participated in this initial evaluation. This field school involved using neem as an alternative to calendar methods of chemical application. On site, participants tested neem plots against farmer practices (using chemicals), and control plots.

For all practices measured, farmer participants showed greater changes than did the Trainers. In the area of farming practices, significant changes (p£.05) included more use of cover crops, composting, weeding, scouting, and using resistant varieties. Field school participants typically reduced their use of chemicals, and in one case ceased using chemicals altogether. Prior to the field schools, participants generally had heard of neem, but did not know how to make use of it. After the field schools, participants judged neem to be valuable in terms of the money saved, but saw the time investments of preparation to be costly. On balance, however, participants said they would still rely on neem, though they would like it if they could get it from someone else who was trained in preparing it. When chemicals were used, there were significant changes in using only recommended chemicals at only recommended times. In addition, there were significant changes in bodily protection while applying chemicals. These changes included greater frequency of using gloves, masks, and covering the body.

Significant changes in knowledge included being able to calculate yield losses, understanding pest-predator relationships, understanding crop-weed associations, knowing the best planting times, recognizing disease symptoms, and being able to differentiate natural enemies from insect pests.

There were no significant changes in average frequency of cowpea consumption among participants in relation to using cowpea as a weaning food or as a table food. After training, however, fewer participants were only rarely eating cowpea, and more participants were consuming cowpea on a daily basis.

While the difference was not significant, average yield per acre was slightly higher after the field school (3.36 bags) than before (2.62 bags). Participants attributed this higher yield to the use of neem, more timely pest control, more timely weeding, timely planting and scouting. These assumptions would be consistent with findings from field schools in other parts of the world (see, van Huis and Meerman,1997). In addition, this indicates that participants are understanding farming as a system.

On average, participants had trained 11others. However, oversight and quality control are needed. The participants also suggested that refreshers be provided. In addition, participants believe that more field schools are needed in Ghana.

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REGIONAL COWPEA TRADE AND MARKETING IN WEST AFRICA

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Presented by Jess Lowenberg-DeBoer

In the last twenty years, the Bean/Cowpea CRSP has made important contributions to cowpea production technology. CRSP scientists have bred new varieties. They have developed improved methods for controlling pests in the field and in storage. CRSP technologies could dramatically increase the supply of cowpeas in West Africa. The question now is who would buy those cowpeas? At what price? And what kind of cowpeas would consumers prefer? Until the current phase of the CRSP, there had been no regional perspective on cowpea markets and no systematic analysis of consumer preferences for cowpea characteristics. This presentation summarized the preliminary results of the CRSP cowpea marketing study in two parts: (1) structure of cowpea markets in West Africa, and (2) consumer preferences as measured in hedonic pricing studies. In addition, this summary will include the results of impact assessments done for varietal development and storage technology in Sénégal and Cameroon.

What is the structure of cowpea markets in West Africa? Cowpea markets in West Africa are part of an ancient trade that links the humid coastal zones with the semiarid interior. This ancient trade is built on comparative advantage in food production of each zone. In the humid coastal areas, it is relatively easy to produce carbohydrates (e.g., cassava, maize, rice), but because of pests and diseases it is difficult to produce animal or vegetable protein. Lack of rainfall limits grain production in the interior, but it also creates good conditions for livestock, cowpeas and groundnuts. In the traditional cowpea growing countries of the Sudano-Sahelian zone, there is a well developed network of village buyers who assemble small quantities from individual farmers into 100 kg bags and merchants who transport and store the bags.

The largest producer and consumer of cowpeas in West Africa (and in the world) is Nigeria. A dense population and oil revenue create an enormous effective demand for cowpeas. Niger is the largest cowpea exporter is West Africa (and in the world) with an estimated 215,000 MT exported annually, mainly to Nigeria. Substantial amounts of cowpea also come in to Nigeria from other neighboring countries, especially Cameroon and Tchad. A large portion of cowpeas from Burkina Faso and Mali are sold into Cote d'Ivoire, though some are said to be trucked along coastal roads as far as Nigeria.

Ghana is a major producer of cowpeas, but in addition it imports about 10,000 MT annually. About 30 percent of the Ghanaian imports comes from Burkina Faso and the rest from Niger. Langyintuo found that in Accra, the large, rough coated Nigerien cowpeas sell for a premium, but they need to be marketed quickly because they do not store well in the humid coastal climate.

The initial hypothesis at the beginning of the cowpea marketing research was that most cowpeas from northern Cameroon were marketed in Nigeria. Work by Jean-Paul Oumarou, a University of N'gaoundéré student, showed that in fact most of the northern Cameroon production went to southern Cameroon, and some was exported from there to Gabon and Congo.

In northern Sénégal as the climate grew drier and the groundnut parastatal declined, cowpeas have increasingly replaced groundnuts as the legume of choice. Some cowpeas are exported to Mauritania and Gambia, but the transportation cost and lack of market links limit access of Senegalese cowpeas to the large markets in Ghana, Nigeria and elsewhere along the African coast.

Sénégal is the only country in the region with a substantial cowpea processing industry. Faye identified five companies producing cowpea-based weaning food, cowpea flour and cowpea- based crackers. All products are made from recipes developed by ISRA's Food Technology Institute (ITA). In addition, there is a cracker manufacturer in Nouakchott, Mauritania, that uses primarily cowpeas from Sénégal.

What have we learned about consumer preferences? Knowledge of consumer preferences is essential to developing cowpea markets. Breeders need to know what characteristics consumers want. Integrated pest management specialists need an estimate of the consumer-level cost of grain damage. The CRSP cowpea price and quality study was launched in Maroua, Cameroon in September, 1996, and later extended to four markets in northern Cameroon, three markets in Nigeria, two markets in Niger, three markets in northern Ghana, three markets in Mali and six markets in Sénégal using a common data collection protocol. Every month CRSP researchers and technicians buy five samples per market from randomly selected sellers. They note the gender and other seller characteristics. In the laboratory, they record the 100 grain weight, average length and width of grains, number of bruchid holes per 100 grains, color and texture of the testa, and eye color. The data are analyzed using a hedonic pricing regression model.

Initial results from the hedonic pricing analysis indicate that consumers in all areas prefer larger grain size. Consumers are more sensitive to bruchid damage than hypothesized. It was thought that West African consumers would tolerate a certain level of damage, but the data indicate that cowpea prices are discounted from the first appearance of damage. Women in Cameroon appear to sell for a higher price than male vendors, probably because women sell in small quantities for immediate consumption. In Sénégal, consumers appear to pay a premium of 20 FCFA/kg for the traditional black speckled varieties.

What has been the impact of CRSP research? Impact assessments in Sénégal and Cameroon show that CRSP production research has reached large numbers of people and is generating a substantial economic benefit. In Sénégal, over 80 percent of stored cowpea are stored with the CRSP drum storage technology. In northern Cameroon, about 23 percent of cowpea area is planted to Vya, BR1 and BR2, varieties that the CRSP helped develop and popularize. About 10 percent of cowpea in northern Cameroon is stored with storage technologies developed by the IRAD/Purdue CRSP team. The CRSP storage technologies developed in Cameroon are now being extended in Nigeria, Niger, Burkina Faso, Mali, Sénégal, Tchad, Zimbabwe and Mozambique. The annual rate of return on CRSP investment in the ISRA/University of California Riverside team in Sénégal for the varietal development and storage after 1985 is about 16 percent. The rate of return to CRSP breeding and storage research in Cameroon alone is about 5 percent. In both cases, the benefits are much higher when taking into account the use of CRSP technology outside of the country of origin.

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EAST AFRICA REGIONAL PROJECT

DISEASES AND BIOTECHNOLOGY IN AFRICA

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Presented by Robert Mabagala

The common bean (*Phaseolus vulgaris* L.) is the most important source of dietary protein in Eastern and Southern Africa. Although yield potentials of over 2000 kg/ha exist, yield averages are still low due to losses caused by diseases, among other constraints. Such diseases include angular leaf spot (*Phaeoisariopsis griseola*), common bacterial blight (*Xanthomonas campestris* pv. *phaseoli)*, rust (*Uromyces phaseoli*), bean common mosaic virus (BCMV), bean common mosaic necrosis virus (BCMNV), halo blight (*Pseudomonas syringae* pv. *phaseolicola*), anthracnose (*Colletotrichum appendiculatus*) as well as nematodes (*Meloidogyne* spp.).

These diseases can be extremely devastating on the bean crop and cause high losses. Management of these diseases using chemicals is not practical because many small holder farmers in the region can not afford them. Breeding for disease resistance remains the most fitting and reliable option for managing bean diseases. Therefore, research activities in this region focus on the development of improved varieties, emphasizing high and stable yields, multiple disease and insect resistance, drought tolerance and fast cooking.

In Tanzania, two bean varieties, SUA 90 (khaki) and ROJO (red) have been released by the Bean/Cowpea CRSP program. These varieties are high yielding, resistant to rust, BCMV, BCMNV and ALS. In addition, they stand up well to bacterial diseases, drought and are resistant to lodging. Furthermore, several new breeding lines with diseases and insect resistance are under development for release in the years 2000 and 2001. In Malaŵi, the variety Kalima has been released by the programme. Kalima has an intermediate level of resistance to angular leaf spot.

Ecologically, team members have confirmed that the disease *X.c*. pv. *phaseoli* can survive on wild legumes such as *Dolichos* spp. and *Desmodium* spp. even in areas far from agricultural land. Taxonomically BCMV and BCMNV which were originally classified as one virus, have been distinguished as two distinct viruses, through collaborative work between the U.S. and East Africa Regional scientists. Such research efforts have resulted in the re-naming of the necrotic strains as BCMNV. In addition, a range of wild legume hosts for these viruses has been established in East Africa. However, more information on the ecology, epidemiology and host-pathogen genetics is needed.

The East Africa Bean/Cowpea CRSP has also established biotechnology laboratories, in Malaŵi and Tanzania. However, biotechnology in agriculture is still in its infancy in Eastern Africa and Africa in general, although its potential for improving agriculture there is obvious. Biotechnology can make life better for developing countries by allowing better characterization of pathogens and germplasms for more rapid development of bacterial, fungal and viral disease resistance. Thus, farmers in a wide range of environments would produce higher than usual yields with less inputs. In addition, biotechnology can contribute to improved natural resource conservation, insect resistance, tolerance to salt and toxic heavy metals, more nutritious food products with improved keeping quality and increased seed trade and germplasm exchange across borders through reliable new techniques to detect seed-borne pathogens.

Using the two PCR laboratories in Malaŵi and Tanzania, the Bean/Cowpea CRSP in the East Africa region has characterized the pathogen *X.c.* pv. *phaseoli* while characterization of the bean gene pools in the centers of origin (Andean or Mesoamerican regions) continues (see paper by Robert Gilbertson). One short-course on PCR has been conducted in each country (Malaŵi and Tanzania). These courses were attended by 11 and 9 scientists representing universities and the Ministries of Agriculture in Malaŵi and Tanzania, respectively.

Using non-CRSP funds, Dr. S. Nchimbi-Msolla was trained at Oregon State University to characterize bean genotypes for purity using PCR and other techniques. Her training allowed the detection of SUA 90 in variety mixtures collected from Kenya. A graduate program (M.S. level) in plant biotechnology including PCR has been developed in Malaŵi. Links with potential customers producing beans for export and who can use PCR services in Tanzania have been established and continue to be strengthened. Testing of on-farm produced seed using PCR for certification is underway.

The following impacts are expected to be realized: Reliable and sustainable disease management (resistant varieties) by small-holder farmers, reduced use of chemicals lowering production costs and resulting in a safer environment, increased yields, and increased food security with a better financial position for small-holder bean producers. In addition, through emphasis on training, the East Africa Regional Project continues to support professional sustainability in the region, increase research and teaching efficiency, provide better leadership, student supervision and strengthened extension to address small-holder bean producers needs. However, degree and non-degree training in biotechnology is urgently needed to backup and increase the utilization of the two PCR laboratories in East Africa.

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DISEASES AND BIOTECHNOLOGY IN THE UNITED STATES

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Presented by Robert Gilbertson

Common beans play a central role in the diets of both rural and urban dwellers in East Africa. They are increasingly being produced for cash. However, their production is limited by both biotic and abiotic constraints. The most important biotic constraints are diseases, particularly angular leafspot, bean common mosaic virus, common bacterial blight, halo blight, rust and others (see paper by Robert Mabagala). Development of resistant bean varieties has been difficult, in part, because of the extensive genetic diversity within many of these pathogens. Because relatively little is known of the selection pressure driving pathogen diversity, attempts were made to understand the genetic diversity of the causal agents of some of these diseases in order to assist breeders develop genotypes that have better resistance to them. Based on several lines of evidence, including seed protein analysis, allozyme marker studies, restriction fragment length polymorphism (RFLP) and random polymorphic DNA (RAPD) analyses, morpho-agronomic characters, and evidence of genes for hybrid lethality, cultivated common beans have been separated into two distinct groups called "Andean" and "Mesoamerican" gene pools. The former appears to have arisen in the Andes Mountains of South America and the latter in southern or western México and/or Central America. It was hypothesized that existence of the two host gene pools might be paralleled by the existence of two gene pools in organisms associated with common bean, such as pathogens or symbionts.

Random amplified polymorphic DNA (RAPD) markers were used to characterize 62 *Phaeoisariopsis griseola* isolates from three countries (Malaŵi, United States and Brazil). The gene pool of the bean plants from which the isolates were obtained was determined by isozyme and Phaesolin analysis. Eleven primers generated reproducible and distinct RAPD patterns that divided the *P. griseola* isolates into two major groups. Group 1 (Andean) isolates were generally recovered from Andean gene pool materials, whereas group 2 (Mesoamerican) isolates were recovered from Mesoamerican materials. *Phaeoisariopsis griseola* isolates representing groups 1 and 2 were inoculated onto selected Andean and Mesoamerican beans. Group 1 isolates were more pathogenic on Andean beans whereas group 2 isolates were more pathogenic on Mesoamerican beans. RAPD and pathogenicity data suggest that groups 1 and 2 may have originated in the Andes and Mesoamerica, respectively, and that coevolution of the *P. griseola* fungus and its common bean host has resulted in increased levels of disease in this host-pathogen interaction. In addition to RAPD, specific detection of the two major groups of *Phaeoisariopsis griseola* (Andean and Mesoamerican) from infected common bean leaves has been achieved by amplification of different-sized DNA fragments by PCR with group-specific primer pairs. These primer pairs were designed based on DNA sequences of cloned RAPD fragments. Using this faster method, *P. griseola* isolates from diverse geographical regions were differentiated into the two previously established groups. A simple and rapid sonication method has been developed that allows for PCR detection of *P. griseola* from mycelia or synnemata and conidia collected from angular leafspot lesions on bean leaves.

Bean common mosaic virus (BCMV) causes one of the most widespread diseases affecting common bean production. This potyvirus is spread non-persistently by aphids and is also seed-borne. The disease is distributed worldwide but necrosis-inducing strains, not considered to be a distinct virus species (i.e., bean common mosaic necrosis virus), which induce systemic necrosis in genotypes carrying the dominant I-gene, are widespread in Africa, Europe and have been detected in some parts of North America. Genetic resistance to the virus is the most effective means of controlling its spread. BCMV resistance is conditioned by a series of strain-specific genes but *bc*-3 gene conditions resistance to all known strains of BCMV. We sought to alleviate the problems associated with the introduction of the recessive *bc*-3 gene by developing an efficient marker-assisted selection system based on markers that tag the *bc*-3, a simplified DNA extraction method, and more reliable PCR amplification protocols through the development of sequence characterized amplified regions (SCARs). We have developed a relatively easy-to-use procedure to introgress the *bc*-3 gene into elite bean cultivars. First, we employed bulked segregant analysis to identify RAPD markers linked to *bc*-3 locus. The ROC11/350/420 marker was codominant with the *bc*-3 gene and the ROC20/460 marker was dominant and linked in *trans*. A survey of cultivated materials allowed us to identify the likely evolutionary origin of the *bc*-3 resistance allele as a member of the Mesoamerican gene pool. Polymorphism of the RAPD markers in a Davis common bean mapping population (BAT93xJalo EE558) allowed us to map the markers and, by inference, the *bc*-3 gene to linkage group D6. Second, we used sequence information from the cloned RAPD fragments to design longer, more reliable PCR primers that differentiate individuals homozygous for the resistance allele from susceptible genotypes in segregating populations of Andean origin. Third, we developed a marker tagging system that used a simplified DNA extraction technique and a PCR-based assay to identify the genotype of common bean plants at the *bc*-3 disease resistance locus. This simplified marker assisted selection system is expected to eliminate the need for costly quarantines and progeny tests in breeding programs for common beans of Andean origin. A survey of common bean germplasm reveals that the marker tags identified appear to be useful for introduction of the *bc*-3 gene from its Mesoamerican background into the Andean gene pool. It was against this background that crosses were planned for Malaŵi. These crosses were of the most prominent Malaŵian elite and preferred genotypes and A- and MCM lines, with *bc*-3 gene, from CIAT with resistance to ALS and BCMV, respectively. These materials were evaluated at UCD for resistance to BCMV and in Malaŵi for resistance to ALS. They are in advanced stages of evaluation and should soon be released for production in Malaŵi and for other programs in the region.

Common bacteria blight (CBB) caused by *Xanthomonas campestris* pv. *phaseoli* is another important disease in East Africa. This bacteria exists in two forms *Xanthomonas campestris* pv. *phaseoli* (*Xcp*) and *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* (*Xcpf*), which produces a characteristic brown pigment on general agar media, such as 523. The question of there being coevolution between this pathogen and the host gene pool has again been examined. Leaves with CBB have been collected from Malaŵi and Tanzania and the pathogen was isolated. These isolates have been divided into two groups depending on pigment production (*Xcp* produces no pigment; *Xcpf* produces a brown pigment). A primer pair has been developed for PCR detection of *Xcp* and *Xcpf*. This pair was designed from the sequence of a repetitive element in the bacterial genome and directs the amplification of an ~800bp fragment. All the Malaŵian and Tanzanian CBB strains were detected with these primers. The PCR detection of CBB allows for: (a) rapid detection of *Xcp* and *Xcpf* (<24h), (b) differentiation of *Xcp*/*Xcpf* from nonpathogenic xanthomonads, and (c) detection of CBB in seeds. After *Xcp*/*Xcpf* identification with specific primers, fingerprints of the pathogenic bacteria are generated by repetitive sequence (rep)-PCR. This method is based on PCR amplification of repetitive sequences interspersed in the bacterial genome. Three types of elements are used, viz. repetitive extra genic palindromic (REP), enterobacterial repetitive intergenic consensus (ERIC), and BOX elements. Results show different fingerprints generated in the nonfuscous *Xcp* pathogenic isolates and little variability for *Xcpf* strains. From the host plants leaves/pods or seeds are collected from which the gene pool is determined using Andean/Mesoamerican PCR primers. These data are then correlated with gene pool of beans from which isolates were collected. Isolates representing pathogen diversity are then selected and used for inoculation on representative materials from the two gene pools. From all pathogenic isolates obtained from Malaŵi and Tanzania most of the *Xcpf* had been collected from Mesoamerican beans whereas most *Xcp* were from Andean beans, providing a first evidence of a coevolution-like phenomenon for these bacteria. Inoculation of Malaŵi *Xcp*/*Xcpf* isolates onto beans of Andean and Mesoamerican backgrounds revealed a striking interaction. The Malaŵi *Xcp* caused severe symptoms on Andean gene pool beans but significantly less severe symptoms on Mesoamerican. The fuscous *Xcpf* caused severe CBB on both gene pools. In contrast Brazilian *Xcp* (where mostly Mesoamerican beans are grown) caused severe CBB on beans of both gene pools. These results suggest that the Mesoamerican genotypes may be good sources of CBB resistance for the Andean Malaŵian or Tanzanian cultivars. Some of the Mesoamerican breeding lines with pyramided CBB resistance genes from *P. acutifolius* and other *P. vulgaris* sources (VAX lines) have been evaluated and they show high levels of resistance to Malaŵi *Xcp*/*Xcpf* isolates. These materials will be used in future breeding for CBB resistance in the ALS/BCMV resistant lines already developed by the East Africa Project.

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VARIETAL DEVELOPMENT

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Presented by James R. Myers

Breeding programs are important to every regional effort the East African Bean/Cowpea CRSP Project. Dry beans have been bred at Sokoine University of Agriculture (SUA) in Tanzania since the project's inception in 1980. Early on, Matt Silbernagel (USDA-ARS, Prosser, WA) made crosses with advancing generations screened at SUA, but now most CRSP breeding efforts are carried out by SUA breeders (see paper by Robert Mabagala). In Malaŵi, Ph.D.s who returned to Bunda College are making important contributions to efforts of that team. At the University of California-Davis, breeding is ongoing for kidney, pink and a few minor market classes of dry beans for Californian environments. CRSP dry bean breeding at the University of Idaho, has now moved to Oregon State University where the CRSP scientist, a vegetable breeder, is responsible for developing improved green bean cultivars.

In contrast to the U.S., dry bean market classes are not clearly defined in East Africa, and seed types found in Africa are considerably more diverse, including types unknown in the U.S. Beans are no longer strictly a subsistence crop but have become an important cash crop in East Africa, with the result of the formation of fledgling market classes. For example, Rozi Koko, Canadian Wonder, and Kablanketi types have more than one cultivar. Production systems and environments are more variable in Africa than the U.S. Not only do latitudinal differences play a role in Africa, but so do altitude, season, and cultural systems. While beans in East Africa have great genetic variability, additional variability is needed to provide resistance to abiotic and biotic stresses. Generally, large-seeded Andean bush types predominate in East Africa, but climbers represent as much as 75 percent of the bean production in the Malaŵi.

Malaŵi and Tanzania share many of the same constraints, but being at a lower latitude than Tanzania, Malaŵi has changes in daylength that may interact with photo period genes. Further, Tanzania has a bimodal rainfall distribution, while Malaŵi's precipitation is unimodal. Farmers in both countries are dependent on rain for bean production, but some farmers also take advantage of residual moisture found in low areas (e.g., Dimba gardens in Malaŵi), or have access to irrigation.

In Tanzania, bean research is divided such that SUA breeds for low altitude environments, whereas the National Program at Uyole in the south breeds for high altitudes, and the National Program at Selian in the north breeds for mid-altitudes. In low altitude zones, heat and drought are the major abiotic stresses. Major biotic factors include: bruchids, nematodes, and bean stem maggot as invertebrate pests, bean common mosaic virus (BCMV) and bean common mosaic necrosis virus (BCMNV) as the major virus pathogens, and common bacterial blight (CBB), halo blight (HB), angular leafspot (ALS), and rust as the most important fungal pathogens. Constraints for Malaŵi include: heat and drought, bruchids, BSM, BCMV and BCMNV, CBB, HB, ALS, and rust. In addition, web blight and root rot pathogens are often of importance.

In the Western U.S., the major market classes are: pinto, pink, small red, great northern, black, light and dark red kidney, and cranberry. The major abiotic constraints include length of season (ID) and heat (CA). BCMV and BCMNV, and beet curly top viruses are important. Fungal and bacterial diseases are usually not a problem because water is supplied by irrigation. Idaho bean dealers sell seed into the Midwest bean production areas, so rust and CBB resistance is needed.

In Tanzania, "SUA-90" and "Rojo," have been released. Both have resistance to rust, BCMV and BCMNV, HB, ALS, and moderate resistance to CBB. SUA-90 is drought tolerant and high yielding whereas Rojo has lower levels of drought tolerance and slightly lower yields. Both, however, will yield three to four times local landraces. Both cultivars are quick cooking and highly palatable. Rojo has large red seed—a preferred type by consumers—while SUA-90's small brown seed is not recognized as a preferred type. Seed dissemination studies have not yet revealed the extent to which these cultivars have spread, but seed has been distributed to many farmers in two of the four mandated regions that are the focus of SUA's breeding program. Also, in a recent study using PCR to fingerprint landraces and advanced lines, the team discovered SUA-90 in a mixed sample of seed purchased from the Bungema village market in Kenya during the 1998 virus survey trip.

In Malaŵi, six cultivars were released in 1980 and three in 1993. The 1980 releases were: Nasaka (beige large kidney, bush), Sapelekedwa (red large kidney, bush), Bwenzilawana (medium gold, climber), Kamtsilo (small black, climber), Namajengo (small red, climber),and Kanzama (medium round red, climber). All these were selections from the Bunda landrace collection and are representative of popular contemporary market classes. Of the later releases, "Bunda 93" is a high yielding climber selection from a landrace with pink mottle seed. "Chimbamba" is large red kidney bush type bred at Bunda. "Kalima," a line originally from South America, has received the greatest emphasis in terms of dissemination. It is a red mottle bush type with high yield and resistance to ALS, and good palatability. It has been distributed in about half of the eight Agricultural Development Districts and has been included in the Ministry of Agriculture's Startup Seed Package program that has gone to thousands of farmers.

In the U.S., the most recently released lines from the Idaho program include "UI 320" pinto, "UI 465" great northern, "UI 259" small red, and "Black Knight" black bean. The pinto and great northern possess *I* gene resistance to BCMV and rust resistance to the races found in the high-plains states of the U.S. "Nichols" and "Vallejo" dark red kidneys are recent releases from UC-Davis. They were bred for adaptation to California and for enhanced processing characteristics from crosses between U.S. and CIAT germplasm.

Preliminary and advanced lines in Tanzania include *arcelin-1* backcrosses to SUA elite lines, crosses to improve the Kablanketi type, and crosses to incorporate nematode resistance into SUA lines. Materials in Malaŵi include the advanced lines shown in Table 1, as well as the incorporation of CBB, ALS, and BCMV resistance into six to eight of the Malaŵian Market types. Nasaka, Sapalekedwa and Namajengo have received priority for improvement in ALS/BCMV resistance. Nyauzembe (an olive green type found in northern Malaŵi) and Kaulesi (cream with small purple specks), Kablanketi (found in southern and northern Malaŵi) have also been included.

Table 1. Advanced Dry Bean Lines Suitable for Production in Malaŵi

Name	Source	Characteristics
Lyamungu 90	Tanz.	Rozi Koko type, high yield, anthracnose res.
ZPV906	S. Afr.	White Kidney, bush, high yield
Enseleni	S. Afr.	Sugar bean, bush, high yield, anthracnose res.
IZ266-1	Rwanda	Small red climber, high yield, HB & anthracnose res.
15P/8	Bunda	ditto

The general direction of research in East Africa is to develop materials with greater stability over a range of environments. This will be done by incorporating multiple disease, insect and environmental stress tolerances. The needs of farmer and consumer markets should drive the research. To that end, the research is broadening the resistance to bruchids and investigating ways to both reduce cooking time and reduce anti-nutritional factors—such as phytic acid. These efforts will reduce the environmental impacts of preparing beans and improve nutrition from their consumption.

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BRUCHID STUDIES AND BREEDING FOR BRUCHID RESISTANCE

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Presented by Susan Nchimbi-Msolla

Bruchids are a major problem in storage of seed for propagation and consumption. There are two species of bruchids which are known to be the major pests of stored common bean (*Phaseolus vulgaris* L). These include the common bean weevil (*Acanthoscelides obtectus* (say)) and the Mexican bean weevil (*Zabrotes subfasciatus* (Boh.)). *Acanthoscelides obtectus* starts to attack beans while they are still in the field and continues the attack in storage. On the other hand, *Z. subfasciatus* attacks beans only in storage (Howe and Currie, 1964).

Bruchid damage reduces the weight, quality and viability of bean seed. The degree of loss due to bruchid attack is very variable. The degree of loss depends on the storage period and the storage conditions. In Tanzania, for example, bean losses by bean bruchids of up to 40 percent have been reported (Kiula and Karel, 1985). Beans, once attacked by bruchids are undesirable on the market causing economic loss to the producer and quality loss to the consumer. This is mainly because damaged seeds are usually covered with eggs and are perforated (Schoonhoven and Cardona, 1986).

The risk of bean attacks by bruchids in East African traditional small-farm storage facilities is possibly the major reason why farmers do not wish to grow large quantities of beans. They fear that the extra grain will be attacked by bruchids while in storage. For this reason, they sell most of their grain quickly (and cheaply) soon after harvest to avoid large storage losses.

Various control methods against bruchids have been utilized, which include cultural and chemical control and breeding for resistance. High levels of resistance against *Z. subfasciatus* have been identified from wild beans in México (Gallepo, 1988). This form of resistance is known to be caused by the presence of arcelin, which is a protein found in the wild beans.

Therefore, the East African bean bruchid studies have the following objectives:

1. Determine bruchid prevalence and variation in bean growing areas of Tanzania and Malaŵi.

2. Incorporate *Zabrotes subfasciatus* resistance in bean lines adapted to Tanzanian conditions and evaluate those lines (arcelin-containing) for bruchid resistance, yield performance and disease resistance and their suitability for release as improved varieties.

3. Look for sources of *Acanthoscelides obtectus* resistance, which includes assessing the resistance of *Phaseolus acutifolus* against *A. obtectus* and the possibility of using *P. acutifolius* to transfer resistance to *P. vulgaris*.

There have been important achievements in addressing these objectives:

1. Bean bruchid prevalence and variation have been assessed during the period of August 1997 to 1999. Bruchid samples were collected in different bean growing areas in Tanzania (Bukoba, Mwanza, Morogoro, Arusha, Kilimanjaro, Tanga, Mbeya and Ruvuma regions). Collections were conducted at four-month intervals. This gave three periods (seasons) for collection of samples. The first season was from January-April, the second from May- August and the third season was from September-December. Mwanza/Bukoba, Mbeya and Ruvuma regions usually receive rain from November to April. From May to mid-August, it is normally dry and cool in those areas and from mid-August to November, it is dry and warm. The results show that in Mbeya and Morogoro regions there is no seasonal variation of the two bruchid species.

A. obtectus was the most prevalent bruchid in all three seasons. In Tanga and Ruvuma regions, seasonal variation has been observed. In Ruvuma region, *Z. subfasciatus* was more prevalent in the January-April season, while during the other two seasons, *A. obtectus* was more prevalent than *Z. subfasciatus*. The higher prevalence of *A. obtectus* in the two seasons may be because *A. obtectus* starts to infest beans when they are still in the field. Therefore, after harvesting in May they are present in large populations until December. Thereafter, *Z. subfasciatus* populations begin to increase (*Z. subfasciatus* infest bean in storage only). In the Tanga region, the same pattern may be present. On the average, *A. obtectus* was more prevalent in May-August and September-December seasons than *Z. subfasciatus,* and in January-April season, *Z. subfasciatus* was more prevalent than *A. obtectus*. This seasonal pattern implies that arc 1 may be effective for long-term storage of bean in Tanzania, but will not prevent field infestation with *A. obtectus*. Therefore, there is still a need to look for sources of resistance to *A. obtectus*.

In Malaŵi, short-courses on identification of bean bruchids and their damage to beans were conducted in several ADD's. Courses were regarded as useful by participants which included Extension staff and a limited number of research field assistants. The survey conducted in 1998, showed that bruchid damage increased from 1.7 to 18 percent from August to October. The result of the survey also showed that farmers sell their beans early to avoid damage and only limited amounts may be kept for seed.

A questionnaire study to gather storage information was conducted in Kisanga, Msolwa, Maharaka, Msongozi and Nyandira villages. Twenty different varieties were found to be grown by farmers in these villages including SUA 90 and ROJO (The SUA released varieties). The results indicated that about 80 percent of farmers prefer red beans (Canadian wonder type) in almost all villages, except Msolwa and Kisanga where they showed equal preference for soya (Kablanketi) and red beans. Insect pest and diseases were said to be a major problem for bean production. Among insects, bruchids were considered a major pest in storage. About 95 percent of farmers store seed in bags, while the rest of the farmers store beans in pots or baskets. Most farmers do not clean their beans after threshing, leaving the job until they want to sell. They said that leaving beans with trash prevents infestation.

2. Performance of *Zabrotes* resistant (arcelin-containing) lines has been assessed. The arcelin-containing lines had low numbers of adults which emerged and also low numbers of bruchid-damaged seed.

   Yields of the bruchid resistant (arcelin-containing) lines ranged from 848.5 kg/ha to 1092.6 kg/ha in low altitude areas (500 – 1000 m.a.s.1.). In medium altitude areas (1500 – 2500 m.a.s.1.), seed yields were at the range of 755.0 to 841 kg/ha.

   The on-farm trials of the arcelin-containing lines are continuing in three villages in Tanzania to determine their suitability to be released as improved varieties.

3. *Acanthoscelides* resistance was also assessed. Germplasm collected from different parts of Tanzania were not shown to have any resistance to *A. obtectus*. Accessions identified previously as possibly having resistance did not give repeatable results. A *Phaseolus acutifolius* line (G40199) originally obtained from CIAT was evaluated for *A. obtectus* resistance and was highly resistance. Six arc1 containing lines have been sent to Oregon State University for further hybridization with tepary lines resistant to *A. obtectus*. OSU obtained four SMARC-lines from Tom Osborne at the University of Wisconsin. These lines are SMARC1-NN (contains arc 1 and Phaesolin), SMARC1-PN (arc1, Phaesolin null), SMARC2-PN (arc2, Phaesolin null), and SMARC4-PN (arc4, Phaesolin null). These were increased in the summer of 1999 for verification of seed storage protein status. The seeds have been sent to SUA for bruchid tests.

   Interspecific hybridization between *P. acutifolius* and suitable *P. vulgaris* lines have been initiated at OSU.

4. Impact is expected to be considerable. Seasonal variation, with *Z. subfasciatus* becoming more prevalent with greater length of storage, suggests that lines with arc1 may increase storage capabilities of farmers. Bean prices show seasonal variation with prices lowest just after harvest and highest during the growing season and before harvest when stored beans are scarce. A farmer would profit from being able to store beans until prices are high. The Rojo arc1 line to be released in 2000, should allow us to determine the value and impact of arcelin on farmers livelihood. The survey of farmers indicates that farmers do perceive bruchids as a serious storage problem suggesting that resistant varieties and perhaps effective cultural practices will make a difference. Efforts to find effective resistance to *A. obtectus* are just beginning, and are expected to require long-term efforts for interspecific hybridization with *P. acutifolius*. Arcelin4 may provide a quicker means of control of *A. obtectus* because it is already in a *Phaseolus vulgaris* background. However, this source of resistance has not been reported to be as effective as arc1 against *Z. subfasciatus*, and because arc1 and arc4 are allelic, cannot be incorporated into the same varieties.

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NUTRITIONAL STUDIES

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Presented by Theobald Mosha

Beans in the East Africa region are produced for both cash income and consumption. They are consumed by the farming community (about 84 percent of the population) and by urban dwellers. Beans are consumed as a protein supplement to the starchy staples such as maize, sorghum, cassava and millets because protein from animal sources is scarce and expensive for many poor families. Beans provide 30-40 percent of the total protein intake in East Africa and account for 65 percent of the legume protein consumed in the region. In the year 2000, per capital consumption is expected to reach 12 kg, up from 9.6 kg (Tanzania) and 9.5 kg (Malaŵi) in 1994. The frequency of bean consumption per week is also high ranging between 3-4 times in Tanzania and 3-5 times in Malaŵi. In addition to providing protein, beans are also a good source of calories and micronutrients. The nutritional value of beans as a source of protein, energy and micronutrients is, however, reduced by the presence of some compounds which bind them reducing their digestibility and the bioavailability of their nutrients when consumed. Such compounds include: phytates, tannins, trypsin, chymotrypsin and amylase inhibitors.

Cookability and organoleptic qualities of beans are important attributes for customer preference, selection and acceptance, particularly for the new bean varieties developed by breeders. Cooking time is an important characteristic of beans as it determines the amount of fuel and time spent on food preparation, both of which are of much concern to women in East Africa. Wood, which is the most common type of fuel used, is often scarce. Women must walk long distances to search for wood and transport it to their homes. Fast cooking bean varieties are thus preferred to the hard-to-cook varieties since they reduce women's drudgery and conserve natural resources. On the other hand, bean varieties that are more tasty and palatable with a long shelf-life after cooking would be better accepted by consumers.

One of the objectives of the East Africa Regional Project is to improve the nutritional and culinary quality of beans through: (a) screening of selected, released and advanced breeding lines for cooking characteristics, nutritional value (chemical composition) and nutritional quality, e.g., digestibility, bioavailability of nutrients, and content of anti-nutritional factors; (b) relating chemical components to culinary and bean quality attributes, e.g., texture and shelf life of beans after cooking and; (c) evaluate consumer preference and acceptability of the released bean lines.

There have been a number of achievements and impacts from this work.

1. Validated methodologies for both cooking trials and estimation of cooking times have been well established and are now in use. These include: (a) the Mattson cooker—for laboratory trials; (b) on-farm cooking methods using charcoal and firewood in collaboration with farmers and; (c) prediction of cooking times from water absorption capacity curves.

2. Cooking times for more than 60 bean varieties comprising released varieties, advanced lines and early generation materials have been established. Rapid cooking bean varieties have been identified. SUA-90, Rojo, Kalima and Bunda-93 have been observed to be fast cooking varieties with average cooking times ranging between 22-44 minutes. Kamtsilo and Nyauzembe have been observed to be medium cooking varieties with average cooking times ranging between 50-84 minutes.

3. Several released and advanced bean lines were evaluated for consumer preference and acceptability. Varieties receiving high/low preference and acceptance by consumers were identified. Studies of consumer acceptability of selected bean lines both in the laboratory and in on-farm sensory tests

indicated that Rojo, Kalima and Kablanketi were very highly acceptable while SUA-90, Bunda-93 and Nyauzembe were highly acceptable. Kamtsilo received low consumer acceptance due to its black color.

4. More than 50 bean varieties were evaluated for nutritional quality, i.e., the content of anti-nutritional factors, particularly, phytates, tannins and trypsin inhibitors. A strong relationship was established between seed coat color and the levels of tannins. Red beans had the highest concentrations of tannins (163.3-934.6 mg/100g beans dry weight basis) followed by beans with a brown seed coat (86.4 -591.5 mg/100g dry weight basis). Other bean colors—white, orange, purple, black and yellow had lower levels of tannins. Red colored beans have been observed to be the most preferred by customers. This called for the need to breed bean lines which are red but low in tannins. Tannin levels in beans can be reduced by germination or soaking the beans for at least four hours prior to cooking. SUA-90, Rojo, Kalima, Kablanketi, Bunda-93 and Nyauzembe had high levels of tannins compared to Kamtsilo.

   Sixteen bean varieties were also evaluated for trypsin inhibitor activities. Beans with high inhibitor activities were identified. All bean varieties evaluated contained significant amounts of trypsin inhibitors, however, cooking the beans for at least one hour reduced the trypsin inhibitor activity by 90 percent. Germination and soaking had no significant effect on the trypsin inhibitor activities.

   Phytic acid content as well as phytic acid:Calcium concentration ratios were determined in several released and advanced lines in on-farm trials. Bean lines with high levels of phytic acid were identified. A significant positive association between phytic acid concentration and the cooking times of beans was observed. Cooking times for beans decreased as the Phytic acid:Calcium concentration ratio decreased. Storage time for the dry seeds increased the concentration of phytic acid thus increasing the cooking time. SUA-90, Rojo, Kalima and Nyauzembe were observed to contain low levels of phytic acid compared to Bunda-93, Kablanketi and other advanced lines.

   Several released and advanced bean lines were also evaluated for *in vitro* protein digestibility. In these studies: (a) an inverse association was established between protein digestibility and tannin concentrations as well as trypsin inhibitor activities; (b) germination increased *in vitro* protein digestibility and crude protein content and; (c) prolonged cooking of beans (beyond 80 minutes) resulted in reduced protein digestibility. Fast-cooking beans could therefore be more digestible than the medium and slow cooking lines.

5. Released bean lines and advanced bean materials in on-farm trials have been tested for brothing characteristics. Several bean lines with superior brothing characteristics have been identified, e.g., Rojo and Kablanketi. Strong broth thickness has been observed to enhance customer preference of bean varieties.

   Studies of the shelf-life of cooked beans using selected bean varieties have shown varied shelf-life across the bean lines. More studies are being conducted to clarify the early findings. The influence of bean components, e.g., reducing sugars on the shelf-life of cooked beans is still being investigated.

As a result of these studies, new bean varieties with detailed nutrition information have been released and breeders are taking this information into consideration as they work with advanced lines. The number of consumers/households using the identified fast cooking and acceptable bean lines has increased, especially in the areas where the bean varieties have been distributed. More people in both rural and urban areas consume these preferable new bean varieties with high nutrition quality. Knowledge of the levels of anti-nutrients in the bean lines and their influence on the cookability and nutritional quality has increased.

<u>Publications</u>

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BASELINE AND IMPACT STUDIES AND TRAINING, PARTICIPATORY RESEARCH

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Presented by Anne Ferguson

This is a brief review of social science research and training progress in the East Africa Regional Project focusing on the countries of Tanzania and Malaŵi.

In Tanzania and Malaŵi over the last decade, there have been significant changes that have affected farmers, consumers and the research context. The implications of these changes for bean production and use are major.

1. One change is increased privatization and market liberalization. As Rick Bernsten pointed out in his presentation, one of the biggest changes in many developing countries is in the policy environment, particularly relative to privatization and market liberalization. In both Malaŵi and Tanzania, there is a growing role by private traders, the downsizing of parastatal marketing boards and the removal of crop (and many other) subsidies. Today, there are more channels for smallholders to market their produce and more farmers are selling beans. In much of Tanzania and Malaŵi, beans now are as much a smallholder cash crop as they are a household food crop. However, increased marketing does not necessarily mean that smallholders have satisfied their food or nutritional needs and are selling a surplus—rather it can be an indication of a growing need for cash and in some cases even increased poverty.

2. A second change is the diminished role of the State and growth of NGOs. This second trend involves the downsizing of state bureaucracies and the transfer of many functions which used to be the state's responsibility to other levels of government and especially to non-governmental organizations (NGOs). In Malaŵi, these organizations, and not the government, now receive the majority of donor support. Organizations with which the CRSP has traditionally collaborated in bean research, seed multiplication, and extension now lack sufficient funds and personnel to carry out their functions. In their place are a growing number of NGOs whose mandates generally are not national but rather local in scope and whose programs and goals are diverse. Today, to extend CRSP varieties and technologies, it is necessary to make contacts with many more organizations than in the past. There is no reason to believe that these organizations are necessarily more transparent, equitable or competent than the central government. Indeed, many of those employed in these NGOs previously worked for the government (see paper by Charles Masangano).

3. A third change is the rise of participatory research strategies and stakeholder participation. This notable trend involves replacement of top-down initiatives in agricultural research and development with participatory strategies, stakeholder decision-making and self-help initiatives. It's not an exaggeration to say that older styles of research and action have gone out with one-party governments and been replaced by more democratic and participatory ways of carrying out agricultural research and extension.

4. Emphasis on sustainability is the fourth change. This trend emphasizes environmental sustainability in agricultural production as seen in the focus on soil fertility programs in Malaŵi, and increased awareness of the importance of biodiversity throughout the region. Sustainability concerns are increasing as climate change progresses, with much of the region prone to extreme shifts between droughts and floods.

5. Finally, there is a decline in standards of living. While the first four trends have positive dimensions, the final point is not so encouraging. Along side of these initial changes, and in some cases related to them, are significant increases in poverty and growing epidemics of disease -AIDS and TB in particular.

Most people in Malaŵi and to a lesser extend in Tanzania have seen their living conditions decline over the last decade. The number of those living below the poverty line has increased and their poverty has deepened as the removal of subsidies has progressed, e.g., on fertilizers, basic foods, health care and education. Particularly worrisome is AIDS and the associated epidemics of other infectious diseases like TB. AIDS is often thought of as a health crisis—but it is much more than that. AIDS is an agricultural and social crisis of monumental proportions. In Malaŵi, it's estimated that somewhere around half of the people currently in middle and upper management positions in government, the universities and the private sector will have passed away in the next decade. These are among the country's "best and brightest." Further, the number of orphan-headed households in Malaŵi and Tanzania—something essentially unheard of 10 years ago—is growing rapidly. It's no surprise that the President of Malaŵi recently appointed the very able Minister of Agriculture to a new post as Minister of Health. Agricultural production is the mainstay of Malaŵi's economy and it depends on people healthy enough to farm, raise and support families, and carry out other agricultural-related work.

How is the East Africa Regional Project responding to these changing circumstances?

1. The new research paradigm continues to be emphasized. There is greater farmer participation in research although Malaŵi and Tanzania have followed different strategies. In Malaŵi in the early 1990s, CRSP researchers carried out focus groups and key informant interviews with farmers in major bean growing areas to identify preferred landraces. While yield was important to farmers, many other traits were identified of equal concern to them—early maturity, leaf quality and fast cooking time being examples. Based on this information, the breeding and improvement programs aimed at introducing disease resistance into farmer-selected landrace classes that have these desired characteristics. This material is reaching the advanced trial stage in Malaŵi.

   In Tanzania, the strategy was to bring farmers on to the research station to evaluate early generation materials in the CRSP breeding program. In this way, researchers learned more about farmer preferences and unacceptable materials could be eliminated from the breeding program at an early stage. One of the materials—ROJO has been released in Tanzania and others are nearing release. In both Malaŵi and Tanzania, we anticipate that the results will be new varieties that go beyond yield to respond to a full range of farmer priorities—those of women as well as men farmers.

2. The focus on sustainability is seen as very important. The East Africa Project continues to promote intra-varietal diversity as a means for farmers to reduce risk and to provide for a range of household and market needs. No one improved variety can incorporate all desired characteristics and not all farmers share the same preferences in the first place. These diverse needs can best be met by CRSP breeding and improvement strategies that focus on improving a number of seed classes with diverse characteristics.

3. Adoption and impact assessments will follow baseline studies and subsequent varietal release. With the exception of SUA 90 and ROJO in Tanzania, most materials in the participatory research programs have not yet been released—they are in advanced trials—so it is not possible to evaluate their adoption or impacts at the farm level. Baseline studies have been carried out in areas where these varieties will be promoted. For example, during 1998-99 an intensive baseline study involving 250 farmers was conducted in villages in Morogoro Rural and Kilosa District in Tanzania to prepare the ground for an adoption and impact study of ROJO in 2000-01.

   To date, two varieties have been released in Tanzania—SUA 90 and ROJO. An impact assessment of SUA 90 was carried out in 1998-99 in rural Morogoro and Kilosa Districts. It revealed that the adoption rate of SUA 90 had been low due to poor access to the new seed, low shelf-life, and small size and color of the seed. Traits that farmers liked about the variety included: resistance to drought, high yield, good taste, shorter cooking time and good thick broth. SUA 90 was a product of the CRSP breeding program prior to its focus on participatory strategies. Lessons learned from this experience resulted in the development and release of ROJO with considerably more input from farmers.

In Malaŵi, six landrace varieties were released in the early-mid 1980s and four new varieties were released in the mid-1990s. Of these, two have been in high demand in NGO seed programs: Kalima (released in 1995) and Naska (released in the mid-1980s). During 1999, an Adoption Study of Kalima was carried out in two Agricultural Development Districts (Kasungu and Lilongwe) where Action AID and Self-Help Universal had disseminated it to smallholders in their seed multiplication program. Questionnaires were administered to 478 households and thirteen focus groups were held. The results of the survey are not yet available. The focus groups revealed that Kalima was well liked by growers for its high yield, early maturity, good seed color and size. Farmers also identified problems with the variety including its susceptibility to web blight, its poor performance in intercropping systems and the fact that its leaves do not taste good when prepared as a vegetable.

In both Malaŵi and Tanzania, there have been significant problems in seed multiplication and dissemination which have reduced the impact of the released varieties (see paper by Alex Mkandawire). The National Seed Company in Malaŵi was purchased by CARGIL in the early 1990s and stopped production of dry bean seed. The Ministry of Agriculture's smallholder seed multiplications program collapsed due to lack of funding. In Tanzania, the government seed producing agency, TOSCA, has proved unresponsive to the needs of bean growers. All this has posed significant challenges in making new varieties widely available to farmers in both countries. In Malaŵi, a number of donor organizations and NGOs recently have established seed multiplication programs, but in Tanzania, this has not occurred and few viable channels for bean seed multiplication and dissemination exist. Recent CRSP studies in Tanzania (Gemignani) indicate that relatively little seed sharing takes place among farmers, so farmer-to-farmer transmission of improved varieties is slow to occur.

4. Market studies have been initiated. CRSP research has examined the impact of market liberalization on the bean market sector. In Tanzania, studies were undertaken in 1997-99 by Kashuliza and Silumba in Arusha, Kilimanjaro, Mwanza, Kagera, Kigoma and Mbeya involving 400 traders, 200 consumers and 110 farmers. The study revealed that beans are playing a more important role in the cash economy than they did prior to liberalization. Market liberalization had promoted the following changes:

    a. An increase in the number of bean varieties traded. Different varieties cater to varying demands including those of local consumers, distant markets, cross border trade and export markets.

    b. Price differences between local and distant markets—Farm gate and general market prices are increasingly differentiated by bean variety, size, quality and distance for place of production. Beans traded across borders appear to generate higher prices than those traded locally or at distant markets within the country.

    c. Growing consumption of beans—results of the study of consumers indicate that in recent years bean consumption has increased. This is especially true as real income has declined making it difficult for many families to buy meat, chicken or fish. The study suggests that the volume of beans traded within the country and across borders has grown considerably in recent years.

    d. Rise in bean trading among women. While men dominate in secondary, wholesale and interregional trade, more women appear to have entered local markets as traders. As a consequence of economic changes, more women have taken up jobs as fast food vendors on streets selling beans with rice or maize meal.

Ph.D. research by Gemignani from 1997-99 focused on the impact of economic liberalization policies on women farmers. The study, which currently is being written up, examined opportunities and barriers faced by women in accessing resources related to bean production and trading.

In Malaŵi, research has also focused on bean markets. The surveys have indicated that bean markets are the second most important source of seed for small-scale farmers. In 1996-97, 240 bean vendors in 40 markets in Southern, Central and Northern Regions of the country were interviewed. Information was gathered on socioeconomic characteristics of the vendors, characteristics of the markets, and vendor bean purchasing, selling and storing practices. In addition, 400 bean samples were collected from these markets. The study revealed that most bean seed bought in local markets is heavily infected by two or more of the seed bourne pathogens. At the national level, halo blight ranked first, followed by BCMV, common bacterial blight and angular leaf spot in that order.

This study was followed by a survey of on-farm seed handling practices in which 192 farmers from all major bean growing Agricultural Development Districts participated. Reflecting the importance of beans in the local economy, 33 percent reported that beans provided the major source of cash for their family. Fifty-five percent sold half or more of the beans they grew and retained the reminder for household consumption and seed. The most commonly used market outlet for sale of beans was local markets (31 percent of those interviewed), although private traders were reported to offer the highest prices.

The study revealed women farmers' centrality in seed handling and selection. Forty-seven percent of those interviewed reported that women were solely responsible for bean seed selection and held the sole responsibility for sorting. Fifty-one percent said that women were solely responsible for storing seeds while seventy-nine percent stated that the major source of their planting stock came from beans they had grown on their farm. This indicated that measures to improve seed quality should focus on-farm. Forty-one percent indicated that they produced most of their seed during the rainy season, the time when disease pressure is often high in fields. Thirty-one percent produced the majority of their planting stock in the relay season and nineteen percent in the dimba season, two seasons when disease pressure is reduced. The second most important source of bean seed was local markets.

5. Institutional and human capacity building through training has been a major activity of the CRSP. However, to date, there are very few agricultural researchers who are thinking through the implications of AIDS for agricultural production. This is one of the pressing challenges for the future. At this point, it is clear that the epidemic has direct implications for CRSP research in at least three ways:

   a. It is changing labor supply availability and patterns on farms and in households and may result in changes in crops planted.

   b. It affects the transmission of agricultural knowledge of all sorts (both scientific and indigenous).

   c. It is increasing the need to train more researchers and to work more collaboratively with farmers and consumers.

Since its inception, the East Africa Regional Project has had a significant impact on Bunda College and Sokoine University. The impact is both in terms of number of professionals trained and in providing sustained research funds which help support the two largest and best trained bean research teams in the region.

<u>Publications</u>
None reported

SEED MULTIPLICATION, DISSEMINATION, QUALITY AND ACCEPTANCE

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Presented by Alex Mkandawire

Governments in the region noted some 30 years ago that the disparity between food production and population increases in Africa south of the Sahara was ever-widening with a resultant decrease in *per capita* food consumption. Due to population increase, land availability was declining. The best approach to increasing food production was, therefore, to increase crop yields rather than acreage. But farmers were growing mostly their own traditional varieties, which are low yielding. Some high yielding varieties had been released but were not available to farmers. As a result *quasi*-government seed companies were established in Malaŵi (National Seed Company of Malaŵi, NSCM) and Tanzania (TANSEED). After a few years of operation, these companies abandoned their self-pollinating crop seed enterprises citing poor profitability. As a result, low adoption of recommended technologies for beans still remains a major problem in the region despite the development of new high yielding varieties. Such barriers to seed dissemination are a major constraint to impact from CRSP programs. The Bean/Cowpea CRSP East Africa Regional Project, therefore, embarked on development of locations and means to multiply and disseminate basic and foundation seed of improved varieties.

Earlier studies at Bunda indicated that growing beans in Malaŵi during the hot dry season acts as a filtration process of seedborne diseases except viruses. As a result, the program embarked on increasing breeders' seed under irrigation on campus. In each of the past five years, breeders' seed has been increased to supply basic seed. At SUA, basic seed is also produced similarly. During the past five years, the Malaŵi/Bunda team multiplied basic seed of Kalima (released 1993) on about 5 ha in each year to produce foundation seed. This seed was sold to NGOs, e.g., ActionAid and Self-Help Development International, and to the Ministry of Agriculture for demonstrations. In Tanzania, the bean seed distribution system is significantly different from that in Malaŵi. Until recently, bean seed was produced exclusively on government farms with little seed being produced or reaching the farmer. As the shortcomings of the official Ministry of Agriculture multiplication and dissemination stations become apparent and as market liberalization has progressed, more decentralized seed production systems are developing.

Barriers to seed dissemination result because of a number of socioeconomic constraints. Poor distribution of inputs and produce in the region results from the poor infrastructure that exists. The road/bridge network is so vulnerable that vast areas are inaccessible, particularly during the rainy season. Markets are not adequately established. The *quasi*-government marketing organizations have better networks of markets but are poorly organized. They offer the farmers the lowest prices and generally do not have ready cash to offer the farmer when the crop is ready for sale. Entrepreneurs are coming into the system due to market liberalization. They may have ready cash and transport but lack necessary knowledge to handle seeds differently from other inputs and produce. In many instances, farmers are not organized into groups or cooperative societies, which are powerful bodies that would assist them do combined efforts to break through the barriers of the marketing systems. In Malaŵi, the credits system broke down as the country changed from dictatorship to a plural society.

It has been realized that small-scale bean farmers: (a) will buy bean seed and not just rely on their own stocks, (b) can afford to buy seed of new varieties, and (c) do not function efficiently as the major agent of varietal diffusion. Non-governmental organizations (NGOs) are increasingly filling a niche in seed dissemination activities and thereby providing temporary solutions to the barriers expressed previously and to facilitate farmers' capabilities for seed production. Their usual goals are food security and poverty alleviation. Malaŵi has a greater profusion of NGOs because of its burden of Mozambican refugees in the 80s and 90s. These NGOs have stayed even after most refugees were repatriated. In general, these NGOs operate two types of seed schemes; viz.: commercially-oriented schemes where a few farmers purchase more seed to produce seed for sale and; the food security-oriented schemes where more farmers are given less seed on credit to produce seed or grain for the market or food. The former crop is certified whereas the latter is hardly inspected but the seed is "approved." Approved seed is that seed which is produced either from certified or known stocks of uncertified seed. Seeds of this category do not necessarily carry a government seal but have to pass seed standards for purity and germination. This has facilitated the operations of many NGOs in seed multiplication and dissemination in Malaŵi (see papers by Anne Ferguson and Charles Masangano).

For Malaŵi, two organizations involved in seed distribution are the focus. The first is an NGO (ActionAid) that has a food security-oriented seed scheme. ActionAid developed a "Malaŵi Smallholder Seed Development Project, MSSDP" after a flood disaster in 1992 when 1.1 million households benefitted from 3,000 tons of relief seed issues. The objectives of this project are to: (a) develop low cost mechanisms, which would improve and sustain availability and accessibility of appropriate, improved seed for resource poor farmers in participating communities, (b) establish sustainable self-motivating community based groups, which will manage seed multiplication and distribution in the communities, and (c) train selected extension staff and participating community groups in seed production, seed quality control, on-farm seed selection and storage, group dynamics and community participatory methodologies. In 1998, a total of 3.6 tons of certified bean seed was supplied and made available to 76 groups with a total membership of 1500, who in turn multiplied more than 12 tons of first generation approved bean seed. About 75 percent of this seed was improved Kalima and Nasaka from the CRSP.

An example of the commercially-oriented seed scheme is that operated by the Maize Productivity Task Force, formed in Malaŵi in 1995, with the aim of increasing agricultural productivity. Its Action Group Two, one of four groups, was set up to increase availability of seeds of self-pollinating and open pollinated crop varieties, which are neglected by the large multilateral seed companies. Funded by the European Union, this group embarked on seed production and marketing as a business. The major activities of this group are: (a) technology promotion through demonstrations, radio programs and field days; (b) training of extension staff and seed growers in seed production techniques; (c) organization of farmers through establishment of farmer associations; and (d) seed production. In 1998/99 season, there were 109 farmers growing seed beans on 28ha producing 24 tons of seed.

The CRSP project in Tanzania released SUA90 and Rojo. These varieties have been introduced into some selected farming communities in the country. The areas where they are currently grown and marketed include Morogoro and Kilosa districts of Morogoro region, Kongwa district of Dodoma region and some areas of Tanga and Arusha regions. Seed of Rojo was recently produced at SUA, Tanzania and was purposely disseminated through two NGOs, viz.: LVIA (Lay Volunteers International Agency) and CCT (Christian Council of Tanzania) and through the CRSP project. The CRSP project distributed the seed to Kongwa, Kisanga and Msolwa villages in addition to farmers in Maharaka and Msongozi, Muhenda and Ulaya-Mbuyuni villages of Morogoro and Kilosa districts. LVIA selected participating farmers based on their willingness to engage in seed production and on financial ability to start seed production. For SUA, attention to gender issues and education were major criteria. CCT selected progressive and innovative farmers in terms of knowledge on improved agricultural production. Notable among the results is the fact that smallholder farmers are willing to purchase foundation seed. However, seed demand and marketing issues are clearly not addressed. Farmers were unable to sell their seed within their villages and thus had to sell it as cheap grain. Adequate extension is lacking. The majority of farmers are still unaware of the new seed. LVIA provided its own extension staff and farmers under their scheme were more knowledgeable. Seed promotion activities also worked better for farmers under their scheme. A general recommendation was that successful seed producers are those more financially endowed and that these are the farmers to be targeted in future.

Publications

Kambewa, P. 1999. *An Institutional Analysis of the Smallholder Legume Seed Multiplication Schemes in Malaŵi*. Ph.D. Dissertation, Michigan State University, East Lansing.

Mtenga, K. 1999. *Public and Private Sector Models for Encouraging Smallholders' Seed Production*. M.Sc. Thesis, Sokoine University of Agriculture, Morogoro, Tanzania.

EXTENSION TRAINING, PUBLICATIONS AND WORKSHOPS

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Presented by Charles Masangano

Extension training, publications and workshops are a necessity if the Bean/Cowpea CRSP is to show impact. The research outputs of the program have to be communicated to its clients if they are to use them. Clients of the program include farmers, extension people, researchers, governments and donors. To reach these groups of clients, the Bean/Cowpea CRSP needs to use a number of approaches including extension training, workshops and publications. This paper briefly outlines some of the means that the East Africa Regional Project has used to communicate its research outputs to its clients.

Agricultural extension in both Malaŵi and Tanzania is the responsibility of the Ministries of Agriculture. Both countries use the training and visit system where emphasis is put on the following principles:

1. Extension workers should be regularly trained to enhance their professional capacity.

2. Extension system must be maintained under a single line of both technical as well as administrative command. While support is required from other organizations such as teaching and research institutions, credit and input supply as well as marketing organization, the extension staff must fully be responsible technically as well as administratively to one department of the Ministry of Agriculture.

3. Extension staff must only concentrate on duties related to extension so that extension has impact on agricultural productivity. Other activities such as credit and input distribution should be implemented by other organizations.

4. Messages and skills must be taught to farmers in a regular and timely fashion so that farmers can make best use of resources at their command. Extension workers are also supposed to maintain a regular and time- fixed visitation schedule to farmers. This schedule should be well known to farmers so that they make themselves available every time the extension worker visits them.

5. The whole extension system must have a farmer and field orientation. To serve farmers more effectively, the extension service must be in contact with them on a regular basis. The extension workers must ensure they contact a large number of farmers representing all major farming and socioeconomic types. Farmers served by the extension worker must be divided into groups and each group must be visited on a fixed day once every two weeks. Other extension workers including supervisors and subject matter specialists must also spend a large part of their time in farmer's fields, on regularly scheduled visits. Researchers must visit the field often and regularly to understand problems faced by farmers and village extension workers.

6. Demonstrations should be used as much as possible in transferring technologies to farmers.

7. A strong linkage must be maintained among research, extension and farmers.

The extension worker is supposed to sub-divide his/her working area into eight sub-sections which are called blocks in the case of Malaŵi. Each sub-section is supposed to have a demonstration site where the crops grown in the area are demonstrated. The extension worker is supposed to visit and meet farmers in each sub-section at least once every two weeks. Farmer training in these visits should, as much as possible, be conducted through demonstration. The recommended number of farmers per extension worker is a maximum of 850. However, the actual average number of farmers per extension worker in both countries is in excess of 1500. It is therefore, very difficult for the extension workers to adequately cover these farmers in their visits to the sub-sections.

Usually, the extension worker meets less than 30 farmers on each visit. This represents a coverage of less than 30 percent. To increase this coverage, extension workers are encouraged to have at least five contact farmers per sub-section. The extension worker is required to conduct additional demonstrations on fields of these contact farmers; and that other farmers from the close by fields should be invited to those demonstrations.

The extension workers are supposed to attend fortnightly training sessions conducted by their supervisors and subject matter specialists. These training sessions equip the extension workers with the technologies which they are expected to teach farmers in the next fortnight. These training sessions are supposed to, as much as possible, be conducted through demonstrations. This means that the supervisors are also required to maintain a demonstration centre at their offices. These demonstration facilities are supposed to demonstrate all the crops and livestock enterprises in the area. The extension system is also supported by farmer training centres which have facilities for farmer training on a residential basis. The residential training centers are also required to have demonstration facilities where all the crops and livestock enterprises are demonstrated.

The Bean/Cowpea CRSP East African Regional Project will introduce its bean varieties in some of these demonstrations especially at the extension planning area (EPA) level (the supervisory level) and residential training centre (RTC) level. This will ensure that the program materials are introduced to the extension workers and to some of the farmers who have opportunity to visit the centers. The farmer's field school is also being introduced on a limited scale as an extension approach in Malaŵi and this provides another opportunity to introduce the CRSP materials to farmers. Field days are going to be used to supplement the demonstrations.

One problem which the government extension programs have been suffering from is reduced funding. Government departments in both countries have of late been experiencing reduced allocations and extension has not been an exception. This has resulted in scaling down their activities. Instead, there has been increased participation in extension activities by NGOs especially in Malaŵi. NGOs are getting more funding from donors and therefore tend to be more financially viable than the government departments. The program has, therefore, been using NGOs to introduce bean varieties from the CRSP. This has mostly involved multiplication of the bean varieties through the NGOs smallholder seed multiplication programs. This has involved some level of extension training to the farmers especially in seed multiplication techniques. In Tanzania, some farmers have directly been trained by CRSP staff in seed multiplication and these farmers have been involved in multiplying some of the varieties like Rojo and SUA 90 (see papers by Alex Mkandawire and Anne Ferguson).

A number of courses for extension staff and a limited number of research field assistants were also conducted in Karonga, Lilongwe, Machinga, Blantyre and Shire Valley Agricultural Development Divisions (ADDs) of Malaŵi. The main objective was to acquaint staff on identification of bean bruchids and their damage to beans. A field guide on pests, diseases and nutritional disorders of common bean in Africa was distributed to the participants of these courses. More courses are expected in the areas where these courses have not been conducted. Two workshops have been conducted in the region. One workshop was aimed at mapping strategies for implementation of the current extension scheme as well as sharing some of the achievements made by the CRSP program. The second workshop was aimed at promoting bean entrepreneurship in the region. This workshop drew people from the Extension Department including all the ADDs in Malaŵi, the Agricultural Research Department in Malaŵi, parastatal organizations working in the small business enterprise development sector and NGOs interested in promoting bean production. Both Malaŵi and Tanzania CRSP teams attended and presented some of their research outputs at the workshops.

The region also plans to conduct two more workshops this year. One of the workshops is for selected non-governmental organizations which are taking an active role in providing agricultural extension services to farmers in the region. The two main objectives of this workshop will be to:

1. Encourage those non-governmental organizations to promote CRSP technologies to farmers in their extension activities. They will be provided with information regarding the various bean varieties released through the program and various bean technologies and recommendations.

2. The other objective of the workshop will be to promote an understanding among the NGOs of the importance of maintaining bean genetic diversity at the farmer's level. Most of the NGOs tend to have one specific objective in their extension activities and this objective is to increase agricultural production for self-sufficiency in food and increased incomes. In order to achieve this objective, they have tended to promote varieties which increase farmers' yields without due consideration of other objectives which farmers tend to have. Generally, farmers in both Malaŵi and Tanzania tend to have multiple objectives for their farming activities. These objectives include:

   a. Adequate supply of food throughout the year. In this regard, beans have played a very important role of providing for the lean months. Those varieties which mature early tend to be available at a time when the farming households are running low in their food reserves. These beans become a major source of food at such times and for such purposes, it doesn't matter whether the bean is low yielding so long as it answers this important need.

   b. The studies show that palatability is another very important objective which farmers use for choosing their varieties. A good example of this is the popularity of Nasaka variety which is one of the early releases of the Bean/Cowpea CRSP program in Malaŵi. This variety is not very high yielding and tends to suffer from a lot of diseases. However, it is a very palatable variety and because of this, it is very highly demanded among farmers.

   c. Many farmers are also interested in a good leaf for making vegetables. Farmers, especially in Malaŵi, eat bean leaves as a vegetable together with their traditional Nsima (a thick porridge made from maize meal). Some of the bean varieties produce a better leaf for vegetable than others.

   d. Cookability is another characteristic farmers use for selecting a variety. With the increasing shortage of firewood which both Malaŵi and Tanzania are experiencing with the increasing problems of deforestation, farmers tend to choose varieties which cook faster and require less fuel wood when cooking.

   e. Attractiveness to buyers at local markets is another major characteristic which influence farmers' choices of bean varieties. It is therefore not possible to provide one bean variety which can satisfy all these multiple objectives which farmers have, and farmers themselves know this very well.

The above points illustrate why farmers have traditionally maintained more than one bean variety on their farms. Extension programs must take this into account and NGOs doing extension activities need to address this issue.

The second workshop will be for extension workers. Its main objective will be to acquaint them with the most commonly encountered bean diseases and pests in Malaŵi. The Bean/Cowpea CRSP's activities over the years has been able to identify most of the commonly encountered diseases and pests in Malaŵi. This information needs to be provided to the extension staff so that they can appropriately advise farmers when they experience such problems.

Publications

Some of the papers presented in the bean entrepreneurship workshop have been published in a Workshop Proceedings Report while a few others were selected for publication in a special issue of the *Malaŵi Journal of Science and Technology*. Another publication of common diseases of beans in Malaŵi is being published. This publication is intended to assist extension workers to easily identify bean diseases in the field and properly advise farmers. This publication will be used to support the extension workers workshop planned later this year.

Both Bunda College in Malaŵi and Sokoine University of Agriculture in Tanzania have been producing Annual Reports of the Bean/Cowpea CRSP Research programs in their institutions. These reports provide the major achievements as well as the recommended technologies coming out of those research works. These reports have been widely circulated to Ministries of Agriculture, the research community as well as extension staff.

LATIN AMERICA/CARIBBEAN REGIONAL PROJECT

VARIETY RELEASE, SUSTAINABLE SEED PRODUCTION, IMPROVED CROPPING SYSTEMS AND DISEASE MANAGEMENT FOR THE LOWLAND TROPICS

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Presented by Juan Carlos Rosas

The Latin America/Caribbean (LAC) Regional Project emphasizes the small red and black (Mesoamerican) types, which are two major bean market classes grown in this region. This report includes information on the achievements and impacts obtained from the activities carried out in variety development and release, sustainable seed production and improved cropping systems for the lowland tropics. Progress on management of the geminivirus/white fly complex (collaboration with the University of Wisconsin), socioeconomic studies from on-farm record keeping, seed production and distribution, and an assessment of the potential value of heat tolerant beans in the lowland tropics (collaboration with MSU) are presented in reports submitted by Drs. D. Maxwell and R. Bernsten.

Bean production in Central America is a small farm operation (i.e., more than 70 percent of the farms in Honduras are in this category). Most are on hillsides, in marginal areas, and are limited by biotic and abiotic constraints. The majority of bean producers utilize low inputs, very few are mechanized. Bean producers experience limited access to markets and credit. Automobile consumption is rather high; however, 55 percent of the beans are sold in markets primarily by intermediaries. Beans are the 7th most important crop in economic value in Honduras, and have the highest economic return among basic grain crops such as corn, rice and sorghum.

One of the most important accomplishments of the LAC Bean/Cowpea CRSP Project has been the integration of project activities into the regional bean network which includes 11 countries in Central America and the Caribbean. This achievement became possible when Zamorano and UPR became members of the PROFRIJOL Network and their PIs were assigned the task of improvement of small reds and Andean bean types grown in the region. Additionally, last year Zamorano assumed the responsibility of the improvement of black beans, one of the other major seed types in the region. Collaborators in Central America include the National Bean Programs (NBPs) from the member countries of PROFRIJOL, CIAT Bean Program, NGOs, the Mesoamerican Participatory Plant Breeding Group, U.S. and regional universities, and farmers groups.

Varietal development and release of improved varieties have been emphasized. Disease resistance and tolerance to abiotic stress germplasm from CIAT, USDA, U.S. universities and NBPs are continuously tested under local agroecological conditions and pathogen diversity using greenhouse and field techniques. A “quick and dirty approach” consisting of collecting infected material, preparing and spraying applications of it in water solutions is used to screen for resistance to angular leaf spot, anthracnose and rust. Otherwise, sites with good levels of infection of a specific disease (i.e., bean golden in Comayagua), or presence of an abiotic stress (i.e., low P), are used for this purpose. Single, double and multiple crosses are used to recombine specific or multiple traits into commercially accepted, agronomically adapted cultivars. Elite lines, improved varieties, landraces and specific sources of germplasm are used as progenitors when necessary. Pedigree, backcross, single seed descent, gamete and recurrent selection are used as breeding and selection methods for developing improved lines. Segregated and advanced populations are selected for multiple traits under disease pressure and abiotic stresses that are obtained by artificial inoculation or by utilizing several sites in Honduras and Central America. More than 60 small red breeding nurseries and trials are distributed every year to 10 member countries of the regional network. In 1999, the Adaptation Nursery (VIDAC) included 102 advanced lines and the Yield and Adaptation Trial (ECAR) 14 lines and two checks; Zamorano and the UPR programs contributed over 90 percent of the lines included in both VIDAC and ECAR. Every year new advanced lines are incorporated to replace the 40-60 percent inferior lines.

Lines already released, or in process, include Tio Canela-75 (Honduras, Nicaragua, El Salvador and Panama) and MD 23-24 (Costa Rica). Among those lines being validated in farmer fields prior to their release are: SRC1-12-1 (Costa Rica, El Salvador and Honduras), SRC1-3-5, UPR9609-22-2 (Nicaragua) and Tio Canela-75 (Haiti). Several sources of germplasm have been developed or selected in collaboration with researchers from the LAC Project and CIAT. Improved lines that recombine heat tolerance and resistance to bean golden mosaic with excellent agronomic and commercial small red seed types have been developed for production at lowland regions and/or warmer tropical seasons. Small red lines are used as sources of bean golden mosaic resistant genes (especially *bgm-1*) for improving Andean and other Mesoamerican types. Resistant germplasm for bacterial blight, rust, angular leaf spot, and low fertility have been identified for improving small reds and blacks for the region. Anthracnose resistant lines derived from Andean and Mesoamerican sources have been identified and are used as additional resistant genes with the exception of the source of Co-6 gene (Catrachita), which has shown susceptibility the last two years in Honduras. Web blight resistant lines, with excellent architectural traits derived from crosses of elite lines x 2-4 resistant parents, have been identified for testing in the north coastal, humid region of Honduras, Panama and Puerto Rico. Good N2-fixing small red varieties (Dorado, Tio Canela-75 and Yeguare) were identified in low N soils, *Rhizobium* inoculated trials. Inoculant is being produced in the region using *Rhizobium* strains selected across environments.

A second emphasis has been placed on improved cropping systems. The focus of this research is on the utilization of management practices and improved varieties for higher and more stable yields and natural resources conservation. Recent information on the performance of improved varieties under diverse cropping systems include 32 percent yield increase using Tio Canela-75 over farmer varieties at 20 sites in El Salvador. MD 23-24 has shown more than 20 percent yield superiority and a better response to management practices to reduce web blight incidence in Costa Rica. The small red line SRC1-12-1 has been the best for two consecutive years at the ECAR trial conducted in more than 15 locations in Central America and the Caribbean. In Nicaragua, TC-75 has been selected for best adaptation to dry, poor soil conditions; the line SRC1-5-3 as the best material for humid regions; and the line UPR9609-22-2 for the “apante” (residual moisture) cropping season. The use of *Rhizobium* inoculant resulted in an increase in yield of 20 percent in Nicaragua and El Salvador. An adoption study is being conducted in Nicaragua to determine the potential of this technology to increase productivity in beans. Inoculation studies indicate high rates of marginal return from this technology.

Integrated management of bean golden mosaic using an improved variety (Tio Canela-75), maize barriers, and yellow sticky traps resulted in 52 percent yield increase over the local susceptible cultivar in El Salvador. The estimated reduction on pesticide application for white fly control was 50 percent or higher. In Honduras, weed control efficiency was increased using Tio Canela-75 vs. the local cultivar. The erect architecture of Tio Canela-75 facilitates hoeing or herbicide application; the prostrate habit of the local variety obligates farmers to avoid entrance to the field to control weeds at a very early stage of development. A more effective control of pod weevil is obtained with Tio Canela-75, or other improved variety, due to better resistance and more uniform, short flowering duration. The results are two applications of a specific insecticide on Tio Canela-75 vs. 5-6 applications of a wide spectrum, highly toxic product (parathion) regularly used by farmers to control this pest in their non-uniform, long flowering landraces. Extracts and baits from other local plants (*Gliricidia*, *Jatropha*, neem and hot pepper) and soaps are being tested as alternative products to control pod weevils and slugs.

The potential value of heat tolerant, bean golden mosaic resistant lines in non-traditional production areas (Pacific and Atlantic coastal regions of Central America) and warmer seasons, is being studied in El Salvador and Honduras. A socioeconomic study on the value of these materials for bean production in the north coast of Honduras suggested a potential increase in production during the warm season, and a greater, more stable bean supply during a more extended period throughout the year.

Seed production and distribution have received major attention as well. The project is assisting several NGOs and farmer groups to produce artisan seed for local distribution. Foundation seed of improved varieties, and training on crop management, post-harvest processing, and marketing of artisan seed are provided to farmers and NGO extensionists. Collaborations with the Seeds of Hope/CGIAR Project in Honduras and Nicaragua, PROMESA/USAID and UPANIC (national farmer association) from Nicaragua, CENTA/MAG from El Salvador, and NGOs and CIALs (farmers agricultural research committees) in Honduras, are part of these activities.

In 1999 in response to Hurricane Mitch, the project coordinated the distribution of seed of Tio Canela-75 and Dorado 10 lb-bag units. The seed, produced by Zamorano Seed unit, was distributed to more than 21,000 farmers throughout Honduras and some regions in Nicaragua in collaboration with more than 40 NGOs. Farmers utilized the seed in the *primera* planting to produce enough seed for their *postrera* (major season) planting. USAID/Honduras, the DFID/Great Britain and Healing Hands International supported this emergency relief project. Currently, the project is participating in a two year (2000-01) Post-Mitch Project funded by USAID to revitalize the Honduran agricultural sector. The bean component of this project is targeting 4,000 families from the East-central and Northeastern regions (together accounting for more than 50 percent bean production), based on training and technology transfer on field production, post-harvest, added value and marketing. The project includes the distribution of seed of Tio Canela-75 and Dorado, and on-farm testing of new materials such as SRC1-12-1. This Post-Mitch Project is carried out in collaboration with 12 NGOs.

In upcoming years, the project will continue to work on varietal development of multiple disease resistant small red and black bean lines, with special emphasis on resistance to angular leaf spot and web blight, the incorporation of the *bgm-1* bean golden resistant gene into a larger number of black breeding lines and cultivars, and the development of breeding lines carrying the *bc3* recessive, bean common resistant gene. A greater effort to incorporate resistance to pod weevil and leafhoppers will be made. Efforts to identify alternative sources of drought tolerance by a closer collaboration with other CIAT and LAC researchers will be conducted. CIAT sources of tolerance to low fertility validated in the region will be used more frequently in the hybridization program. A greater effort to improve black beans for the lowland tropics will be made; for this purpose, collaboration with the NBPs from Costa Rica, Guatemala, Haiti and the Mexican lowlands will be emphasized.

Integrated approaches to manage biotic and abiotic constraints on predominant bean cropping systems, including soil and water conservation, will be applied in collaboration with CIAT/Hillside program, NBPs, NGOs and farmer groups. Collaboration with projects that specialized in designing equipment and transferring technology based on the use of animal traction for steep hillside agriculture will be increased. Technology for *Rhizobium* and mycorrhiza inoculation will be tested and validated. Artisan seed production initiatives will be reinforced by providing foundation seed and training and technology assistance to improve farmer production, processing, storage and marketing skills. Participatory research approaches, including participatory plant breeding, are being applied to increase farmer groups and NGOs influence on research decisions.

Training activities will focus on various aspects of artisan production with NGOs and farmers. Training on the management of breeding nurseries and trials, participatory research, socioeconomic (adoption and impact) studies, and molecular applications for bean breeding will be offered to NGOs and NBPs personnel. Institutional linkages and collaboration will support regional network activities; continue breeding nurseries and trials, as well as supply seed stocks for validation and release trials. Strong interactions with the NBPs and PROFRIJOL will be needed. Efforts will be made to maintain a network of NGOs collaborating with Zamorano, and with CIALs and other farmer groups from Honduras; access to seed stocks and training and technical assistance is necessary. Resources from the Post-Mitch USAID Project will be used for these purposes. Collaboration within the Bean/Cowpea CRSP and with CIAT, USDA, universities and NGOs will be strengthened.

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VARIETY RELEASE, SUSTAINABLE SEED PRODUCTION, IMPROVED CROPPING SYSTEMS AND DISEASE MANAGEMENT FOR THE LOWLAND TROPICS

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Presented by Eladio Arnaud-Santana

The Bean/Cowpea CRSP research in the Dominican Republic (DR) has enabled farmers to sustain bean production in spite of severe pest and disease epidemics, unstable government policies and a changing global economy. In addition, it has provided genetic materials, technological packages and professional expertise to other bean programs in the LAC region. One goal of this component of the regional project has been to integrate lowland cultural practices and improved varieties to manage diseases and pests of dry beans with a minimum input of pesticides and the efficient use of land and water. During the past two years, we have also identified farm practices (land preparation, seeding and harvest) that reduce costs of production and maximize yield potential.

The DR presented a unique case in the region where CRSP researchers were given the leadership from 1992-96 to effect changes in government policies related to planting dates and the introduction of a fallow period to manage the whitefly-bean golden mosaic complex. The implementation of the combination of practices by farmers in all of the bean growing areas in the DR contributed to the sustainability of bean production at a time when bean golden mosaic was causing up to 100 percent losses elsewhere in the LAC region. The first step consisted of establishing only one planting season in the different cropping areas. Second, the enforcement of a three month quarantine period prior to the bean planting time, during which no crop or plant host of the bean golden mosaic virus and its vector, the whitefly (*Bemisia tabaci*), could be planted. Third, a specific date of dry bean planting was established within the cropping season. This was determined on the basis of the environmental conditions favoring crop development and negatively affecting the white fly vector population. The fourth, and also an important step, was the continuous observation of bean fields where infected plants were rogued and limited applications of insecticides were used to control whitefly.

The CRSP team in the DR has released nine bean varieties: PC-50, JB-178, CIAS-95, Saladin-97 (red mottled beans), Anacaona, Arroyo Loro #1 (white beans), Arroyo Loro Negro, Negro Cibao and Negro Sureño (black beans). The first seven are being planted by farmers around the country, especially the varieties PC-50, JB-178 and Arroyo Loro Negro. All of the released varieties have good seed quality, out yield the commercial land races, and possess varying levels of resistance to common bacterial blight, web blight, rust and other fungal diseases. These varieties perform well under drought stress and also respond well to fertilization, making them attractive for both small and medium landholders. These bean varieties have made a contribution not only to the DR bean program, but also to other bean programs in Haiti, Nicaragua and Guatemala where varieties are used for commercial purposes or for parental crosses.

Phenotypic data were collected in the DR for reactions to the web blight fungus and common bacterial blight (and the small pustule type of rust detected in Nebraska). Based on these data, QTLs (nine genes) for resistance to these pathogens were mapped using recombinant inbred lines of the cross BAC6 (Brazil) x HT7719 (CIAT). This research has increased our knowledge about clustering genes for resistance and for use in breeding.

The CRSP project began to utilize a participatory research program in 1992. Initially, a series of workshops were conducted with bean growers to identify the major problems affecting bean production and how these constraints could be solved. When new knowledge and technology were developed they were transferred for use in the production system by means of: (a) field days organized by farmer associations, (b) workshops organized by the CRSP scientists in conjunction with farmer groups, (c) 13 crop and disease management brochures and six variety release pamphlets published and distributed by the CRSP technical staff,

(d) Information delivered by radio, and (e) demonstration plots grown on farmers' land. Similar activities were conducted with women's groups.

During the past two planting seasons, CRSP researchers have shown that by using appropriate technologies and adequate resource management it was possible to reduce production costs by 30-35 percent, and to improve total bean production and seed quality. Cost benefits include reducing planting density, using better weed control, and controlling disease and insect attacks by integrated management (including reduction in number of pesticide applications and use of proper pesticide and timing of application). These costs could be reduced further if the planting and harvest operations were mechanized with equipment appropriate for small landholders. In the past planting season (1999-2000), selected bean growers who used these management strategies were able to increase production by about 40 percent compared to their neighbors. Their cost of production was approximately US $875 dollar/hectare (US $350/acre) which is competitive with cost of bean production in irrigated areas of the U.S.A.

Presented by Graciela Godoy-Lutz

Studies on the epidemiology and genetics of the pathogens that cause web blight and rust have contributed to the development of disease resistance and other disease management strategies. Web blight of dry bean is a yield-limiting disease found throughout the LAC region. PROFRIJOL scientists reported losses due to foliage and seed damage from web blight up to U.S. $7.1 million in El Salvador and on 19 percent of total bean acreage in Honduras in 1993.

Research on web blight was initiated by CRSP research scientists in the early 1990s after CIAT scientists reduced their research activities on this disease. A better understanding of the genetics of the WB pathogen *Thanatephorus cucumeris*, (which is an aerial form of *Rhizoctonia solani*), have been obtained through traditional and molecular methods. Isolates from Puerto Rico, Dominican Republic, Honduras, El Salvador, Costa Rica, Nicaragua, Panama, Cuba and Argentina were examined and characterized into five distinct polymorphic groups which cause the same disease, but differ in virulence. Thus, screening for web blight resistance will be more successful with appropriate selection of isolates.

Epidemiological studies on the web blight pathogen indicated that, similar to other diseases caused by aerial isolates of *Rhizoctonia*, soil populations do not correlate with levels of incidence and severity of disease. Fungus inoculum (basidiospores, micro- and macro sclerotia and mycelia) is located primarily in the aerial portion of plants. Therefore, management practices should concentrate on reducing aerial dissemination and modifying canopy microclimate to promote disease escape. Before 1990, studies of the pathogen in Central America were aimed at reducing the soil population, but little or no improvement in disease control was found. Pathogen isolates also have been found to be independent populations (no clonal relationship) distributed among the bean growing zones within each country. Virulence, fungicide resistance and optimal growth temperature vary in these populations. This variation contributes to wide ecological adaptation of the pathogen. The web blight pathogen causes seed coat blemish discoloration in all bean types. The fungus also can be transmitted in both symptomatic and asymptomatic seed. If infection occurs at the pod maturation stage, losses of 50-60 percent, due to seed blemish and reduced seed weight, can occur. Seed blemish or discoloration accounts for more than 50 percent of marketable seed loss. The new information on the genetic variability and epidemiology of the pathogen has led to improved disease screening techniques, breeding for architectural traits that avoid aerial disease development, an increased awareness of the need for clean seed and a search for new sources of resistance such as in *P. coccineus*.

In the DR, changes in planting dates have reduced web blight incidence in the South West. Arroyo Loro Negro and red mottled varieties being developed with web blight resistance will contribute to a reduction of the disease in other DR bean growing areas and other countries in the LAC region.

Rust on dry beans is another yield-limiting disease that is widespread in the LAC region and throughout the world. In the early 1990s, outbreaks of rust were found on PC-50 and red mottled land races that had been resistant. This was caused by new emerging pathotypes highly virulent on bean genotypes of Andean origin. These Andean-specific pathotypes caused large pustules at earlier dates than non-specific pathotypes. Yield losses were estimated to have been in a range of 4 to 7 kg/ha per 1 percent disease severity increase on the partially resistant PC-50 and José Beta/host/susceptible, respectively. Farmer training programs reduced the use of systemic/contact fungicides entirely or to only one application after the rust outbreak. A mobile nursery was developed to monitor pathogenic changes in the field. More than 400 pathotypes have been identified from Africa and the Americas with over 140 in Honduras alone. Pathogen virulence patterns can be used to recommend resistance gene deployment. Identification of the role of leaf pubescence and adult plant resistance offers a horizontal resistance strategy to add durability to specific gene resistance deployment. A study of rust pathotypes on wild beans may address host/pathogen co-evolution and help predict rust pathogen virulence patterns. In the DR recently released red mottled varieties JB-178, CIAS 95 and Saladin 97 with partial rust resistance have shown susceptibility in the last two growing seasons. Due to the proximity of the San Juan Valley to bean regions in Haiti, we expect aggressive rust pathotypes to challenge beans in Haiti. Resistance genes effective against the new pathotypes are being incorporated into advanced breeding lines.

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GEMINIVIRUS CHARACTERIZATION, IPM, AND BEAN TRANSFORMATION

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Presented by Douglas P. Maxwell

Bean-infecting geminiviruses have caused major bean losses in South America, Central America, México, and the Caribbean Islands for nearly two decades, and more recently extensive losses have occurred in Southern Florida. Geminiviruses are ssDNA viruses and the ones infecting beans are transmitted by the whitefly (*Bemisia tabaci*). Various molecular methods were used to isolate full-length clones of both DNA-A and DNA-B for the geminiviruses from beans with golden mosaic symptoms collected in Brazil, Guatemala, the Dominican Republic, and México. Infectivity of these clones was determined by particle gun inoculation and all caused typical symptoms except the clones from beans collected in México which were non-infectious clones. Sequence analyses showed that three distinct geminiviruses were associated with these collections: *Bean golden mosaic virus* (BGMV) from Brazil, *Bean golden yellow mosaic virus* (BGYMV, previously designated BGMV type II) from Central American, the Caribbean Islands, and Southern México, and *Bean calico mosaic virus* (BCMoV) from Northern México. Bean dwarf mosaic virus, which does not cause golden mosaic symptoms, was also cloned and sequenced, and the full-length clones were infectious. In Costa Rica, *Tomato yellow mosaic virus* was associated with beans with golden mosaic symptoms. Recently, a new bean-infecting geminivirus has been detected in the southwestern part of Costa Rica and it is being characterized.

The use of pseudo recombinants among the DNA-A and DNA-B components of geminiviruses was found to be a useful means of helping to clarify the concept of a geminivirus species. In research with Dr. Gilbertson at the University of California, the intermolecular recombination of DNA from one component to the other was shown using pseudo recombinants between *Bean dwarf mosaic virus* and *Tomato mottle virus*. Subsequent detailed sequence analysis by others has shown that recombination between distinct geminivirus is an important mechanism for creating genetic diversity in geminiviruses.

Polymerase chain reaction and DNA hybridization methods were developed for the non-specific detection of whitefly-transmitted geminiviruses. Currently, specific PCR primers and DNA probes are being developed for six bean-infecting geminiviruses. Using these techniques, the genetic diversity of bean-infecting geminiviruses has been studied in the Caribbean Basin, Central America, and Brazil (Faria and Maxwell, 1999). All bean-infecting geminiviruses causing golden symptoms on beans in Central America and the Caribbean islands are BGYMV. In northern México, the main bean-infecting geminivirus is BCaMV, whereas in southwestern México, the geminivirus infecting beans is very similar to BGYMV. In Brazil, the main virus is BGMV (Faria and Maxwell, 1999).

Epidemiological studies have focused on evaluation of weeds with golden mosaic symptoms as possible sources of inoculum for bean-infecting geminiviruses. Extensive efforts to detect BGYMV in weeds in the Dominican Republic have failed, and we have concluded that beans are the primary source of inoculum. Consequently, a bean-free period was mandated by the Government in the Dominican Republic and the result has been greatly reduced losses from bean golden mosaic. Similar practices were implemented for management of *Tomato yellow leaf curl virus* (TYLCV), a geminivirus introduced in the Dominican Republic in the early 1990's from the Middle East, and tomato yields were returned to their original pre-TYLCV yields in two years (70 percent increase). New geminiviruses were characterized from *Leonurus sibiricus* from Brazil (Faria and Maxwell, 1999) *Calopogonium* sp. from Honduras and Costa Rica, *Rhynchosia minima* from Honduras, pigeon pea from Puerto Rico, *Sida* spp. from Honduras and Jamaica, *Macroptilium lathryroides* from Jamaica, and *Wissadula amplissima* from Jamaica (Roye et al., 1997). Additionally, efforts were initiated in Honduras and Costa Rica to develop a cropping system approach for management of geminiviruses in vegetables, which included beans. During this study, three tomato-infecting geminiviruses where characterized in Honduras and two in Costa Rica. Non-CRSP efforts have shown that there are at least seven different tomato-infecting geminiviruses in Central America and this complicates the development of vegetable cropping systems. Additionally, non-CRSP funding has allowed scientists in Costa Rica to characterize the geminiviruses in squash and papaya as being a new virus, *Squash yellow mottle virus.*

Studies of the functions of various ORFs of BGYMV from Guatemala (GT) have provided evidence for the role of the *rep* gene in replication, the *trap* gene in transactivation of the *cp* gene (Karkashian, 1998) and the *bc1* gene on DNA-B in symptom development. Transcript mapping identified major transcription initiation sites for the *cp* gene promoter, as well as for the *trap* and *rep* genes (Karkashian, 1998). A detailed analysis of the *cp* gene promoter was completed and the most important promoter sequences for transactivation by the Trap protein were identified (Karkashian, 1998). Transgenic beans with the *cp* gene of BGYMV-GT were engineered with the particle gun at Agracetus, Inc., Middleton, WI, and these beans expressed both herbicide resistance and GUS activity (the blue beans). Eight R_2 lines were exposed to viruliferous whiteflies in Puerto Rico and found to be susceptible. These lines expressed mRNA for the *cp* gene, but no coat protein was detected. Antisense constructions for *rep/trap/ac3* genes and *bc1* gene of BGMV from Brazil were engineered into beans at EMBRAPA, Brazil, and R_3 transgenic lines showed considerable resistance, when challenged by inoculation with high numbers of viruliferous whiteflies (Aragão et al., 1998). Transient assays with NT-1 tobacco suspension cells have shown that lethal mutants (single or multiple codon changes) in either the DNA-nicking motif or the NTP-binding motif of the *rep* gene of BGYMV-GT (Hanson and Maxwell, 1999) or BGMV-BR effectively inhibit the replication of the homologous geminivirus. Additional constructs with part of the *trap* and *ac3* genes broaden the effectiveness of these *rep* gene mutants against heterologous geminiviruses (Hanson and Maxwell, 1999). Most recently, collaborators at EMBRAPA, Brazil have engineered beans with *rep* gene mutants in the NTP-binding motif from BGMV-BR and plants from one R_2 plant were highly resistant. Similar constructions have been tested in transgenic tomatoes and resistant tomatoes obtained (Stout et al., 1997). Besides the particle gun, another method involving DNA electroporation is being evaluated for bean transformation at Michigan State University by Dr. R. Allison.

Besides research on geminiviruses, the etiology of amachamiento disease of beans was studied in Costa Rica. The main symptoms associated with this new disease are delayed and greatly reduced flowering and increased vegetative plant growth. Additionally, deformation and roughness of the foliage is sometimes evident. The symptoms increase over time in a field and it is thought that the pathogen is insect transmitted. Preliminary evident indicated that geminiviruses may be the cause of this disease but this has not been proven. Subsequent research has shown that several RNA viruses are associated with these diseased plants. These include *Cowpea chlorotic mottle virus*, *Cowpea mosaic virus*, and *Bean roguse mosaic virus*. Dr. F. Morales from CIAT has also reported that *Cowpea chlorotic mottle virus* is associated with these diseased beans.

In collaborative studies with scientists from Argentina, Dr. Ramírez has molecularly characterized a geminivirus associated with soybeans. A full-length DNA-A clone was obtained and partially sequenced. From the sequence analysis, it was determined that this was a whitefly-transmitted geminivirus. Studies are continuing on this new virus.

Training Activities: During the last three years, 3 Ph.D. students have received their degrees and over 15 scientists have received short-term training in geminivirus detection and characterization methods either at University of Costa Rica or the University of Wisconsin. Additionally, six undergraduate students at University of Wisconsin, two at EAP and two at the University of Costa Rica have completed research projects.

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VARIETY RELEASE, IMPROVED MANAGEMENT PRACTICES AND DROUGHT TOLERANCE FOR THE HIGHLANDS

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Presented by Jorgé Acosta Gallegos

In the semiarid highlands of the LAC region, drought is the main contributor to yield reduction in common beans. In these highlands, intermittent drought is common, while in the tropical lowlands, terminal drought is a problem since planting there is done towards the end of the rainy season. Other drought endemic regions are the Great Lakes in Africa and northeastern Brazil. Since CRSP research was initiated in México, the focus has been on the development of drought resistant bean cultivars for the highland areas. Lately emphasis has also been given to root-rot resistance and cooking time. Early efforts produced three improved cultivars, two of the Durango race (Pinto Villa and Bayo Victoria) and one interracial cultivar (Negro Durango). Of those, Pinto Villa has been very successful, mainly due to its drought resistance and high and stable yield. In 1998, it was estimated that Pinto Villa was grown in 150,000 ha in the state of Chihuahua and 80,000 ha in Durango. In the current grant period, new bean cultivars are being developed for regions other than the semiarid highlands, i.e., for the lowlands in the tropical black bean class.

In the semiarid highlands of México, the seed of Pinto Villa and other cultivars released by the CRSP are being distributed through a conventional system involving the production of certified seed and the re-use of seed for several generations. In this last category, the seed must be of good quality. A new system of non-conventional seed distribution was observed in 1999 in the state of Zacatecas. Farmers re-distribute seed of [for example] Pinto Villa in exchange for grain of Flor de Mayo, a higher prized bean. The popularity of the cultivars released by the CRSP has been enhanced by the establishment of large demonstration plots in farmer's fields in the main bean producing areas in the states of Chihuahua, Durango and Zacatecas. In those plots, field days are conducted towards the end of the growing cycle.

In addition to the demonstration plots, short training courses are offered to farmers. In 1999, such courses were given to more than 1,800 farmers in the state of Durango. In the state of Chihuahua, similar courses are given yearly to extension agents. In return, the agents establish and conduct demonstration plots with the cultivars released by the CRSP. A field day also takes place on those plots.

The strategy for developing new cultivars with drought resistance include the development of interracial populations derived from genetically distinct parental stocks, all of them possessing drought resistance. The hypothesis is that different genotypes may possess different traits/strategies to cope with drought. The traits that characterize drought-resistant cultivars in the semiarid highlands are indeterminate growth habit, earliness, high pod number and high harvest index under stress. Some of those drought resistant cultivars, i.e., Pinto Villa, display some morphological attributes that may be important under stress, such as low stomata number in the upper leaf surface, high stomata number in the lower surface, large number of structures on the leaf surface, i.e., trichomes, and relative high photosynthetic rate under stress. The opportunity to utilize secondary traits and molecular markers for selection after inheritance studies is going to be explored in the near future.

Progress has been made in identifying a number of genotypes from different origins that have above average yield under drought. In populations of Recombinant Inbred Lines (RILs) derived from drought resistant parents, we are looking for traits and mechanisms that confer superior adaptation to drought and then will determine the inheritance of those traits. Progress was possible due to:

1. Extensive characterization of germplasm from different gene pools.

2. Identification of drought resistant genotypes in different genetic backgrounds.

3. Identification of attributes that are related to yield under stress.

4. Collaborative research efforts with partners in the U.S.A., CIAT and advanced Mexican research institutions (CINVESTAV and UNAM).

5. Leverage of funds from the National Council for Science and Technology of México.

Resistance to root-rot pathogens is essential in drought stressed environments. Root-rot is a devastating disease in the highlands of México and in other areas of the world. This problem is due to a lack of crop rotation, i.e., beans being planted in consecutive years in the same field, and to climatic conditions that are favorable for the development of causal agents. In 1999, 15 root-rot resistant bean genotypes from different origins, including a wild population, were challenged with local isolates of *Rhizoctonia solani* and *Fusarium solani* under field and greenhouse conditions. In the field, *R. solani* caused larger damage in the V3 stage, while *F. solani* did in the R5 stage, there seems to be a succession in the aggressiveness of those pathogens in the field, probably related to changing climatic conditions and/or genotype susceptibility throughout the season. In the field, Wisconsin RRR was resistant to *R. solani* in the V3, R7 and R8 growth stages, while some other genotypes were resistant only in the R7 and R8 grown stages. In the case of *F. solani*, genotypes Negro Cotaxtla 91 and P1203958 showed the least damage during the growing cycle.

The same 15 genotypes will be tested in the lowlands in a Macrophomina phaseolina (Mp) infested field and in the greenhouse. Mp is the main root-rot causing agent in the lowlands.

In regard to quality, and in order to offer better bean products to consumers, cooking time and other quality traits are being characterized in the parental stocks and advanced lines grown under stress and non-stress. Genotype characterization is delayed to advanced generations due to intermediate heritability of cooking time and to significant environmental effects on this trait. The quality of superior genotypes is reduced by environmental stresses, while those with average and poor quality, is not. Since there is a significant negative association between seed water uptake capacity and cooking time, this character is being utilized in intermediate generations to screen for cooking time. Genotypes with low water uptake capacity are discarded. Usually this is in the order of 50 percent of the populations being tested. The risk of discarding genotypes with short cooking time has varied among different trials between 2 to 4 percent. For example, a trait that has shown an important negative relationship with water uptake capacity is the structure and composition of the seed coat.

Improved drought resistant germplasm has been shared with other collaborators in the CRSP LAC Regional Project as well as with the East Africa Regional Project, and other institutions.

The technologies for bean production in drought stressed environments, developed so far, have been extensively adopted in the drought prone areas of México. CRSP scientists are now ready to transfer these technologies to farmers in other countries and to collaborate in the development of even better technologies.

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IMPROVED BNF, DISEASE RESISTANCE AND SOIL CONSERVATION, MANAGEMENT AND FERTILIZATION PRACTICES FOR THE HIGHLANDS

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Presented by Peter Graham

This research activity in the LAC Regional Project seeks enhanced nitrogen (N_2) fixation and crop production of *Phaseolus vulgaris* grown under low input conditions in the Andean highlands. *Phaseolus vulgaris* in the Andean highland region is a crop often grown under small farmer conditions, on marginal lands, and with minimum inputs. Nutrients including N, P, Zn and Mn are commonly limiting, and diseases such as rust, anthracnose and root rots are common constraints.

A major focus has been the improvement of N_2 fixation in *Phaseolus* beans, because it is a species consistently shown to be weak in this trait. This focus initially emphasized Mesoamerican bean cultivars, and sought bean lines exhibiting different reasons for above average N_2 fixation. With Puebla 152, BAT 277 and RHIZ21 identified as promising parents, a recurrent selection breeding program was developed with field evaluations for high N_2 fixation undertaken at the low N Becker Sandplain research station. Three breeding lines with superior ability in N_2 fixation have been identified and methods for the routine ongoing evaluation of nitrogen fixation in this crop established. Under N-limited conditions the breeding lines have consistently out yielded all other varieties with which they have been compared. This phase of the research is essentially complete.

Breeding Andean bean cultivars with enhanced ability for N_2 fixation has required two approaches. Initially, and while INIAP lacked plant breeders, we emphasized CIAT-generated Andean grain type lines and their evaluation under low N and inoculated conditions in the field. Three lines were identified as well-adapted to Ecuadorian conditions and subsequently released by INIAP. The most recent release, Jema, is both highly resistant to rust and showing some tolerance to anthracnose. A drawback to this line is its relatively late maturity. Because of this problem, backcrossing and screening have been implemented to incorporate the BNF ability and the resistance of Jema into local cultivars. The first F_3 lines developed from this program are currently in the field. Paralleling these studies are investigations to identify low P tolerant and good BNF lines of Andean grain type. ANT22 and E295 have been identified as N_2 fixing at low P and are currently being characterized. Initial studies suggest acid rhizosphere modification, differences in P partitioning and carbohydrate metabolism as factors in this difference.

A surprisingly consistent result, considering that Ecuador is considered to lie within a center of origin for *Phaseolus vulgaris*, has been a striking response to rhizobial inoculation. This technology, now widely disseminated in demonstration plots, is accepted by farmers and has now resulted in the development of an inoculant laboratory at Santa Catalina. Over time, we envisage that this facility will become responsible for a significantly wider array of inoculant and biocontrol products for the region. Though *Phaseolus vulgaris* is somewhat promiscuous in its acceptance of *Rhizobium* strains, diversity differences have been shown between strains associated with Mesoamerican and Andean bean varieties within Ecuador, using strains recovered from the northern and southern bean-producing regions.

Finally in Ecuador, major progress has been achieved in response to micro nutrient deficiency. Soils in Ecuador are all essentially somewhat alkaline and prone to zinc, manganese and iron deficiencies. Soil and foliar-applied zinc chelates are effective in overcoming zinc deficiency, with yield increases up to 30 percent. Until recently, extensive use of these chelates by flower growers has limited their availability to bean growers; zinc chelate availability in Ecuador has improved dramatically in the last six months.

Research accomplishments have also had significant impact in Minnesota. Root rot in Minnesota is a major problem with losses estimated at $(U.S.) 4.6 million annually. Biocontrol using Kodiak as a seed treatment can significantly reduce infestation and damage with improvement in nodulation and nitrogen fixation and increase crop yield as much as 17 percent. In 1999, yield increases with biocontrol treatments in pivot area demonstration plots had a major impact for farmers in the area. Almost 200 tons of bean seed were treated for the 2000 planting. Success in this area has attracted commercial interest in undertaking additional trials in 2000, comparing mixed root rot control and *Rhizobium* inoculants.

In Ecuador, INIAP has few staff with post-graduate qualifications. Because of this, training has been a major thrust throughout the life of the CRSP there, with undergraduate *egresado* training and extension workshops emphasized and one or two INIAP staff enrolled in graduate degree programs at all times in the United States. A successful training program has been undermined to a significant degree by recent economic problems in Ecuador. M.S. graduates at INIAP are now receiving only $(U.S.)120-150 a month in salary. A change in the training model is needed, that considers long-distance education as a means to provide training to a wider audience throughout the region.

Dissemination of information has also been a major focus. Technical bulletins, extension workshops and farmer's meetings have been emphasized by INIAP, with Consuelo Estevez, while in Minnesota also actively involved in extension meetings. More recently the HC-PI has moved aggressively to develop quality germplasm and extension manuals, and to have these available on CDs. The Rhizobium Research Laboratory website, now available in both English and Spanish, provides nitrogen fixation information to a wide audience. In the last 12 months there have been almost 100,000 hits on this site, with 33,000 site visitors from 71 different countries downloading more than 510 MB of information. More conventionally, the U.S. group at Minnesota has published more than 20 peer-reviewed papers and book chapters in recent years, with the U.S.-PI co-editing special issues of Field Crops Research dedicated to grain legumes (FCR [1997] 53, 1-217) and applied aspects of nitrogen fixation (FCR [2000] 65, 91-270).

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IMPROVED NUTRITION AND PRODUCT DEVELOPMENT

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Presented by Ana Bonilla Leiva and Maurice Bennink

Heat-induced cell wall crystallization during bean cooking is a primary barrier to starch digestibility and has been the research focus at Michigan State University. Cryogenic milling (-195C) with a 6700 SPEC freezer/mill was necessary to disrupt cell walls prior to cooking and achieve complete starch digestibility. Research showed that both the genotype and processing method affected the digestibility of dry beans. Significant differences in total dietary fiber, indigestible starch, and indigestible protein were found among 6 market classes and three preparation methods (stove-top cooking, autoclaved, and thermally processed in tin cans). Navy bean was the market class with the most digestible starch (»90 percent). Black beans and kidney bean had the least digestible—starch <85 percent. Manteca, a Latin American market class was similar in digestibility to navy beans. Manteca beans are favored for their qualities of taste, texture, and good digestibility. The current research on indigestible starch appears to confirm the high digestibility, low-flatulence attributes of Manteca bean.

Thermally processed beans in tin cans (canned beans) have been found to contain significantly less total dietary fiber and indigestible starch than those cooked by the autoclave or stove-top methods. Stove-top cooked beans had the highest amount of indigestible protein among the preparation methods.

Two recombinant inbred populations of kidney beans were developed to ascertain canning quality and yield. Both populations were evaluated in North Dakota in 1996 and Michigan in 1996-1998.

Genotypes and genotype x environment interactions were significant based on analyses of variance. In Population 1, three lines, based on appearance of canned beans, consistently performed in the top 25 percent in all environments. Four lines in Population 2 were consistently in the top 25 percent in all four environments, also based on appearance. One line in particular, Line 1-90 had consistently better canning quality than the better canning parent, Montcalm, although its yield was slightly lower than both parents. RAPD primers were used to amplify DNA from these RILs. Polymorphisms were found to be of low incidence in Population 1. This is probably due to the narrow genetic base of kidney beans in general.

At Purdue University the research focus has been on the:

- Effect of fermentation on nutritive value (proteins, carbohydrates, minerals, vitamins), quality, and acceptability of dry beans.

- Effect of germination on nutritive value (proteins, minerals) of dry beans.

- Development and sensory acceptability of bean (black) and rice weaning food and bean (red) and corn weaning food.

For fermentation, dry beans were coarse ground, soaked in water, cooked, cooled, then inoculated with *Rhizopus oligosporus* to ferment for 15-35 hours. For germination, dry beans were soaked in water then germinated for 27 hours before cooking. To create bean-rice or bean-corn weaning foods, control (i.e., unfermented, ungerminated), fermented, or germinated beans were homogenized, combined with rice or corn, then drum dried.

Of interest was the effect of fermentation and germination of beans on bioavailability of minerals (iron and zinc) and protein digestibility. Beans were grown under greenhouse conditions in a circulating hydroponic culture and radio-labeled with ^{65}Zn or ^{59}Fe. These beans were fermented or germinated, then incorporated into experimental diets for feeding to rats. Both fermentation and germination improved zinc retention in the animals. Germination alone positively influenced iron retention. Neither fermentation or germination increased the PDCAAS (protein digestibility—corrected amino acid score), but germination did increase the true protein digestibility.

Also of interest was the effect of fermentation time on composition of beans. Beans fermented for various time periods (0, 15, 20, 25 hours) were tested for proximate composition (i.e., moisture, protein, fat, ash, and total carbohydrate), starch, total dietary fiber, protein digestibility, tannins, lectins, trypsin inhibitors, amino acid composition, minerals, and oligosaccharides (i.e., raffinose, stachyose, verbascose; these are related to flatulence problems). The most interesting finding was that the oligosaccharide content of beans fermented for 25 hours was lower than in the other treatments. Further studies have shown that with extended fermentation, stachyose levels decreased and raffinose levels increased.

A third set of activities involved the sensory evaluation of bean-based weaning foods. Bean-rice and bean-corn weaning foods (~30 percent beans, ~70 percent rice or corn; ~53 percent bean protein, ~47 percent rice or corn protein) were made with and without fermentation of the beans, and products were tested by sensory evaluation in rural villages in Costa Rica and Honduras, respectively. Panelists did not find products made with fermented beans to be less acceptable than control samples.

At the Universidad de Costa Rica, research has focused on developing a bean-based weaning food product. A dehydrated bean product has been developed. The product was fortified to supply 50 percent of the daily iron requirement for 1-3 year old children and given to 124 children to determine product acceptability. The product was judged acceptable by 68 percent of the children. The product was further evaluated through the following studies:

- A nutritional intervention study with 164 children (anemic, malnourished and normal) was performed. Anemic and malnourished children eating the fortified product showed significant improvements ($p<0.05$) in hemoglobin and hematocrit status. Even healthy children significantly improved their iron reserves ($p< 0.05$).

- The shelf life of the product stored in BOPP bags at 21 °C , 82 percent RH and exposed to light was estimated to be 9 months, based on a 10 percent Vitamin C loss.

This study addressed such issues as Costa Rican agricultural bean activity, general diagnostic of a bean production area, marketing studies, product acceptability, concept analysis for an iron-fortified product, evaluation of the image of a ground bean product fortified with iron, technical-engineering study, and a financial-economic study. Results: The marketing study showed that 74.8 percent of the interviewed mothers would give the product to their children and 60 percent believed the product could be sold in the supermarkets. A plant was designed to establish a processing industry. However, the financial study showed that it was not economically feasible to establish a bean processing industry with the proposed conditions. Strategies to minimize costs to enable establishment of an economical food industry are being evaluated. An agricultural producers organization, PROUDESA, is interested in technological transfer. There are 350 producers from the highest bean production area in Costa Rica associated with this group. We are jointly seeking financial resources to start a production unit.

In order to develop new products with higher digestibility, the following studies had to be performed and have generated the following results:

- Effect on starch digestibility (SD) of grinding beans before or after cooking: Grinding beans before cooking significantly ($p < 0.05$) improved bean digestibility. Scanning electronic microscopy showed that improved digestibility was associated with increased starch gelatinization. However, acceptability of the products ground before cooking was lower than products cooked before grinding ($p<0.05$).

- Effect of the enzymatic treatments on SD: Treating bean slurries with α-amylase did not improve SD ($p>0.05$). Two other microbial sources of a-amylase are being tested**.** Addition of a pectinase increased SD 12-13 percent in both black and red bean varieties. Addition of cellulase increased SD 12 percent in red beans ($p>0.05$) and 5 percent in black beans ($p>0.05$). There was no difference in acceptability of beans with or without cellulase treatment ($p>0.05$) and lower acceptability for the ones treated with pectinase ($p<0.05$). These results will allow the food industry to produce bean products with different digestibility characteristics.

- Educational Campaign Promoting Bean Consumption: Qualitative and quantitative studies have been done in a middle class community with school children to identify knowledge, attitudes, and practices of the population with regard to beans. The results are being used to define messages that should be given to the population during the bean consumption campaign.

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SOCIOECONOMIC STUDIES

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Presented by Richard Bernsten

Dry beans are the second most important staple crop, following maize, in the region which includes the U.S., México, Central America and the Caribbean. The Bean/Cowpea CRSP collaborates with scientists in countries that account for 92 percent of the region's total bean production—the U.S. (45 percent), México (35 percent), Central America (10 percent), and the Caribbean (2 percent).

During the 1990s, production, harvested area and yields have varied greatly from year-to-year. In general, total production has trended up in the U.S., trended down in México, remained constant in Central America, and trended down in the Caribbean. In contrast, harvested area has remained relatively constant in the U.S. (750,000 has), has varied greatly from year-to-year in México (1.296 to 2.146 m. has) but exhibits no trend, has increased steadily in Central America since 1965, and has trended down in the Caribbean. During the 1990s, U.S. yields increased steadily since 1993, setting a record in 1999 (1.984 mt/ha). Despite the release of many new varieties in México, Central America, and the Caribbean, their greater yield potential is not reflected in country-level yield data: Mexican yields have averaged 600-700 kg/ha; Honduran yields rose rapidly from 1995 to 1998, but fell sharply 1999 (due to Hurricane Mitch); Dominican Republic (DR) yields remained level during 1995-1998, but rose sharply in 1999; Costa Rican yields rose through 1995, but fell sharply thereafter; Guatemalan yields trended down during most of the decade; and Nicaraguan yields remained relatively level through 1996, but fell sharply before recovering in 1999.

Many factors help explain the region's high degree of variability in production, harvested area, and yields. First, throughout the region, beans are grown primarily as a risk-prone rainfed crop (subject to abiotic stress)—except in the DR, where about 50 percent of the bean area is irrigated. Second, during the 1990s, the Central America and Caribbean bean crop was subjected to severe biotic stress (including BGMV). Third, seed availability remains a major constraint in the region—thereby limiting the use of improved varieties to primarily more commercial farming areas. Fourth, most national bean research programs have targeted specific agro ecologies/production systems, which represent only part of each country's bean area. Thus, in the non-targeted areas, improved bean varieties may not be superior to traditional bean varieties (TVs). Fifth, even if new CRSP releases produce higher yields than TVs, their impact may not be fully reflected in aggregate-level data because national yields are estimated as the weighted average of yields in both commercial and semi-commercial areas. For these reasons, CRSP research will have only a limited impact on national-level statistics, unless greater effort is made to expand the research agenda to target all major agro ecologies, relax the seed constraint, and develop linkages with farmers' organizations and governmental and non-governmental agencies to insure more widespread dissemination of newly released improved varieties.

Increasing regional bean production is especially challenging, given widely varying consumer preferences (market class) and greatly differing agro ecologies/production systems (i.e., semiarid highlands vs. humid tropical; rainfed vs. irrigated crops; flatland vs. hillside farms; semi-commercial vs. commercial farmers), which limit the transfer of varieties within and between countries. Furthermore, farmers' production decisions are greatly influenced by government policies, which vary among countries. For example, agricultural policy in México may be characterized as "moving rapidly towards market liberalization" (i.e, replacing input subsidies, price supports with PROCAMPO, a non-commodity based income support program). In Honduras, the government has treated the bean subsector with "benign neglect" (i.e., implementing structural adjustment without introducing an alternative program). In the DR, the government "strongly protects" bean farmers through seed subsidies, price support, and bean import restrictions. As governments continue to liberalize their economies, as required by NAFTA and the WTO, farmers in the region must significantly increase their productivity (reduce costs of production), or lose their national market share to imported beans.

Improved bean varieties (higher yield potential, greater drought/disease tolerance) and new management practices have the potential to increase productivity by reducing production costs per kilogram—thereby making locally-produced beans more competitive with imports. Available data indicates that CRSP varieties, developed in collaboration with national programs, give higher yields than TVs and have been widely adopted in the semiarid highlands of México (i.e., Pinto Villa, 350,000 has, 30 percent of the semiarid area in 1998), Honduras (i.e., Dorado, Catrachita, 33 percent of the main bean-producing area in 1994), and the DR (i.e., PC-50, JB-178; almost 100 percent of the San Juan Valley's irrigated area in 1997).

To assess the profitability of recently-released varieties, farm record keeping studies were carried out (1997-1999) in the DR (2 winter seasons), Honduras (*primera*, 2 years; *postrera,* 2 years), México (1 winter season), and Nicaragua (*postrera*, 2 years; *Apante*, 1 year). In each country, data were collected from 20-30 farmers, in selected years/seasons/locations. These data document considerable variability in farmers' yields, input use, bean sales price, and gross margins (profits). Highest single-season yields were achieved in the DR (1,128 kg/ha, SJV, winter 1997-98) and Honduras (1,177 kg/ha, *primera* 1998). Factors responsible for very low yields varied by country/year (México, drought, winter 1998; Honduras and Nicaragua, Hurricane Mitch, *postrera* 1998). In most instances, improved bean varieties gave substantially higher yields (341 to 415 kg./ha) than TVs. Purchased input costs varied from $410/ha (DR, 1997-98) to $43/ha (Honduras, *primera* 1999). Total labor costs varied from $69/ha (Nicaragua, *postrera* 1998) to $297/ha (DR, 1997-98). Prices farmers received for their beans ranged from $1.42/kg (DR 1997-98) to $0.50/kg (Honduras, *primera* 1999). Gross margins per ha (yield times price, minus production costs) ranged from $623 (DR, 1997-98) to $-45 (Honduras, 1998 *postrera*, due to Hurricane Mitch). In "normal" seasons (no severe drought or hurricane), the cost per kg of beans produced was lower for improved varieties vs. TVs, and ranged from $0.68/kg (DR, 1997-98) to $0.27/kg (Nicaragua, 1997 *postrera*).

Regional scientists have followed various strategies to address the seed constraint. In México, since the mid-1980s when the government downsized its seed parastatal (PRONASE), INIFAP has utilized on-farm demonstration plots to promote and multiply its new releases. In addition, INIFAP has developed linkages with farmer cooperatives, private seed firms, and government programs (kilo-for-kilo) to facilitate seed multiplication/dissemination. In Honduras, Zamorano produces certified seed for sale to commercial farmers (50 lb bags), makes available its improved varieties to NGOs for distribution to smallholders, and works with NGOs interested in helping farmers develop revolving seed banks/artisan seed schemes. Following Hurricane Mitch, Zamorano launched an "emergency" seed supply initiative, producing 200 mt. of seed, packaging it in 10/ 25 lb. bags, and distributing it to over 40 NGOs, who supplied seed to 21,000 small farmers. In the DR, CIAS supports the Ministry of Agriculture's (SEA) seed production/distribution program by providing foundation seed to SEA. SEA contracts with about 50 pre-selected growers in the San Juan/Cibao Valleys to multiply the seed, buys the harvest at a pre-negotiated price (about 35 percent above the grain price), and processes it for sale to farmers. In recent years, CIAS has provided foundation seed to several SJV farmer associations, which multiply it for their seed banks. Despite these innovative strategies, seed availability remains a major constraint in the region—especially for non-commercial farms in the more inaccessible areas of each country.

The CRSP has developed many new varieties which farmers have adopted—thereby increasing their yields and incomes. CRSP scientists must continue to give priority to developing new varieties tolerant to the region's abiotic/biotic stresses. While each national program must identify the specific constraints to and opportunities for increasing technology adoption, two general strategies are proposed to increase the impact of the CRSP's research programs. First, scientists should expand the "target area" of their research by developing new initiatives to address constraints in major agro ecologies/production systems that have yet to be addressed. Second, regional scientists should expand on-going efforts to relax the seed constraint, giving priority to assessing the most appropriate roles for research institutions, farmer organizations (cooperatives, farmer research committees), private sector participants (seed, input dealers), and NGOs. These efforts should give priority to designing cost-effective and sustainable seed systems that meet the needs of both small, semi-commercial farmers and more commercially-oriented producers.

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IMPACT OF THE LAC REGIONAL PROJECT ON U.S. BEAN RESEARCH AND PRODUCTION

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Presented by James Kelly

In their analysis of "Who Gains from Genetic Improvements in U.S. Crops?," Frisvold et al., *AgBioForum* 2(3&4) 1999 report results of a study using a world agricultural trade model to estimate the size and distribution of economic gains from yield increases in major U.S. crops attributable to genetic improvements. The net global economic benefits of a one-time, permanent increase in U.S. yields are about $8.1 billion (discounted at 10 percent) and $15.4 billion (discounted at 5 percent). The U.S. captures 50-60 percent of these net gains. Gains to consumers in developing and transitional economies range from 6.1 billion (10$ discount rate) to $11.6 billion (5 percent discount rate). What is interesting is that in addition to the target market in the U.S., developing countries benefit from advances in genetic improvement within the U.S. agricultural sector. Within the framework of the CRSP, impact follows as a consequence of achieving research results, through project activities which relax the identified constraint (R. Bernsten, personal communication). Given the mission of the CRSP, the constraints identified and researched are within the LAC region. In contrast to targeted constraints with the U.S., the impacts on U.S. agriculture generated by the CRSP are, therefore, an indirect spinoff of CRSP research activities overseas.

Relative to impact, commercial dry bean yields in Michigan reached an all time high of 21 cwt/acre in 1999. This represents a 13.5 percent increase over the last record high yield recorded in 1991. As a result, Michigan bean growers produced over 7.5 million cwt of dry beans equivalent in size to 1982 production. To produce a similar volume in 1982, growers had to plant 550,000 acres compared to 350,000 acres in 1999. Improved performance contributed to a savings in land planted to dry beans, land that could be devoted to other commodities. In general, most estimates attribute 50 percent of the improved performance in crops to improved varieties, the other 50 percent is attributed to improved management including better disease, insect, and weed control. The farm-gate value of the 7.5 million cwt bean crop produced in 1999, is $150 million and if genetics (new varieties, LAC germplasm) contributed 6.75 percent of that value, the impact of genetic improvement to bean producers in Michigan would be around $10 million in 1999. The figure compares yield gain between the two most recent "best" production years of 1991 and 1999 to help reduce the favorable "weather" factor in the calculation. Similar yield gains have been reported in other states as a direct result of CRSP-sponsored research.

There has been the release of varieties and breeding lines in the U.S. that have LAC germplasm. U.S.-based CRSP scientists have served as a conduit of information and germplasm to non-CRSP researchers in the U.S. New sources of heat and drought tolerance, agronomic traits (architecture, maturity, yield), disease resistance (anthracnose, rust, common blight, white mold, root rot and others), and general adaptation to unique environments have all aided U.S. bean researchers, public and private.

- Release of nine varieties in six commercial classes in the U.S.
- Release of BGMV resistant white lines in Puerto Rico and snap bean germplasm in South Florida
- Heat tolerance of Indeterminate Jamaica Red used to improve kidney beans for CA
- Enhanced anthracnose resistance from Honduran and Mexican germplasm
- Drought tolerance in Michigan breeding lines from Mexican germplasm
- Enhanced common bacterial blight resistance in Nebraska
- PC-50 (Andean origin—Dominican Republic) is a new source of resistance to white mold

- Collaborative release of 36 (11 navy, 18 pinto, 7 Great Northern) multiple disease resistant breeding lines. These lines have been used in crosses by public and private breeders as sources of disease resistance with adaptation, yield potential and moderate seed quality.

- Enhanced rust resistance in pinto and great northern beans. Estimated value $5 million to inter mountain region based on higher yields (7-10 percent gain), and reduced input of fungicides (R. Perrin, personal communication)

The technology developed can contribute to all bean programs. Information on molecular mapping of genes for disease resistance and agronomic results has led to increased knowledge of the organization of the bean genome, and is leading to more efficient breeding for disease resistance.

- Identification and mapping of new genes (Kelly and Miklas, 1998)
- Use of linked molecular markers to pyramid resistance genes (Miklas et al., 2000)
- Transgenic beans developed in collaboration with Agracetus, Inc.
- Development of detection methods for geminiviruses which have been used extensively in Florida and California for virus detection in beans, tomatoes, and melons
- Help private companies in identifying sources of resistance and screening techniques

The new technologies will facilitate monitoring potential new diseases or emergence of new races of pathogens.

- Studies on the pathogenic variation for rust, anthracnose, and common blight
- Mobile Nursery: Ban disease resistance genotype nursery that can be easily transported to diseased bean fields to assess pathogen variation within 10-14 days (bean rust)
- Minnesota scientists, working with Ecuador, have shown that root rot problems found in central Minnesota can be alleviated at least in part by use of Kodiak, a *Bacillus subtilis* product. In 1999, this product was used on 20,000 acres of red kidney bean production in Minnesota
- Development of screening methods for white mold and root rot

LAC graduate students conduct research helpful and of benefit to the U.S.

There is increased awareness of potential markets for U.S. agriculture.

Finally, one of the intangible benefits attributed to the Bean/Cowpea CRSP is collaboration. Within a minor commodity such as beans, collaboration is vital if future gains are to be made. The CRSP has helped foster a strong collaborative effort within the U.S. bean community. That collaboration strengthened similar efforts of the Bean Improvement Cooperative—BIC and the W-150 Regional Project. Bean scientists who may not have actively cooperated previously found themselves “connected” through the Bean/Cowpea CRSP and their research was strengthened as a result. Although the benefits of such collaboration are recognized, their impact is difficult to measure.

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INTERCRSP REPORT

ADAPTIVE RESEARCH WITH INTERCRSP NATURAL RESOURCE MANAGEMENT TECHNOLOGIES FOR REGIONAL TRANSFER IN WEST AFRICA

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Presented by Johnson Olufowote

Soils in most of West Africa, because of the type of parent material, have undergone intensive leaching. They also lack volcanic rejuvenation and have a high degree of weathering. Thus, most of these soils have relatively low inherent fertility.

In traditional agriculture, when crop yields decline to unacceptable levels, the overcropped land was abandoned and new areas opened leaving the old land under natural fallow to restore their fertility. However, increasing population pressure has reduced the availability of land and resulted in reduced ratio of length of fallow to cropping years to the point that shifting cultivation is losing its effectiveness. As a result, soil fertility is decreasing in many areas.

In Africa, 65 percent of the agricultural land, 31 percent of the permanent pasture land, and 19 percent of the forest and woodland is affected by human-induced soil degradation. It is estimated that about 332 million hectares of African drylands are subject to soil degradation. Nutrient depletion is the most important element in the soil degradation equation (Bationo and Lompo, 1996).

The Collaborative Research Support Projects (CRSPs) working in West Africa have as their main thrust, technology development. For several years, these bilateral research teams have developed natural resource management (NRM) technologies for specific environments in individual countries. Many of these technologies can be adapted for wide use throughout West Africa. However, national and regional adaptation and transfer of technologies are constrained by weak coordination, cooperation, communication and linkages across the countries.

Through support from the Africa Bureau, an NRM InterCRSP initiative in West Africa has a specific charge to transfer NRM technologies in West Africa. The major objectives of the project are:

1. To develop a model for CRSP/NGO (non-governmental organization) collaboration that will mobilize the existing knowledge, technologies, and capacity of CRSPs for major regional impact.

2. To engage this resource to improve natural resource management, reduce natural resource degradation, and improve farmer food security and incomes in West Africa through regional adaptation and transfer of sustainable NRM technologies.

The primary outcomes of the project are expected to be:

1. A model regional mechanism for collaborative adaptive research and transfer of CRSP NRM technologies in West Africa.

2. Strengthened and mutually-reinforcing West African institutions and professional resources for NRM technology adaptation and transfer.

3. The successful functioning of the model mechanism, leading to more productive exchanges among CRSPs, NARS, NGOs, and farmers in West Africa, improved regional technology adaptation and transfer, and more sustainable yields with greater profitability for farmers.

The initial CRSPs are the Bean/Cowpea CRSP, which is the lead CRSP, and the Sorghum/Millet CRSP (INTSORMIL). Both the United States and Host Country scientists of these CRSPs collaborate in the project.

World Vision maintains programs in eight countries in West Africa, with a comparative competency in West African regional technology transfer. World Vision maintains a healthy collaborative relationship with the NARs and NESs in the countries in which it works.

Collaborative adaptive research and technology transfer teams, composed of CRSPs, NARs, NESs, WVI, other NGOs, and farmer collaborators were formed for each participating country. Each team, led by a team coordinator, establishes and implements work plans, setting targets and developing the work plans for the adaptation and transfer of technologies. The CRSP and NARs team members coordinate in adaptive research activities, while WVI, NES, other NGOs, and farmer team members coordinate transfer activities. Their feedback is important to the researchers. Farmer team members are known and innovative farmers selected from farmer organizations.

The Bean/Cowpea CRSP and WVI facilitate the exchange of NRM technologies among team members and among country teams. They complement internal and external linkages with additional regional collaborative relationships, such as with the following networks in the region: the West and Central Africa Sorghum Research Network (WCASRN), the West and Central Africa Millet Research Network (ROCAS), the West and Central Africa Cowpea Research Network (RENACO) and PEDUNE.

Activities are currently in progress in Chad, Ghana, Mali and Niger. Sénégal was included in 1999. Hence, the participating countries cut across the Sudan-Sahelian zone of between 200 and 1200 mm of annual rainfall.

Current technologies are mainly in the area of genetic materials of cowpea, sorghum and millet. Also given prominence is the dissemination of cowpea storage technologies.

Incorporation of cowpea into the cropping system is crucial for sustainable crop production in sub-Saharan Africa. Cowpea improves the soil through the fixing of atmospheric nitrogen. Similarly, cowpeas, when intercropped with cereals, help reduce the menace of Striga, a major problem confronting smallholder farmers in the region. Two major cereals grown in the target areas of the project are sorghum and millet. It is hoped that incorporating cowpea in the cropping system, either as a sole crop or intercropped with sorghum and millet, will go a long way to reduce natural resource degradation.

A major deterrent to cowpea production is the problem of cowpea storage. Farmers grow limited acreage, as storage of seed is often problematic. Hence, the project puts much emphasis on disseminating cowpea storage technologies that have been developed and are appropriate for adoption. These technologies were developed by the CRSP project in the Cameroon.

<u>Highlights of Achievements</u>:

1. Collaboration: The project has created a 5 country network of over 50 collaborators from more than 15 different organizations, encouraging both in-country and cross-country collaboration. Within each country, scientists from different disciplines are working together to develop, test and disseminate technologies best suited to local conditions. There have been improved working relationships between WVI, NARs, NESs and farmers. Internationally, technologies are being shared throughout West Africa by NARs, CRSPs, IARCs and the commodity networks.

2. Mutual Learning: Exchange of expertise has been encouraged and facilitated by the project. Because farmers have been empowered by the project, scientists have learned a lot from the farmers. For an example, during the storage technology workshop in Ghana, farmers demonstrated the age-old methods of local seed preservation including the use of shea butter. Similarly, in Niger, scientists learned how farmers used powder from the leaves of *Anona senegalensis* for seed preservation. Hence, scientists,

extension personnel and farmers are all both teaching and learning as they work together to improve and extend NRM technologies throughout the region.

3. Dissemination of Technologies: Technicians and farmers were trained on cowpea storage technologies (solar heater, triple bagging and improved ash storage) developed by CRSP scientists in the five participating countries. Technicians and farmers trained have further trained more farmers. For example in Chad by 1999, 1113 farmers have been trained.

   Improved cultivars were introduced to farmers through both adaptive and on-farm trials.

CHAD

Cowpea
- Top yielders: IT 994, C7-29, MÉLAKH and C93W-24-130
- Farmer's preference for IT994 and IT89KD-288

Sorghum
- Identification of the sorghum variety, GRW as promising
- Local variety out-performed newly developed varieties on farmer's fields
- Participatory Sorghum Selection

Sorghum-Cowpea Intercropping
- Sorghum and Cowpea in alternate hills of the same row or in alternate rows most effective in reducing Striga, while maintaining good sorghum yields.

GHANA

Cowpea
- Two CRSP cultivars (MÉLAKH, C93W-24-130) to go on-farm after being promising in adaptive trials.
- The three Cameroonian/CRSP lines (C93W-2-38, C92S-12-58, C93W-24-130) significantly out-yielded all entries in fodder production.

Sorghum
- P 9407 utilized as a source for genetic resistance to Striga in national program
- Integrated Striga management: workshop and demonstrations
  - use of resistant varieties
  - use of fertilizer/manure
  - crop rotation
  - intercropping
- Cowpea intercropped with sorghum, irrespective of the pattern reduced Striga infestation
- Soybean intercropped with sorghum more effective in reducing Striga infestation

MALI

Cowpea
- Variety "Korobalen" (IT89KD-374) was early, high yielding and preferred by most farmers
- Other farmer preferences were:
  - drought tolerance: IT89KD-245
  - Striga tolerance: IT89KD-245
  - early maturity: IT89KD-374
  - palatability: IT 89KD-374
  - Haulm output: IT89KD-245
  - grain whiteness: IT89KD-245
- High performance (over local varieties) of C93W-2-38, Mouride, Mélakh and Mame Fama)

Sorghum

- Seguetana cinzana seems preferred; most farmers complained of the weak stems (hence, lodging) of "n'tenimissa"
- N'tenimissa preferred by some farmers for the whiteness of its grains and the taste and consistency of its porridge
- With exception of one of the sites, the local varieties out-yielded the tested varieties (N'tenimissa, 96CZF498 and 96CZF499). Average yield data over locations showed the superiority of the local varieties.

Millet

- Though there was no significant difference in the average yield of the varieties (Guefore, Tontoro 21 and Indiana 05), some out yielded the controls in the three ADPs where the trials were conducted.

Cereal/cowpea intercropping

- Intercropping of sorghum or millet with the improved cowpea cultivar IT89KD-245 in row intercropping or in alternate rows gave the best results in combating Striga.

NIGER

Cowpea

- Top performance of Mouride (ISRA/CRSP), IT89KD-349 and IT89KD-374 for grain yield and the local variety (TN5-78) for fodder production.

Sorghum

- Top performance of the hybrid, NAD-1

Millet

- Top performance of HKP from INRAN

SÉNÉGAL

Millet

- Identification of GBS 8735 as an overall performer

Cowpea

- Mouride and Mélakh top yielders and preferred by farmers.

Direct (TOT) training on post harvest technologies reached a number of farmers and extension professionals

- Ghana 150
- Chad 50
- Niger 25
- Mali 66
- Sénégal 110

In addition, two WVI extensionists from other West Africa countries were trained in Maroua, Cameroon. There was follow-up training of 1113 persons in Chad. It has been shown that NRM can be improved in West Africa under the framework of current InterCRSP/WVI initiative that has involved the mobilization of existing capacities within Bean/Cowpea CRSP and INTSORMIL. An excellent demonstration of collaborative technology development and transfer is typified by the current West Africa NRM InterCRSP.

Looking to the future, there is a need to expand the number of NRM technologies included in the technology packages, particularly soil and water conservation technologies.

MIDCOURSE 2000
MEETING PARTICIPANTS

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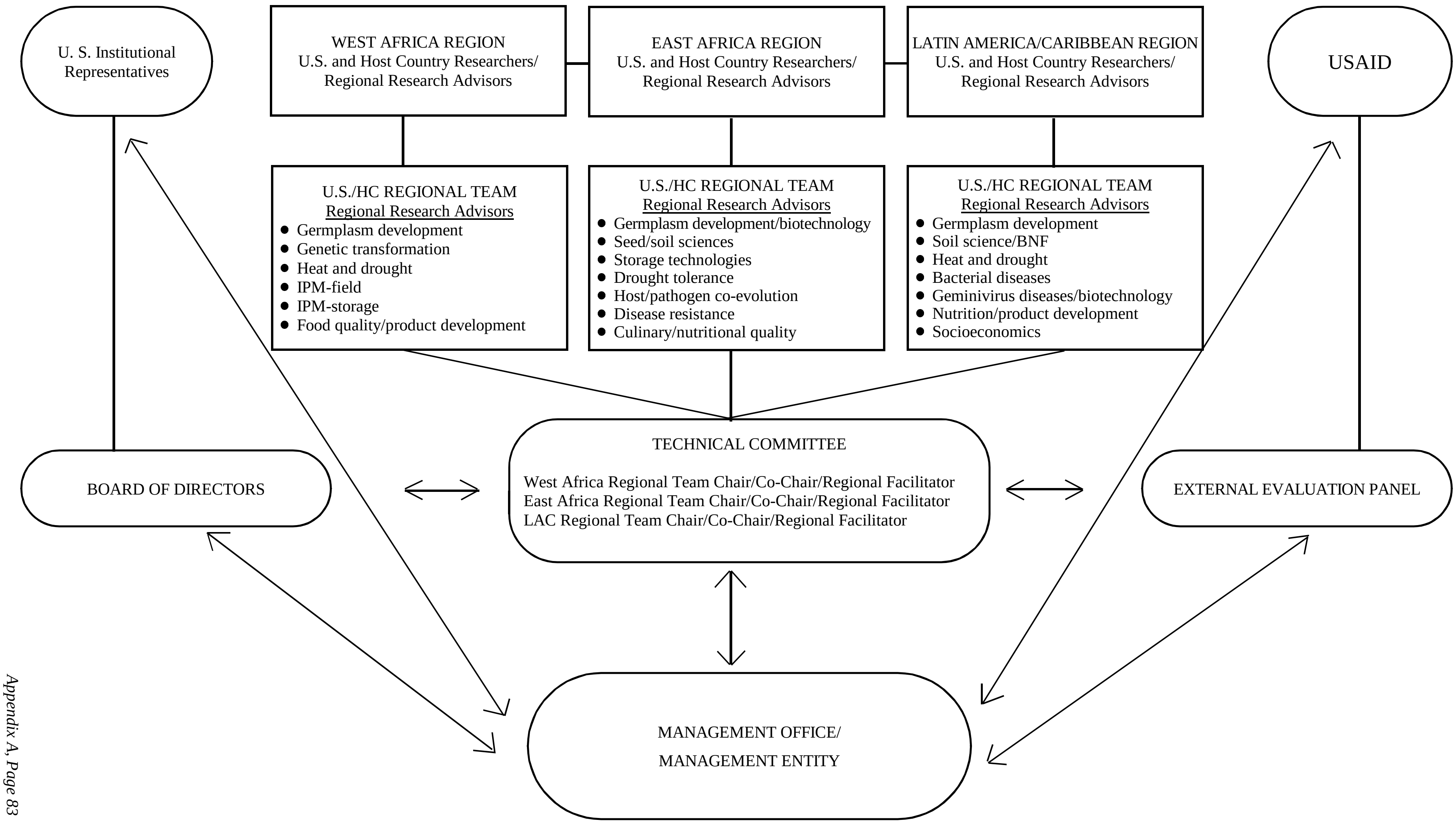
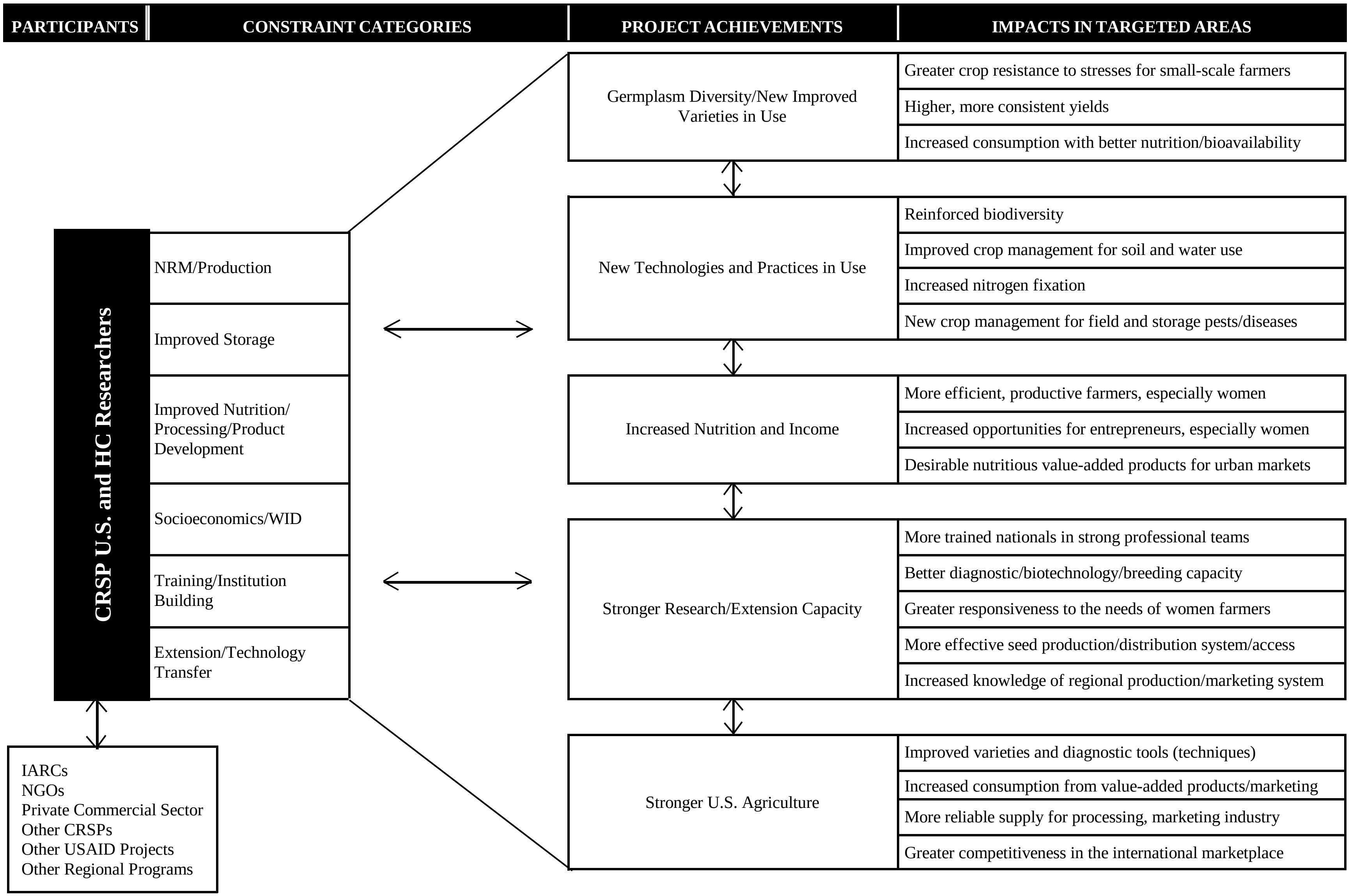
APPENDIX A

BEAN/COWPEA CRSP
NEW ORGANIZATION PLAN: Period 1997-2002



BEAN/COWPEA CRSP
ANTICIPATED FIVE-YEAR IMPACTS



BEAN/COWPEA CRSP
WEST AFRICA REGIONAL PROJECT PROFILE (Cowpeas)

GOAL: ***Increased Nutrition and Income Through the Production and Utilization of High-Quality Cowpeas***

PROJECT PARTICIPANTS	
HOST COUNTRIES:	Cameroon, Ghana, Sénégal
U.S. INSTITUTIONS:	Auburn University, Clemson University, Purdue University, University of California-Riverside, University of Georgia
ORGANIZATIONS:	IITA, World Vision International
WITH IMPACT IN:	Burkina Faso, Chad, Gabon, Ivory Coast, Mali, Niger

ANTICIPATED IMPACTS IN FIVE YEARS

1. Cowpea production in CRSP-targeted areas consistently (a) exceeding 500 kg/ha (currently 0-300 kg/ha) with minimal insecticides and (b), in new areas, providing substantial quantities of fresh shell grain available during the hungry time just before the year's first harvest
2. Insect losses in storage reduced by at least 10 percent in CRSP-targeted areas
3. Cowpea subsector better understood and utilized to generate new cowpea market demand and value-added products
4. Stronger and more sustainable research capacity in Host Countries with better integration of disciplines and intra-regional collaboration

TARGETED RESEARCH CONSTRAINTS (not in order of priority)		
#1–Insufficient NRM and Production Technologies	Improved technologies and facilities for scientific research	● Improve bioassay methods to identify resistance traits ● Develop better cowpea transformation techniques ● Strengthen technologies for breeding within *Vigna unguiculata* ● Develop biotechnology-based strategies for using resistance sources outside *Vigna unguiculata*
	Germplasm diversity and management for crop improvement	● Increase germplasm collection, characterization and conservation ● Make promising lines widely available ● Search for novel sources of resistance to insects, drought, heat, seed-borne and aphid-borne diseases and the parasitic weed *Striga*
	New varieties through conventional breeding and plant transformation	● Develop varieties better adapted to the semiarid Sahel and savannas ● Emphasize yield stability with multiple disease and insect resistance ● Improve nutritional quality in consumer-preferred varieties ● Complete and release improved lines currently in the pipeline ● For California, improve varieties for the dry cowpea grain industry (black eyes as well as all-white cowpeas) with greater yield and genetically conditioned resistance to insect pests to increase production efficiency, decrease pesticide use and reduce water pollution ● For the southeast U.S., improve varieties for the fresh vegetable and processing industries (e.g., canning, frozen food) reducing environmental and production costs

Major Constraints	Identified Need	Research to Meet Need
	Expanded IPM technologies and strategies	● Integrate entomology and breeding to develop resistance to leaf, pod, flower, grain, stem and root feeding insects ● Improve crop management practices
#2–Limited Storage Options	Expanded affordable storage technologies	● Multiply for extension new varieties with grain and pod resistance to multiple insects (field/storage) ● Identify/better explain biological control mechanisms (e.g., natural enemies and botanicals) (field/storage)
#3–Insufficient Utilization Research for Improved Nutrition, Processing and Value-Added Products ***(Research partially funded by USAID's Office of Nutrition)***	Nutrient bioavailability research in cowpea improvement programs	● Improve bioavailability of proteins, zinc and other essential micronutrients in new varieties ● Develop simple reliable tests of food quality that can be used easily by breeders ● Develop food quality assessment technologies for evaluation of storage efficiency ● Assess new U.S. varieties for nutrient bioavailability ● Improve processing technologies for nutrient bioavailability
	Value-added food products	● Develop improved methodologies for fortifying traditional foods with cowpea flour for households, small-scale (e.g., street vendors) and industrial use ● Develop new foods–weaning foods, nutritional rescue foods for at-risk children, school foods ● Make use of new, white-seeded cowpeas for commercial production of cowpea flour (no black-eyes to be removed) as a more economical, high-value nutritional additive ● Explore baked goods supplemented with cowpea flour to improve nutritional quality through blends that are nutritionally complementary ● Develop quick-cooking (microwaveable and boil-in-bag) cowpeas addressing the time and effort constraint to their use (*NOTE: This is of interest to Southern Frozen Foods of Montezuma, Georgia, a major processor of frozen legumes and entrees*)
#4–Socioeconomic Research Insufficiently Integrated with Production and Utilization Research	Clarification of the cowpea subsector	● Conduct national and regional market research ● Define the roles and needs of women as cowpea consumers, processors and entrepreneurs
	Research integration between social scientists and breeders/ entomologists/food scientists	● Construct models to determine crop loss thresholds identifying potential yield loss severity from insects and action/inaction levels (considering e.g., economics, labor and impact on natural enemies) ● Evaluate and monitor appropriateness of value-added products ● Document impact of the CRSP
TARGETED TRAINING CONSTRAINTS		
#5–Insufficient Cadre of Trained Personnel	Degree training	● Train research professionals in agricultural economics with a strong WID orientation; IPM with a farmer education component; plant breeding; food science ● Support training venues within the region as well as in the U.S.

Major Constraints	Identified Need	Research to Meet Need
	Non-degree training	• Organize experiences for extension workers to learn the requirements, potential, and limits of CRSP technologies • Collaborate with extension to expand potential for farmer training schools • Expand opportunities for CRSP and non-CRSP colleagues to keep up-to-date with the latest scientific knowledge and communication technologies • Provide continuing education in support areas, e.g., research project management, accessing new sources of research support, resource management (time, funds, equipment, labor) • Encourage subject matter short-term training for professionals from one another's disciplines, e.g., socioeconomic aspects of technology development, diffusion and adoption
TARGETED EXTENSION CONSTRAINTS		
#6–Insufficient Extension Services Supporting Cowpeas in the Region	Expanded pre-extension efforts for certified seed of adapted varieties	• Provide foundation seed for seed multiplication • Explore potentials for government and private seed multiplication entities
	Extension of new technologies to cowpea farmers	• Work with national extension programs • Work with World Vision International's Africa program and other relevant NGOs • Search for ways to better integrate responses to the needs of women into extension process
	Expanded public and private sector outlets for cowpea technologies and products	• Make new cowpea processing technologies available for grain processors • Identify mechanisms for other entrepreneurs and business people to access cowpea technologies and food products throughout the region • Establish systems for assessing impact across the public/private sector
#7–Insufficient Collaboration between Research and Extension:	Improved mechanisms for research/extension collaboration	• Improve feedback mechanisms for researchers who understand the requirements for, and potential of, each new variety and farmers who know what characteristics are needed • Develop research/extension on-farm trials collaboration
	CRSP crop management technologies shared with extension agents	• Plan opportunities with extension entities • Prepare materials on CRSP technologies for use by extension agents

BEAN/COWPEA CRSP

EAST AFRICA REGIONAL PROJECT PROFILE (Beans)

GOAL: ***Improved Household Food Security from Beans Supported by Strengthened NARS/University Research***

PROJECT PARTICIPANTS

HOST COUNTRIES: Malaŵi, Tanzania
U.S. INSTITUTIONS: Michigan State University, Oregon State University, University of California-Davis, Washington State University
ORGANIZATIONS: ActionAid, CIAT, World Vision International
WITH IMPACT IN: Mozambique, South Africa, Uganda, Zambia, Zimbabwe

ANTICIPATED IMPACTS IN FIVE YEARS

1. Bean yields increased by 15-25 percent in CRSP-targeted production areas with overall bean production in Malaŵi and Tanzania increased by 5-10 percent from expansion into previously unsuitable areas
2. Strong complementary bean improvement programs in Malaŵi and Tanzania collaborating with each other in the provision of improved technologies and services throughout the region
3. An improved system for domestic seed multiplication and distribution established
4. Improved control of seed-borne disease movement in and out of Africa by the international seed industry having global impact, especially in U.S.

TARGETED RESEARCH CONSTRAINTS (not in order of priority)

Major Constraints	Identified Need	Research to Meet Need
#1–Insufficient NRM and Production Technologies	Improved technologies and facilities for scientific research	• Explore further the co-evolution of pathogens and host plants for resistance breeding • Develop more reliable methods to screen for diseases including viruses • Establish complementary laboratories in Malaŵi and Tanzania to identify diseases, monitor pathogenicity and facilitate varietal development
	Germplasm diversity and management for crop improvement	• Increase germplasm collection, characterization and conservation • Explore the extensive East African germplasm pool for new sources of resistance to insects, drought, bacterial blights, viruses and other seed-borne and aphid-borne diseases • Identify and seek to remove barriers to formal regional and global germplasm exchange • Make promising lines widely available in the region • Institute and coordinate two bean nurseries–drought nursery/Malaŵi, bruchid nursery/Tanzania
	Expanded technologies and strategies for IPM (field)	• Identify and better explain cultural control mechanisms for bean stem maggot • Monitor U.S. fields as virus early warning/detection systems and identify major viruses • Institute technologies and procedures for virus eradication in U.S. as needed

Major Constraints	Identified Need	Research to Meet Need
	New varieties through conventional breeding and biotechnology	• Develop new varieties adapted to the region • Emphasize yield stability with multiple disease and insect resistance • Improve nutritional quality in consumer-preferred varieties • Complete and release improved lines currently in the pipeline • Broaden the narrow genetic base of current varieties used in the bean industry in the U.S. • Improve varieties for the bean processing industries (e.g., canned and frozen food) reducing environmental and production costs • Generate additional technologies to reduce production costs and environmental pollution
#2–Limited Storage Options	Affordable technologies for IPM (storage)	• Pursue weevil control through varietal improvement and better crop handling methods • Assess control technologies from other projects via on-farm trials
#3–Insufficient Utilization Research for Improved Nutrition and Processing	Nutrient bioavailability research in bean improvement programs	• Improve bioavailability of proteins • Improve bioavailability of other essential micronutrients
	Improved food quality in new varieties	• Test new varieties for food quality (e.g., nutrition, cooking time and other culinary traits) • Test new varieties for micronutrient bioavailability • Assess new U.S. varieties for nutrient bioavailability • Improve processing technologies to enhance nutrient bioavailability • Assess new lines for U.S. processing standards • Maintain preferred market classes among lines for U.S. exporters
#4–Insufficient Socio economic/WID Research to Optimize Production Gains	Characterization of the bean market sector	• Conduct market research to clarify the changing role of beans in the market economy • Identify how current population and market changes are affecting bean market classes and entrepreneurial opportunities • Expand mechanisms for consumer participation in bean improvement programs
	Expanded WID research	• Define the roles and needs of women as bean growers/processors/entrepreneurs/consumers • Investigate the impact on women of current market changes • Document impact of the CRSP
	Seed-related research	• Identify constraints to formal seed multiplication schemes • Assess on-farm seed multiplication, handling and storage techniques
TARGETED TRAINING CONSTRAINTS		
#5–Insufficient Cadre of Trained Personnel	Degree training	• Train research professionals with strong biotechnology skills in the fields of entomology, plant breeding, pathology and mycology • Train additional professionals in entomology/nutrition/social science/extension education • Support training venues within the region as well as in the U.S.

Major Constraints	Identified Need	Research to Meet Need
	Non-degree training	• Organize biotechnology training for researchers in-country • Expand opportunities for CRSP and non-CRSP colleagues to keep up-to-date with the latest scientific knowledge and communication technologies • Provide continuing education in support areas, e.g., research project management, accessing sources of support (proposal writing), resource management (time, funds, equipment, labor) • Encourage subject matter short-term training for professionals from one another's disciplines, e.g., socioeconomic aspects of technology development, diffusion and adoption
TARGETED EXTENSION/TRANSFER CONSTRAINTS		
#6–Insufficient Access to Improved Seed, Especially of Preferred Varieties	Improved mechanisms for seed multiplication, distribution and handling	• Improve farm-level seed multiplication, selection and handling practices • Identify existing constraints to formal seed multiplication schemes • Evaluate different means of disseminating released varieties • Facilitate adoption and spread of new varieties • With seed agents, establish communications channels between researchers who understand each new variety's requirements/potential, and farmers who know the characteristics needed • Identify and seek to remove barriers for germplasm exchange among scientists
	Expanded pre-extension efforts for certified seed of adapted varieties	• Provide foundation seed for seed multiplication • Explore potentials for government and private seed multiplication entities • Develop research/extension on-farm trials collaboration
#7–Insufficient Extension Services Supporting Beans in the Region	Sharing of technologies with extension entities	• Develop opportunities for collaboration with extension entities • Prepare informational materials on CRSP technologies for extension use
	Extension of new technologies to bean farmers	• Work with national extension programs • Work with World Vision International's Africa program, ActionAid and other relevant NGOs • Search for ways to better integrate responses to the needs of women into extension process
	Expanded public and private sector outlets for bean technologies and products	• Make new bean processing technologies available for grain processors • Identify mechanisms for other entrepreneurs and business people to access bean technologies and food products throughout the region • Establish a system for assessing impact across the public/private sector

BEAN/COWPEA CRSP

LATIN AMERICA/CARIBBEAN REGIONAL PROJECT PROFILE (Beans)

GOAL: ***High-Quality Beans for Domestic Consumption and Income from More Stable Yields and Lower Production Costs***

PROJECT PARTICIPANTS	
HOST COUNTRIES:	Costa Rica, Dominican Republic, Ecuador, Honduras, México
U.S. INSTITUTIONS:	Michigan State University, North Dakota State University, Purdue University, University of Minnesota, University of Nebraska, University of Puerto Rico, University of Wisconsin
ORGANIZATIONS:	CIAT, PROFRIJOL
WITH IMPACT IN:	El Salvador, Guatemala, Haiti, Jamaica, Other Caribbean Countries

ANTICIPATED IMPACTS IN FIVE YEARS
1. More stable bean yields increased by 5-10 percent in CRSP-targeted production areas
2. Beans growing productively in previously unsuitable areas–low altitudes and marginal rainfall sites where the population is spreading
3. Strong, complementary bean improvement programs in participating countries providing improved technologies/services throughout the region
4. Improved systems for domestic seed multiplication and distribution established in HCs
5. The U.S. bean industry stronger and more competitive internationally through more stable production and reduced production costs

TARGETED RESEARCH CONSTRAINTS (not in order of priority)

Major Constraints	Identified Need	Research to Meet Need
#1–Insufficient NRM and Production Technologies for Lowland and Highland Agriculture	Improved technologies and facilities for scientific research	• Develop better bean transformation techniques • Establish complementary regional centers of service, research and training in HC institutions • Establish small regional rhizobium inoculation trials to identify superior strain differences
	Germplasm diversity and management for crop improvement	• Increase germplasm collection, characterization and conservation • Screen for disease resistance and develop breeding lines for disease management • Establish drought tolerant nurseries for the region • Exploit the potential of wide crosses through biotechnology • Screen germplasm for nitrogen-fixing ability under low soil nitrogen • Develop germplasm with tolerance to low soil phosphorus • Clarify plant mechanisms for low phosphorus and calcium, and acid soils tolerance
	Management of natural resources other than germplasm	• Explore strategies for soil improvement including ways to increase soil organic matter • Develop new crop management systems for acidic oxisols/utisols with limited fertility • Develop greater nitrogen-fixing support • Explore strategies to improve nutrient uptake

Major Constraints	Identified Need	Research to Meet Need
	New varieties through conventional breeding and biotechnology	• Pyramid genes for disease resistance, heat and drought tolerance • Exploit resistance complementarity between Andean and Middle American germplasm pools • Enhance temperature tolerance traits and incorporate them into a range of seed types • Improve nutritional quality in consumer-preferred varieties • Complete and release improved lines currently in the pipeline • Continue cooperation with USDA/ARS on molecular markers/disease monitoring/early warning system • Develop varieties for the U.S. with disease resistance and heat and drought tolerance
	New knowledge and methods for virus control	• Clarify patterns of geminiviruses's dissemination by whiteflies • Inventory geminiviruses in crops and wild plants • Investigate cultural management practices for virus control • Evaluate integrated crop management strategies in validation plots • Explore the new virus class, comovirus • Identify the most virulent pathogens and characterize and monitor pathogen variations
#2–Limited Storage Options	Expanded affordable storage technologies	• Identify predominant storage constraints • Evaluate storage technologies generated by other CRSP participants
#3–Insufficient Utilization Research for Improved Nutrition/Product Development ***(Research partially funded by USAID's Office of Nutrition)***	Nutrient bioavailability research in bean improvement programs	• Improve bioavailability of proteins and other essential micronutrients in new varieties • Improve starch digestibility • Assess new varieties for nutrient bioavailability • Improve processing technologies for nutrient bioavailability
	Better breeding and nutrition cooperation	• Increase nutritional quality in preferred bean types • Reduce cooking time through breeding
	Value-added food products	• Develop new foods–weaning foods, nutritional rescue foods for at-risk children, snack foods • Continue product development research with Gerber Products Company
#4–Socioeconomic Research Insufficiently Integrated with Production/ Utilization Research	Bioecology studies for disease management and abiotic stress	• Characterize existing farming systems including technological and socioeconomic profiles • Involve growers in on-farm trials and participatory research to assure appropriate technologies • Identify socioeconomic constraints to farmer/consumer use of research products • Assess potential profitability of new techniques • Analyze institutional constraints to the diffusion of technologies
	Well-integrated WID research	• Ensure inputs from women farmers/consumers in research and evaluation of technical output • Define the roles/needs of women as cowpea growers, processors, consumers and entrepreneurs
	Macro-level research	• Identify policy constraints • Investigate pricing structures/conditions limiting production and distribution of improved seed • Explore other relevant macro issues including intra-regional trade • Document impact of the CRSP

TARGETED TRAINING CONSTRAINTS		
Major Constraints	**Identified Need**	**Research to Meet Need**
#5–Insufficient Cadre of Trained Personnel	Degree training	• Train research professionals in agricultural economics with a strong WID orientation; IPM/entomology with an emphasis in biocontrol; biometrics; food science; pathology • Support and strengthen training venues within the region as well as in the U.S.
	Non-degree training	• Organize training opportunities for HC breeders to learn new biotechnology tools • Encourage subject matter short-term training for professionals from one another's disciplines e.g., socioeconomic aspects of technology development, diffusion and adoption, impact assessment, nutrition and utilization, drought, cropping systems and disease management • Expand opportunities for keeping up to date with new scientific and communication technologies • Provide continuing education in support areas, e.g., research project management, identifying sources of support, resource management (time, funds, equipment, labor) • Organize extension worker training (requirements, potential, limits of new technologies)
TARGETED EXTENSION CONSTRAINTS		
#6–Insufficient Extension Services Supporting Bean Production in the Region	Expanded pre-extension efforts for certified seed	• Provide foundation seed for seed multiplication • Explore potentials for government and private seed multiplication entities
	Opportunities for improving extension of new technologies	• Work with national extension programs • Work with regional programs like PROFRIJOL, CATIE, CIAT and relevant NGOs • Search for ways to better integrate responses to the needs of women into extension process
	Expanded public/ private outlets for technologies/products	• Make new bean processing technologies available for commercial food sector • Establish system for assessing impact across the public/private sector
#7–Insufficient Collaboration between Research and Extension	Mechanisms for improved seed research/extension	• Work with seed agents to establish feedback mechanisms for researchers • Develop research/extension on-farms trials collaboration • Involve farmers actively in the process
	Opportunities for sharing new technologies with extension entities	• Plan opportunities with extension entities • Prepare informational materials on CRSP technologies for use by extension agents

APPENDIX B

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