EXECUTIVE SUMMARY

INTSORMIL

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Annual Report 1996

SORGHUM/MILLET COLLABORATIVE RESEARCH SUPPORT PROGRAM (CRSP)

Fighting Hunger with Research ... a team effort

Funding support through the Agency for International Development

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Cover Photographs
(top to bottom)

1. Ergot on sorghum at the Good Hope Station in Southern Botswana.

2. Plant Pathologist Esther Mtisi (right) with RSS in Zimbabwe and Agricultural Assistant Kevin Garutsa in a sorghum disease nursery at the Panmure Station north of Harare.

3. Left to right, all with DAR, Botswana, Plant Pathologist Phoebe Ditsipi, Entomology Assistant Motsweri Obipile, and Entomologist Chris Manthe in a late-planted seed increase plot of Phofu sorghum at the Sebele Station near Gaborone.

4. Dr. Yacouba Doumbia, IER Entomologist on left with three field technicians in a sorghum head bug nursery, Sotuba Research Station, Bamako, Mali.

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Grain Sorghum/Pearl Millet Collaborative Research Support Program (CRSP)

The Sorghum/Millet Collaborative Research Support Program (CRSP) is an initiative of the Agency for International Development, Grant No. DAN-1254-G-00-0021-00, Title XII and the Board for International Food and Agricultural Development (BIFAD), the participating U.S. Universities and other collaborating institutions.

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A Research Development Program of the Agency for International Development, the Board for International Food and Agricultural Development (BIFAD), Participating Land-Grant Universities, Host Country Research Agencies and Private Donors

INTSORMIL INSTITUTIONS

Kansas State University
Mississippi State University
University of Nebraska
Purdue University
Texas A&M University

INTSORMIL Institutions are affirmative action/equal opportunity institutions.

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Introduction and Program Overview

The Collaborative Research Support Program (CRSP) concept was created by the U.S. Agency for International Development (USAID) and the Board for International Food and Agriculture Development (BIFAD), under the auspices of Title XII of the Foreign Assistance Act, as a long term mechanism for mobilizing the U.S. Land Grant Universities in the international food and agricultural research mandate of the U.S. Government. The CRSPs are communities of U.S. Land Grant Universities working with USAID and USAID Missions, other U.S. Federal Agencies, developing country National Agricultural Research Systems (NARS), developing Country Colleges and Universities, International Agricultural Research Centers (IARCs), private agencies, industry, and private voluntary organizations (PVOs). The Sorghum and Millet Collaborative Research Support Program (CRSP) is one of eight CRSPs currently in operation.

The Sorghum and Millet Collaborative Research Support Program (i.e., INTSORMIL CRSP) conducts collaborative research using partnerships between U.S. University scientists and scientists of the National Agricultural Research Systems (i.e., NARS). INTSORMIL is programmatically organized for efficient and effective operation and captures most of the sorghum and millet research expertise in the United States. ***The INTSORMIL mission is to use collaborative research as a mechanism to develop human and institutional research capabilities to overcome constraints to sorghum and millet production and utilization for the mutual benefit of U.S. and LDC agriculture.*** Collaborating NARS and U.S. scientists jointly plan and execute research that mutually benefits developing countries and the United States. Prime sites will be maintained in the agroecological zones of western, southern, and eastern Africa, and in Central America. These sites support the general goals of building NARS institutional capabilities, creating human and technological capital for solving sorghum and millet constraints with sustainable global impact, promoting economic growth, enhancing food security, and encouraging entrepreneurial activities. The universities which are active in the INTSORMIL CRSP are Kansas State University, Mississippi State University, University of Nebraska, Purdue University, and Texas A&M University.

Sorghum and millet are important food crops in moisture stressed regions of the world. They are staple crops for millions in Africa and Asia which, in their area of adaptation, cannot be substituted by other cereals. The development of food sorghums and sorghums with improved feeding properties such as increased digestion and reduced tannin content has contributed to sorghum becoming a major feed grain in the U.S., and in other countries in South America. Pearl millet is becoming an important feed source in poultry feeds in the southeastern U.S. The new food sorghums produce grain that can be used for special ethnic and dietary products as well as for traditional food products. Special white sorghums in Mali have the potential for allowing farmers wives to process sorghum into high value food products for sale in village and urban markets which can compete with wheat and rice products. The traditional types of sorghums cannot make effective food products that can compete with wheat and rice products. Pearl millet also has great potential for processing into high value food products which can be sold in village and urban markets that can compete with wheat and rice products. These developments have occurred because of the significant interaction that INTSORMIL scientists, U.S. and Host Country, have from grain production through processing and marketing.

Although significant advances have been made in improvement and production of sorghum and millet in the regions which INTSORMIL services, population continues to exceed production capacity. There remains an urgent need to continue the momentum of our successes in crop improvement as well as our efforts in strengthening the NARS.

INTSORMIL has maintained a flexible approach to accomplishing its mission. In preparation for the 1996-2001 grant extension proposal, INTSORMIL has implemented several critical recommendations made by the External Evaluation Panel and an Internal/External Committee, with input from the INTSORMIL Technical Committee (TC) and Ecogeographic Zone Council (EZC).

The success of the INTSORMIL program can be attributed to the following strategies which guide the program in its research and linkages with technology transfer entities.

- **Developing institutional and human capital**: INTSORMIL will promote educational outcomes in collaborating host countries. The outcomes include institutional strengthening, development of collaborative research networks, promoting and linking to technology transfer and dissemination infrastructure development, and enhancing national, regional, and global communication linkages. ***A major innovative aspect of the INTSORMIL focus is to maintain continuing relationships with collaborating host country scientists upon return to their research posts in their countries. They become members of research teams of INTSORMIL and NARS scientists who conduct research on applications of existing technology and development of new technology. This integrated relationship prepares them for leadership roles in regional networks in which they collaborate.***

- **Conserving biodiversity and natural resources**: Research outcomes of the collaborative research teams include development and release of enhanced germplasm; development and improvement of sustainable production systems; development of sustainable technologies to conserve biodiversity and natural resources and to enhance society's quality of life, and enlarge the range of agricultural and environmental choices. Thus, INTSORMIL promotes conserving millet and sorghum germplasm, conserving natural control of sorghum and millet arthropod pests and diseases, developing resource-efficient cropping systems, developing integrated pest management programs, developing cultivars with improved nutrient and water use efficiencies, and evaluating impacts of sorghum/millet technologies on natural resources and biodiversity.

- **Developing research systems**: Collaboration in prime sites have been strengthened by using U.S. and NARS multi-disciplinary research teams focused on common objectives and unified plans. INTSORMIL scientists provide global leadership in biotechnology research on sorghum and millets. The output from these disciplinary areas of research are linked to immediate results. Biotechnology and other tools of science integrated with traditional science will contribute to alleviating production and utilization constraints in sorghum and pearl millet within the medium term of 5-10 years. New technologies are then extended to farmers' fields in developing countries and the United States through further collaborative efforts. In addition, INTSORMIL plays a part in initiating consideration of economic policy and processing constraints to regaining the competitiveness of sorghum and millet as a basic food staple.

- **Supporting information networking**: INTSORMIL research emphasizes working with existing sorghum and millet networks to promote effective technology transfer from prime sites to local and regional institutions. Technology transfer is strengthened by continued links with regional networks, International Agricultural Research Centers, and similar local and regional institutions. Emphasis is placed on strong linkages with extension services, agricultural production schemes, private and public seed programs, agricultural products supply businesses, and nonprofit voluntary organizations, such as NGOs and PVOs, for efficient transfer of INTSORMIL generated technologies. Each linkage is vital to development, transfer, and adoption of new production and utilization technologies.

- **Promoting demand driven processes**: Development of economic analysis for prioritization of research and farm-level industry evaluation and development of sustainable food technology, processing and marketing systems, are all driven by the need for stable markets for the LDC farmer. INTSORMIL seeks alternate food uses and new processing technologies to save labor and time required in preparation of sorghum millet for food. Research products transferred to the farm will seek to spur rural economic growth and provide direct economic benefits to consumers. INTSORMIL assesses consumption shifts and socioeconomic policies for reducing effects of price collapses, and addresses methods for reducing processing for sorghum and millet. Research outcomes seek to reduce effects of price collapse in high yield years, and to create new income opportunities. INTSORMIL socioeconomic projects measure impact and diffusion and evaluate constraints to rapid distribution and adoption of introduced new technologies.

The INTSORMIL program addresses the continuing need for agricultural production technology development for the developing world, especially the semiarid tropics. There is international recognition by the world donor community that the developing country agricultural research systems must assume ownership of their development problems and move toward achieving resolution of them. The program is a proven model that empowers the NARS to develop the capacity to assume the ownership of their development strategies, while at the same time resulting in significant benefits back to the U.S. agricultural sector and presents a win win situation for international agricultural development.

Administration and Management

The University of Nebraska (UNL) is the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of USAID. UNL subgrants are made to the participating U.S. Universities for the research projects between individual U.S. scientists and their host country counterparts. Country project funds, managed by the ME and U.S. participating institutions, flow to the country program in support of the research activities at the host country level. The Board of Directors (BOD) of the CRSP serves as the top management/policy body for the CRSP. The Technical Committee (TC), External Evaluation Panel (EEP) and USAID personnel advise and guide the ME and the Board in areas of policy, technical aspects, collaborating host country coordination, budget management, and review.

Several major decisions and accomplishments were made by the ME, BOD, and TC during the past year.

- The INTSORMIL Five Year Grant Extension Proposal was completed and submitted to USAID.

- INTSORMIL made its presentation for a new five year grant and was recommended for continuation, March 1996.

- The major publications organized and published by the ME office during the year included:

* INTSORMIL Annual Report 1995, INTSORMIL Publication No. 95-1 .

* INTSORMIL Annual Report 1995, Executive Summary, INTSORMIL Publication No. 95-2.

* INTSORMIL CRSP Directory, INTSORMIL Publication No. 95-3

* INTSORMIL Grant Extension Proposal, 1996-2001, INTSORMIL Publication No. 95-4

* INTSORMIL CRSP Directory update, INTSORMIL Publication No. 95.5

* Sanders, J., Shapiro, B.I., and Ramaswamy, S. 1996. The Economics of Agricultural Technology in Semiarid Sub-Saharan Africa. The Johns Hopkins University Press. 301 pp.

- The INTSORMIL Board of Directors appointed Dr. Oumar Niangado, Director General, IER, Mali to a two year term to the INTSORMIL Board of Directors.

- The Board of Directors approved the temporary appointment of a UNL faculty member, Dr. Dan Walters, at one quarter time to, fill the position of Associate Director.

- The 1995-96 Technical Committee (TC) was elected. The TC members are: Dr. Stephen Mason, University of Nebraska, Dr. George Teetes, Texas A&M University, Dr. Lloyd Rooney, Texas A&M University, Dr. Darrell Rosenow, Texas A&M University, Dr. John Axtell, Purdue University, Dr. Gebisa Ejeta, Purdue University, Dr. Aboubacar Touré, IER/Mali and Dr. Franciso Gomez, EAP/Honduras.

- The announcement for the "International Conference on Genetic Improvement of Sorghum and Pearl Millet", in Lubbock, TX, September 23-27, 1996 was distributed world wide. ICRISAT, INTSORMIL, Rockefeller Foundation and the ODA/Great Britain are cosponsors for this event.

- The USAID/Africa Bureau entered into an agreement with the IPM CRSP and the CRSP Council for implementation of an Inter-CRSP Natural Resource Management regional project for West Africa. The IPM CRSP was designated the lead CRSP for development of this effort. The starting date for this initiative was September, 1995.

- INTSORMIL has entered into an Memorandum of Agreement with the Institute of Agricultural Research (IAR) of Ethiopia.

Training

Training of host country scientists contributes to the capability of each host country research program to stay abreast of environmental and ecological changes which alter the balance of sustainable production systems. The strengthening of host country research institutions contributes to their capability to predict and be prepared to combat environmental and ecological changes which affect production and utilization of sorghum and millet. A well balanced institution will have to be prepared to prioritize and blend its operational efforts to accomplish the task of conserving and efficiently utilizing its natural resources. To this end training is an extremely critical component of development assistance.

During 1995-96, there were 57 students from 18 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. This was a decrease of 24% from the previous year. Approximately 77% of these students came from countries other than the U.S., which illustrates the emphasis placed on host country institutional development. INTSORMIL also places importance on training women which is reflected in the fact that 23% of all INTSORMIL graduate students were women.

The number of students receiving 100% funding by INTSORMIL in 1994-95 totaled 21. An additional 16 students received partial funding from INTSORMIL. The remaining 20 students were funded from other sources but are working on INTSORMIL projects. The number of students receiving 100% funding from INTSORMIL has dropped from a high of 71 in 1986 down to a low of 17 in 1993-94 and then 21 in 1995-96. This is, in part, due to training taking place under other funding sources, but an even more significant factor is that budget flexibility for supporting training under INTSORMIL projects has been greatly diminished due to reductions in our overall program budget and because of inflationary pressures.

In addition to graduate degree programs, short term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Several host country scientists were provided the opportunity to upgrade their skills in this fashion during 1995-96.

Networking

The Sorghum/Millet CRSP Global Plan for Collaborative Research includes workshops and other networking activities such as research newsletters, publications, the exchange of scientists, and the exchange of germplasm. The INTSORMIL Global Plan is designed for research coordination and networking within ecogeographic zones and where relevant between zones. The Global Plan:

- Promotes networking with IARCs, NGO/PVOs, Regional networks (ROCAFREMI, SADC and others)

private industry and government extension programs to coordinate research and technology transfer efforts.

- Supports participation in regional research networks to promote professional activities of NARS scientists, to facilitate regional research activities (such as multi-location testing of breeding materials), promote germplasm and information exchange, and facilitate impact evaluation of new technologies.

- Develops regional research network, short-term and degree training plans for sorghum and pearl millet scientists.

Over the years, established networking activities have been maintained with ICRISAT, SADC/ICRISAT, SAFGRAD, ICRISAT Sahelian Center, ICRISAT West Africa Sorghum Improvement Program, ROCAFREMI, EARSAM of ICRISAT, ICRISAT/Mexico, CIAT and CLAIS of Central and South America. There has been excellent collaboration with each of these programs in co-sponsoring workshops and conferences, and for coordination of research and long term training. INTSORMIL currently cooperates with the ICRISAT programs in East, Southern, and West Africa, and the ROCAFREMI (Réseau Ouest et Centre Africain de Recherche sur le Mil, Niger) of West/Central Africa. Sudanese collaborators have provided leadership to the Pan African *Striga* Control Network. INTSORMIL plans to strengthen linkages among the NARS it works with, as well as international and regional organizations and networks. INTSORMIL will continue to promote free exchange of germplasm, technical information, improved technology, and research techniques.

Benefits to Host Countries

Realized Benefits of Program

INTSORMIL can document a wide range of benefits to host countries, U.S. agriculture, and the broader scientific community. Many of these benefits have reached fruition with improved programs, economic benefits to producers and consumers, and maintenance or improvement of the environment. Others are at intermediate stages ("in the pipeline") that do not allow quantitative measurement of the benefits at present, but do merit identification of potential benefits in the future. The collaborative nature of INTSORMIL programs has built positive long-term relationships between scientists, citizens and governments of host countries and the United States. This has enhanced university educational programs and promoted understanding of different cultures enriching the lives of those involved, and hopefully making a small contribution to world peace, in addition to sustainably improving sorghum and pearl millet production in developing countries and in the United States.

International

Scientific by Technical Thrust

Germplasm Enhancement and Conservation

Germplasm exchange, movement of seeds in both directions between the U.S. and host countries, has involved populations, cultivars, and breeding lines carrying resistances to insects, diseases, *Striga,* drought, and soil acidity, as well as elite materials with high yield potential which can be used as cultivars per se or used as parents in breeding programs. Specific germplasm releases (including breeding lines) for host country use include the following.

- Improved yield (for all host countries)

- Improved drought tolerance (Africa and drier areas of Latin America)

- Acid soil tolerance

- *Striga* resistance (West, Eastern Africa, and Southern Africa)

- Midge and Greenbug resistance (Latin America)

- Downy mildew resistance (Latin America and Botswana)

- Anthracnose resistance (Latin America and Mali)

- Charcoal rot and lodging resistance (Africa and drier areas of Latin America)

- Head smut and virus resistance (Latin America)

- Foliar disease resistance (for all host countries)

- Improved grain quality characteristics for food and industrial uses (for all host countries)

The hybrid sorghum success story in Sudan traces to ICRISAT/INTSORMIL/ARC collaboration in which they developed, produced seed, and popularized the first hybrid sorghum, Hageen Dura-1 (Tx623 x K1567), for this country. The female line Tx623 was used due to its wide adaptation, high yield potential and drought resistance. It currently is produced on about 12% of the sorghum area in the Sudan Gezira Irrigation Scheme, the largest in the world under one management. The Hageen Dura-1 success story provides an example of the potential economic gains possible through plant breeding research, followed by seed production/marketing activities. Impact studies show that the internal rates of return to this research without further extension of the production area in Hageen Dura-1 were 23% for low fertilizer levels, and 31% for high fertilizer use levels. With the present rate of diffusion, the investment on this research would pay approximately $1 million of annual benefits. The

line Tx622 (a sister line to AT623 in Hageen Dura) has been introduced to China, and is used in hybrids planted on tens of thousands of hectares.

In Honduras, three food-type high yielding sorghum maicillo cultivars have been tested and released. These are Tortillero (CS3541 Sel.), Catracho (Tx623 x Tortillero), and Sureño [(SC423 x CS3541)E35-1]-2-2. Sureño, in particular, has widespread acceptance by Honduran farmers because of its superior grain quality, high yield potential, disease resistance, and dual purpose use for both forage and grain. It is the first sorghum cultivar released by the MNR that has found its way into informal seed markets in Honduras. INTSORMIL's socioeconomic research has also shown that in Honduras the internal rate of return to the development of two new sorghum cultivars, Sureño and Catracho, which are in diffusion, is estimated at 32% or, on annuity basis, $0.7 million annually for the next 30 years. These new sorghum cultivars have economically benefited small farmers dependent on small-acreage hillside farms, the poorest farmer segment in Honduras. Seed production continues to be a problem, however, this is expected to be resolved through the assistance of the new seed processing plant at Escuela Agricola Panamericana (EAP). This linkage will assure production of good quality, certified seed.

The INTSORMIL/Honduras sorghum project has been cooperating with the "Poligono Industrial Copaneco", a religious NGO funded by the Belgium and Canadian governments. The sorghum project has been providing technical advice on agronomic management and marketing of broom corn fibers. The NGO project is producing broom corn fiber and selling it to "Broom and Mops", a broom export factory located at San Pedro Sula in Honduras. Traditionally broomcorn fiber is either imported from Mexico by two or three companies in Central America or produced by small farmers using seed removed from the imported fiber. The result is an increase in costs due to imported fibers and poor fiber quality produced by the small farmers. INTSORMIL/Honduras has developed a new long fiber variety of "broom corn" sorghum which will compete more successfully with imported fibers from Mexico. Seed increase of this new variety was made in 1995. In January, 1996 another field was planted to produce approximately 200 kg of basic seed which will be used to produce certified seed for use by the broom corn producers. Cost benefit analyses indicate this to be a profitable business for small producers to participate in.

Honduras plays a unique role in conservation of local landrace sorghum germplasm (maicillo or photoperiod sensitive sorghum). Central America is the only location in the world where sorghum has evolved to fit the cropping systems of the steepland hillsides. The INTSORMIL/Honduras sorghum project has assumed the responsibility for conserving this sorghum gene pool. The goal of the conservation effort is to create a mosaic of maicillo, enhanced maicillo, and improved variety fields in which genes flow freely among these different kinds of sorghum. Ostensibly, an informal network of village level landrace custodians will care for this germplasm as they have cared for maicillo. The creation of enhanced maicillo cultivars and their subsequent deployment on-farm, not only is intended to increase genetic diversity *in-situ*, but to stave off maicillo's replacement by introduced cultivars. Two new improved varieties, Gigante Mejorado and Porvenir Mejorado have shown outstanding performance across five testing locations in Honduras. Other new enhanced cultivars are being tested on farmer's fields through the on-farm demonstration system in 1966.

In Central America sorghum utilization patterns are shifting as the demand for poultry rapidly increases (8.4% annually in Honduras). For the time period of 1990-1993 sorghum production in Central America grew 18 percent, at a rate of 4.42% per year. Seventy six percent of the sorghum was utilized for animal consumption and 17% for human consumption in Honduras in 1994. For human consumption 6% was for on-farm use and the other 11% was sold. With the rapid expansion of poultry feeding, sorghum has been fillling much of the increased demand for feed grains. Of the cereal component in Honduran commercial feeds, sorghum increased its share from 4% in 1985 to 26% in 1993. All over Central America there has been a rapid growth of hybrid sorghum seed sales for use in production of sorghum grain for feed. It is estimated that 35% of the sorghum area was planted to hybrids in 1995. Sorghum is successfully replacing maize in animal feed and releasing an equivalent amount of white maize for human consumption.

The principal objective of an impact assessment activity completed in July, 1996 was to measure the impact of the new cultivars and associated technologies developed in the SRN/EAP/INTSORMIL program in Honduras. Secondly, the assessment team looked at the impacts and production systems in other principal sorghum producing countries in the region, El Salvador, and Nicaragua. The primary research output in all three countries was the selection of new higher yielding white seeded varieties of sorghum. Conclusions reached from this impact assessment of the Sorghum/Millet CRSP research in Central America indicate that benefits from the varietal research in the three countries ranged from $437,000 per year in Nicaragua, $600,000 in Honduras (low side estimate), to $1,900,000 per year in El Salvador. The two new cultivars introduced in El Salvador were introduced with more extension and public policy support for improved seed production and credit. Estimates include only the benefits accruing from the adoption of cultivars developed by the public research systems. Note that only the Honduras benefits can be totally credited to the SRN/EAP/INTSORMIL program. In Honduras improvements in the quality and availability of seed of varieties will continue to be critical for small-and medium-scale farmers.

A new drought tolerant sorghum hybrid designated NAD-1 (NAD-1 = Tx623 x MR732) has proven to be highly productive and well adapted in Niger. The grain quality is acceptable for local food preparations and the yields reported from 100 on-farm demonstration plots in 1992 were approximately twice the yields of local varieties. Overall,

the average yield of NAD-1 between 1986 and 1994 is 2758 kg/ha on-station, ten times the average yield of the farmer in Niger (273 kg/ha). In 1993 the farm level plots showed the average farmer yield for the Konni and Jirataoua region was 2365 kg/ha for NAD-1. In 1994, NAD-1 yielded an estimated 1725 kg/ha (Say), 3500 kg/ha (Jirataoua), 3800 kg/ha (Cerasa), and 4600 kg/ha (Konni) for an overall farmer yield of more than 3000 kg/ha. This is compared to the national average of 273 kg/ha. In 1995 farmer demonstration trials were conducted in an area extending from Konni to Zinder eastward and as far north as Dakora. The 1995 trials compared the NAD-1 hybrid yields to one of the best local landraces, Mota Maradi (MM). The objectives were to check the extent of NAD-1 superiority over locals under as diverse conditions as possible with farmer management, and assess its area of best performance. A preliminary yield analysis showed that, overall, NAD-1 yielded an average of 1.6 t/ha compared to 1.1 t/ha for MM. This is about 50% better yield for the hybrid. This is especially important because 1995 was not a good year. Farmer interest has been very high. Head size and grain yield have been impressive. This is the first sorghum hybrid that has actually reached farmer fields. In early 1996 a seed program consultancy sponsored by INTSORMIL was put into place. The draft report indicates that the Hybrid NAD-1 and the country of Niger fulfill three basic requirements for the establishment of a seed industry, i.e, (1) it is important that a cultivar be identified that has significant yield, good grain quality and is not more susceptible to pest than local varieties; (2) the area in the country should be large enough to support a seed industry and this exists in Niger (area sown to sorghum is in excess of one million hectares); and (3) the cultivar involved should be a hybrid to permit the establishment of a suitable market and the hybrid should be readily produceable. Results of Regional Trials indicate a wide adaptation of NAD-1 in other countries of the region indicating the opportunity for an international market. The experience of developing a private seed industry in Niger would be immediately valuable to other countries of the region with the production and marketing of hybrid seeds as they realize superior hybrids from their research.

Through the integrated cooperation of sorghum breeders and food scientists we now understand many of the factors necessary for improving the nutritional value of sorghum through local village processing. Sorghum flour is less digestible than most cereal flours unless it is processed using local village procedures which have evolved over hundreds of years. We now understand the scientific reasons why processing is important. This knowledge will help modify and improve the traditional processing methods and to develop improved processing methods for utilization in other countries in the world where sorghum is used as a feed for food grain. This annual report notes for the first time that a genetic solution may be possible for the digestibility problem. Dr. Bruce Hamaker, INTSORMIL scientist in the Food Science Department at Purdue University, has been collaborating on studies of new genetic lines of sorghum with protein digestibilities equivalent to maize. Studies are in progress to determine the inheritance of this important newly identified trait in sorghum.

A *Striga* resistant variety, SRN-39, has been identified as promising and released for production in Sudan. In one area alone about 1200 ha of SRN-39 was grown in 1992. SRN-39 and other possible sources of resistance to *Striga* are being used in breeding programs in Sudan, Mali, Niger and other countries to improve adaptation, yield potential and agronomic characteristics. They are being tested in integrated control programs with various cultural practices, fertilizer management, and different mechanical and chemical control strategies. Recently eight tons, one ton each of eight high yielding *Striga* resistant food grain sorghum varieties were released by Purdue University to the PVO, World Vision, for use in nine countries in Africa. During the first eleven months of operation these *Striga* resistant food quality sorghums have been tested on field stations or in farmers fields, or both, in the following countries: Ghana, Senegal, Mali, Niger, Sudan, Rwanda, Mozambique, and Eritrea. Information and data about the impact and potential impact of these varieties will be available by the end of calendar year 1996.

Excellent progress has been made in Mali to develop white-seeded, tan-plant guinea cultivars. F_6 progenies from crosses involving Bimbiri Soumale and CSM388 look very promising. Emphasis is also being placed on intercrosses using the experimental guinea-type white seeded tan-plant cultivar named N'Tenimissa (Bimbiri Soumale x 87CZ-Zerazera) with elite local guineas and with other high yielding non-guinea breeding lines which lack the necessary head bug tolerance. They have good guinea plant, grain, glume, and panicle characteristics, and some have juicy stems. Two new lines were selected in 1995 for on farm farm testing in the rainy season of 1996. Grain of N'Tenimissa will be increased on about five ha in 1996 for use in utilization and value-added product development. The PVO, World Vision, plans to distribute N'Tenimissa in 20 on farm trials in 1996. In Northern Mali, CARE is cooperating with IER and testing new sorghum cultivars at about 20 sites.

Sustainable Production Systems

In agronomy and soil/crop management, a major INTSORMIL impact has been understanding the soil/cropping system/genotype interactions. Rotation with cowpea in Mali increased pearl millet grain yield by 19,17,31,27,and 30% in 1991,1992,'993,1994, and 1995 respectively, while application of 40 kg/ha N fertilizer increased grain yield 8,20,16,35,and 6%. All cropping system plots had lower ph, N,K, and Mg levels than the fallow after four years, suggesting that all continuous, rotational, and intercrop systems studied were mining nutrients. Research in Mali has shown that small nitrogen (N) additions are beneficial and necessary to sustain sorghum grain yields. In 1994, the increase in pearl millet yield due to N application was 31% and 66% with 20 kg/ha N and 40 kg/ha N, respectively, in monoculture and 64% and 66% for 20 kg/ha N and 40 kg/ha N, respectively, in millet-cowpea rotation. Crop rotation (mil-

let-cowpea) alone without N increased millet grain yield by 74%. The legume effect appears worth 30 to 40 kg N/ha. This information has been compiled and is being used by extension personnel in their recommendations to farmers.

In both Mali and Niger, increasing the production level through use of manure and fertilizer, higher plant population resulted in increased grain yield of all pearl millet cultivars, suggesting that differential production practices are not required. However, in both locations, cultivar grain yield differences were large among cultivars, indicating the importance of cultivar selection.

INTSORMIL research results have demonstrated 18 to 203% yield enhancement of pearl millet and grain sorghum yields in Africa by use of crop rotation with legumes, and a 20 to 50 kg/ha N equivalent contribution to cereals following legumes. In Mali and Niger, intercropping has shown land use efficiency increases of 14 to 48% over sole crops, and also enhanced yields of succeeding crops when intercrop legume yields are high. Obviously legume production, no matter the system, is important to producing optimal sorghum and pearl millet yields when N fertilizer is limiting, especially for improved cultivars.

In Mali crop residue management research with residues removed, left on the surface, and incorporated had no effect on pearl millet or cowpea yield or stover yield. Similar results have been recently reported by the ROTOPHOS project, University of Hohenheim, Germany, on Nigerien sites that were not degraded and that had medium to higher soil P levels.

New research on production practices for improved pearl millet genotypes was initiated. Advanced, recently released, and improved local cultivars were produced at different fertilizer levels (manure and N) and plant populations. No cultivar by production practice interaction was found, suggesting that the cultivars respond similarly to these practices. The advanced cultivars "Benkadinio" and "Sanioba 03" yielded 100-300 kg/ha better than the other cultivars. Increasing the fertilizer rate to the highest level (15 t/ha manure plus 100 kg/ha N) increased grain yield from 1246 to 2475 kg/ha and stover yield from 3178 to 5067 kg/ha. Increasing plant population slightly decreased grain yield.

In Botswana, the benefits of single element fertilizer have been determined and demonstrated to farmers. Water harvesting technology has been evaluated and appropriate recommendations have been extended to farmers. Management practices on water runoff show if additional water could be diverted to a site, better yields resulted. Increased water availability must be coupled with the proper plant population, fertilizer level and pest control to produce high yields. In the event that excess water occurs, the system must be designed to release water without erosion. The National Tillage Trials showed early tillage frequently improved soil water storage. This coupled with 15 kg P ha^{-1} fertilizer increased yield. Due to low sorghum yield potentials, addition of phosphorus (P) was not economical where soil P was greater than 5 mg kg^{-1}. Nitrogen did not increase yields unless rainfall was uniformly distributed during the season, while manure/crop residue additions were effective in increasing water intake and grain yield.

Research in Mali and Botswana has shown that grain yields do not always increase with applied fertilizer N when conditions are extremely dry. However, in the higher rainfall regimes, yield increases are consistently obtained with N application. In Mali, the local varieties such as Tiemarifing have produced higher N use efficiencies than the improved types such as Malisor 84-7. There is a need for P in sandier soils, and this often is the mineral element most limiting in Mali and Niger sorghum and pearl millet production.

Stand establishment problems of sorghum and pearl millet, especially improved cultivars, is common due to heat and water stress, crusting, and due to the small seed size. Pearl millet research indicated that screening for large seed, or producing large seeds by partial head removal, improves stand establishment and often grain yield.

Stand establishment research on sorghum indicates that kernel density is associated with seedling vigor and emergence, and the germination/emergence temperature response varies greatly among genotypes. Emergence potential in crusted soils is associated with large coleoptile diameters, and is a highly heritable trait with additive gene effects.

Sustainable Plant Protection Systems

In crop protection, a wide range of sources of resistance for insects, diseases, and *Striga* have been identified and crossed with locally adapted germplasm. This process has been improved immensely by INTSORMIL collaborators developing effective resistance screening methods for sorghum head bug, sorghum long smut, grain mold, leaf diseases and *Striga*.

INTSORMIL scientists and their collaborators identified sorgoleone, a group of chemically reactive oily quinones exuded from the root hairs of sorghum, as the first natural germination stimulant identified from a *Striga* host. Sorgoleone has other properties, including herbicidal and antibiotic, and is a powerful contact allergen. In the field, *Striga* germination is not controlled by sorgoleone but by a different set of compounds exuded by host roots. These compounds are more stable and more water soluble than sorgoleone.

The INTSORMIL PIs have studied each stage of the *Striga* life cycle separately. They are characterizing the host-parasite interaction at each stage, particularly the chemical signals exchanged. For each stage, simple ways to detect ineffective interactions are sought such as an agar gel assay for germination stimulant production. These screening methods are being used to identify crop genotypes

bearing the resistance-conferring traits, and to map the traits on the sorghum genome.

The necessity of coordinating the life cycle of *Striga* with that of its host has led to the recognition of the tight integration of the *Striga* life cycle with growth and development of the host by means of a series of chemical signals exchanged between the two. INTSORMIL scientists have played an important role in the identification of the first signal, germination stimulant, and have provided evidence for later signals exchanged in both directions between *Striga* and its host by means of vascular connections, rather than through the soil medium as for germination stimulant and haustorial initiator.

The collaborative research on African sorghum head bugs in West Africa, especially in Niger and Mali has quantified damage (yield and quality loss); identified resistant genotypes, including practical methodology to screen for resistance; and described bug species composition, biology, and population dynamics. Research activities have studied the bio-ecology of head bug (*Eurystylus marginatus*) and the identification of new resistance sources to be used in integrated pest management programs. The larva and adult populations of head bugs vary naturally across years. During 1995/96 field observations at Sikasso and other areas south of Bamako, Mali, especially where sorghum had not been grown extensively for many years, head bug infestations were observed to be low. At Cinzana experiment station, bug infestation was very severe. Bug infestation at Sotuba was low. The lateness of planting at Sotuba could have caused bug infestations to be lower than usual. There was evidence that bug infestation levels were increasing, and this was especially true at Samanko (ICRISAT) where bug infestation was beginning to increase to very severe levels. Progress is being made by Malian sorghum breeders to develop improved sorghums, especially the improvements to Guinea-type sorghums. It also, is now apparent that resistance to panicle-feeding bugs can be transferred to elite varieties. The important possibility is that if improved Guinea sorghums have moderate levels of resistance and bug severity is less in farmers' fields, panicle-feeding bugs may pose little production constraint to sorghum in Mali.

Sorghum lines resistant to sugarcane aphid have been identified in Botswana and Zimbabwe, and the mechanism of resistance assessed. Genes for resistance have been identified, confirmed, and initially utilized. Efforts are now being made to move the resistance genes into parental lines which are used in hybrid combinations for combine height, early maturing genotypes with acceptable agronomic trans..

Work continues on identification of the most important disease constraints and for design of disease control strategies. This includes continued studies on the variability of *Colletotrichum graminicola* (anthracnose) and genetic resistance of sorghum grown in Honduras to anthracnose. INTSORMIL pathologists continue to collaborate with ICRISAT on growing, distributing, and evaluating the Sorghum Anthracnose Virulence Nursery. The program continues to monitor the major downy mildew screening program run by the Honduran National Program to evaluate disease and host plant resistance.

In Mali, efforts are being continued toward the establishment of a National Sorghum and Millet Disease program. This includes evaluation of INTSORMIL nurseries for reaction to the prevalent pathogens in Mali. INTSORMIL pathologists (NARS and U.S.) are collaborating with program entomologists to study the interaction of head mold and insects (head bug) on grain deterioration in the field.

In Niger, INRAN/INTSORMIL pathologists are continuing to monitor for resistance to long smut, and evaluation for resistance to head smut, Acremonium wilt, and anthracnose. The Niger program has reported the infestation of nematodes on pearl millet for the first time. The species found belong to the genera, *Helicotylenchus, Criconemella* and *Tylenchorynchus.* Preliminary results do not prove that nematodes are a serious threat to pearl millet, but they do give some indication of their relative importance. Pearl millet does serve as a good host for many species of plant parasitic nematodes. Until now, there have been no reports on the importance of nematodes on pearl millet in the Sahel. This lack of research on nematodes on millet and sorghum in the Sahel may be partly explained by the assumption that nematodes cannot survive in an environment which is to dry and hot. These species of nematodes plus *Pratylenchulus spp.* were also found on sorghum in the Konni area where the level of infestation was much higher and threatening. This is the first time that nematodes have been shown to infect sorghum in Niger. This finding is very important because the Konni area is the sorghum belt in Niger.

In Honduras and Niger, INTSORMIL entomological collaboration has resulted in development of sustainable biological control strategies for stem borers, and information on pest and natural enemy biologies has contributed improved approaches to IPM. For whorlworms in Honduras, techniques were developed to manipulate key natural enemies; for stem borers. An efficient natural enemy was imported, released in Honduras and established; for stem borers in Niger, natural enemies have been demonstrated to occur in greater densities in natural vegetation than in millet, a suggestion that the substantial changes in pearl millet production practices is interfering with biological controls.

MHM, Pearl millet head miner *(Heliocheilus albipunctella)* is a serious insect pest of West Africa, and has been found to be an excellent candidate for biological control since it has a predictable habitat, consistent annual habits, produces one generation per year, and has several natural enemies. Two major predators and two commonly encountered parasites have been identified, and are being studied. During 1995/1996, two NARS scientists from West Africa were admitted as graduate students in the Department of Entomology at Texas A&M University. In 1996 they will

begin their graduate degree research at the ICRISAT Sahelian Center. Their research objectives and results will build on findings for MHM biological control reported by INTSORMIL scientists in 1994 and 1995 Annual report. When this research is complete, the key mortality sources, including natural enemies of MHM, will be identified and methods of manipulation will be described for those that can be effectively managed for optimal mortality to MHM populations. The INTSORMIL MHM research continues to coordinate closely with the West Africa ROCAFREMI millet network. INTSORMIL participated in the three ROCAFREMI network meetings during this program year.

Derivatives of SC326-6 continued to show good adaptation and resistance to anthracnose and other foliar pathogens in Zambia and Zimbabwe but a few did show some vulnerability to sooty stripe disease. These lines are being utilized as parental lines in breeding programs. A virus apparently similar to MDMV-A again caused high infection in a late planting of A-lines of released hybrids at one location in Zambia and it (or another virus) was also present in several sorghums in the Pandamatenga and Southern regions of Botswana including a newly released sorghum variety. Live virus samples collected from Zambia and Botswana and sent under a special import permit are being characterized by Dr. S. Jensen at the University of Nebraska.

A bacterial disease of pearl millet first observed in Southern Zimbabwe in 1995 has been tentatively identified as *Pseudomonas syringae* by D. Frederiksen at the University of Zimbabwe. If confirmed this would be the first report of *P. syringae* on pearl millet outside of the United States.

In Honduras insect pest control developed for one species or a complex of species involves the integration of specific management tactics, possible applied throughout the crop growing season, in a holistic crop management system. This holds true for insect pest management in subsistence farming, as it does for high technology crop production. Host plant associations have been identified and ecological relationships have been identified and ecological relationships defined for three of the "langosta" defoliator species. These investigations have provided the information for design of integrated insect pest management programs for designated crop production areas. The use of cultural methods (e.g., planting dates and weed management in production fields), crop varieties with insect resistance, and limited and judicial use of insecticides, as previously identified will benefit sorghum-maize production in Honduras and other areas in Latin America having similar crop production problems.

Crop Utilization and Marketing

In Mali a survey on "Sorghum Diversification of Processing and Utilization" was done using the new white-seeded, tan-plant variety N'Tenimissa. Two hundred 500 gram packets of sorghum grits and flour were placed in a supermarket. Results indicated that 80% of the people that brought the samples liked the products very much, and the other 20% did not respond. This test will be expanded in 1996/97 to about 10 supermarkets.

Major economic changes in Mali relate to the price and availability of wheat for bread and biscuits. There is an economic demand for sorghum, millet or maize flour to extend wheat flour in biscuits (cookies) and French breads. Industry personnel wanted to use maize because they had reports discouraging the use of sorghum because the local sorghum flour has been of poor quality. This poor image of sorghum and millet as a food item is a major problem.

The Cereal Quality Laboratory (LQC) at INRAN in Niger has conducted several surveys to determine the effect of crop selection and pearl millet varieties on couscous preparation in Niger. Sorghum, pearl millet, and durum wheat all produced acceptable couscous in this study. Work continues with INRAN/Niger scientists on sorghum and millet-based couscous. A couscous processing unit has been put into place at INRAN, with funding assistance from the Niger USAID Inter-CRSP initiative. The processing unit consists of a decorticator/mill, agglomerator/siever (designed by CIRAD, France), steamer, solar drier, and packaging sealer. This will be used for research purposes, and also as a demonstration and testing unit to encourage local entrepreneurs to commercialize millet or sorghum couscous. A commercial-type product will also be tested in the market place.

MILEG, a prepared weaning food from dehulled pearl millet and cowpea flours (3:1 blend), is being produced and sold by a small food company in Bamako, Mali. The product prototype was developed cooperatively by the Institute of Rural Economy food technology laboratory, with assistance from INTSORMIL/Texas A&M University food scientists. The businessman, who formerly worked as a technician in the IER Food Technology Laboratory, was financed by a loan from a Canadian agency. The product has been in production for nearly two years. It is being prescribed by medical staff for children suffering from malnutrition. It is not a complete weaning food, but it definitely has improved nutritive value at a reasonable cost compared to other more completely balanced imported weaning foods.

Benefits to the U.S.

Germplasm Enhancement and Conservation

INTSORMIL PIs have developed numerous germplasm lines resistant to biotype C, E, and/or I biotype greenbug which have been distributed to private seed companies for use in their breeding programs. Testing of advance B-line selections resistant to biotype E greenbug continued in 1995. Lines identified for release, with their experimental designations are GR107090M17, GR108-90M23, GR134A-90M50, and GR127-90M21. Each line produces hybrids with excellent yield. Increased emphasis was given in 1995 to development of new germplasm lines resistant to both greenbug biotypes E and I. Two excellent sources of resis-

tance have been identified for biotype I resistance, PI550607 and PI550610. To diversify the germplasm base of greenbug resistant germplasm, PI550607 is used exclusively in R-lines and PI550610 primarily in B-lines. Gene mapping has shown that genes conferring resistance to different greenbug biotypes are slightly different, but probably control the same resistance process.

INTSORMIL research has confirmed that sorghum midge abundance the subsequent year is reduced when sorghum residue containing overwintering larvae is shredded, disked, and deep plowed after harvest compared to when residue is only shredded or shredded and disked. Sorghum midge resistance in sorghum is caused by morphology of spikelets and asynchrony between time of flowering during the day and the presence of sorghum midges. Germplasm resistant to sorghum midge, developed through INTSORMIL support, has served as the foundation for many similar breeding programs throughout the world. Experimental sorghums with female parents A91-6, A92-3, and A93-6 produced superior hybrids during the previous two years and will be released to the commercial seed industry. Hybrid seed has been distributed to commercial seed companies and extension personnel to evaluate hybrid performance in a large range of environments with or without sorghum midge present. The lines will be released to other breeders during the fall of 1996. These will be the first sorghum midge resistant A/B pairs with the traits needed to produce commercially acceptable resistant hybrids.

Materials from the INTSORMIL/USDA/Texas A&M University Sorghum Conversion Program and selected breeding cultivars from other projects are evaluated regularly for resistance to internationally important diseases and insects in a cooperative/collaborative program throughout the sorghum growing world. INTSORMIL PIs have cooperated in the release of 360 converted exotic sorghum lines. The releases were made in three groups: 240 lines in 1986, 110 in 1992, and 50 fully converted exotic lines and 253 partially converted bulks were released in 1994/95. Sets of the 50 converted lines and the 253 partially converted bulks released in May, 1995 have been distributed to 11 private companies and 4 public sorghum breeding programs.

In January 1995, INTSORMIL/Purdue University reported a breakthrough in sorghum digestibility research. Irregularly shaped protein bodies discovered in sorghum kernels under the electron microscope may signal improved human nutrition in some developing countries and higher quality livestock/poultry feed worldwide. In 25 experimental genetic lines of sorghum, two have been identified with significantly faster protein digestion. These two genetic lines of more highly digestible sorghum fall right between maize and wheat in digestibility. The more digestible lines maintain 80 percent digestibility, even after cooking. Most sorghum varieties lose digestibility in cooking; some drop to as low as 46 percent. That makes sorghum potentially competitive with other cereal grains as a source of dietary protein for humans and livestock/poultry. Poultry feeding tests have been initiated to verify the findings.

Sustainable Production Systems

Research in the area of mineral stress, particularly nitrogen, has shown that certain genotypes cope with low soil nitrogen better than others by a rapid mobilization of that element to actively growing tissue which sustains whole plant photosynthesis and thus growth. Also, certain sorghum genotypes have higher photosynthesis rates at lower tissue nitrogen concentrations than others, which allows continued growth at low nitrogen supply. Sorghum varieties having known N use efficiency (NUE) characteristics were studied to determine the physiological basis for superior NUE. The study clearly demonstrated the superiority of two sorghum lines from China for CO2 assimilation capacity when leaves were experiencing N stress (deficiency). Analysis of the data indicated that the enzyme of particular interest is most likely phosphoenol pyruvate carboxylase, the first catalytic enzyme in the CO2 capture process in cells.

Studies to develop an agronomic production practices package for dwarf pearl millet as a new alternate crop for the U.S. have been initiated. Narrow row spacing, nitrogen application, and good weed control were identified as important practices, although pearl millet appeared to be more competitive with weeds than grain sorghum.

Sustainable Plant Protection Systems

INTSORMIL PIs developed an International Anthracnose Virulence Nursery which is used to monitor the pathogen. This nursery is now managed in cooperation with ICRISAT. The system of networking includes the growing of several uniform nurseries in locations where sorghum/millet diseases are important, such as the International Sorghum Anthracnose Virulence Nursery, which is grown where anthracnose is endemic. Other nurseries include a uniform nursery for head smut, sorghum downy mildew, sorghum viruses, and grain mold. Growing of these nurseries permits a quick evaluation of pathotype differences among locations and the severity of the problem. INTSORMIL also evaluates and distributes elite sorghums in nurseries for evaluation of the multiple resistance of sorghum. These are international nurseries and represent a means of distributing elite germplasm from different breeding programs in INTSORMIL.

INTSORMIL PIs have developed a dot immunobinding assay (DIA) to distinguish different bacterial pathogens of sorghum and millet. The test is easy to perform, inexpensive, requires limited equipment and chemicals, and was designed with LDC laboratory conditions in mind. It has been shown that the causal agent of bacterial leaf streak is seedborne and can remain viable in the seed for more than two years.

International collaborative research programs with NARS and ICRISAT scientists have resulted in the devel-

opment of sustainable insect management strategies and identification of sorghums resistant to sorghum midge, greenbug (biotypes C, E, and I), African sorghum head bugs, sugarcane aphid, and yellow sugarcane aphid. Mechanisms and inheritance of resistance have been determined, and genes conferring resistance have been introgressed into elite parental lines that have been evaluated alone and in hybrid combinations. Levels of resistance have been quantified, and economic injury levels established for most of them.

INTSORMIL research has employed a holistic approach to identify, evaluate, and deploy sorghum midge, greenbug, and yellow sugarcane aphid resistant sorghums as a component of IPM, and develop and validate sorghum plant and sorghum midge dynamics computer models.

Significant advances were made in developing the technology to allow farmers to manage these sorghum insect pests. Significant advances have been made in biological control and these advances contribute to improved IPM of sorghum and millet, and to improved concepts for using biological control in annual crops. For aphids attacking sorghum in the U.S., predators were demonstrated as key natural enemies for effective biological control of these pests. In the U.S., phytoseiid predators have been demonstrated as an effective alternative to pesticides for control of spider mites and parasites, and were shown to be effective on the American sugarcane borer attacking sorghum.

Biological and ecological relationships and insecticide susceptibility for fall armyworm for Florida, Mississippi, Honduras, and Jamaica have been determined. This provides a basis for understanding infestations and developing control strategies for this migrating insect pest of economic importance in the U.S.

The impact of insect resistant germplasm in sorghum production of the U.S. has been dramatic. For example, insecticide use on sorghum in Texas was at an all-time high at the initiation of this CRSP. In 1978, nearly 60% of the sorghum acreage in Texas was treated with insecticide, while in 1990 only about 24% of the acreage was treated. The savings gained from not using insecticide were $6,000,000 per year, and this does not consider the ecological or environmental benefits, or benefits from reduction in insect pest resurgence or secondary pest outbreaks. During this project, the economic benefit to Texas farmers has been at least $90,000,000.

Crop Utilization and Marketing

INTSORMIL scientists originally addressed the tannins as antinutritional factors. They developed methods, now widely used by others, for assaying and characterizing these materials. They also developed a simple method for detoxifying and improving the nutritional value of high tannin sorghum. They are elucidating the biochemical mechanisms by which tannins exert their antinutritional effects. They are also characterizing the role of tannins and related materials in resistance to birds, molds, and leaf diseases. Methods for polyphenol analysis, purification and characterization have been widely adopted and used by nutritionists and ecologists studying tannins in other crops and range plants.

The most significant finding of late concerns the poor protein digestibility of sorghum. In screening 25 selected sorghum genotypes for *in vitro* protein digestibility they found a range from 66 to 88% for uncooked values and 48 to 81% for cooked values. Two sorghum lines had notably higher digestibilities compared to the other sorghums tested. Perhaps more important, digestibility of these two sorghums did not decrease appreciably on cooking, which is commonly seen with sorghum. This was verified using two *in vitro* enzyme systems. Chemical studies showed that in the two highly digestible sorghums the major storage protein (about 65% of total protein), α-kafirin, was digested much earlier than the other sorghum samples. Also, a group of high molecular weight proteins, that usually restrict the digestion of α-kafirin, was digested very rapidly. This group of sorghums is now being grown to determine if this is a heritable trait. If this proves to be so, we believe that a rapid screening assay for digestibility can be developed based on chemical differences between genotypes.

The chemistry, composition, structure and nutritional value of sorghum kernels has been related to genes that control pericarp thickness and color and the presence and absence of a pigmented testa. From this knowledge, several white, tan plant sorghum inbreds have been released to the seed industry and are being grown in the United States. These food hybrids have improved quality for use in livestock feed as well as ingredients in food systems.

New prototype food products including noodles, ready-to-eat breakfast foods, weaning foods, granolas, instant porridges, baked products and others have been developed from 100% sorghum and millet for potential utilization in several countries. Products have been made with sophisticated techniques like extrusion and micronizing and also with simple, low-technology methods appropriate to targeted countries. The major constraint limiting their application is the lack of a consistent supply of good quality sorghum and pearl millet grains at a competitive price.

Sorghum has been used to produce tortilla chips, tortillas and related products from alkaline cooking. Several new cultivars with improved tortilla making quality have been or are near release in Central America because of collaborative work within the breeding programs. A simple test to evaluate tortilla potential of sorghums has been successfully utilized.

New waxy and heterowaxy sorghum cultivars and hybrids have been developed with unique properties for use in food systems. A white, tan waxy sorghum produced flakes for granola using micronizing. These JOWAR flakes have excellent potential for use in a wide variety of products. The same grains have excellent steam flaking properties and may

have improved feed efficiency when fed to ruminants and swine.

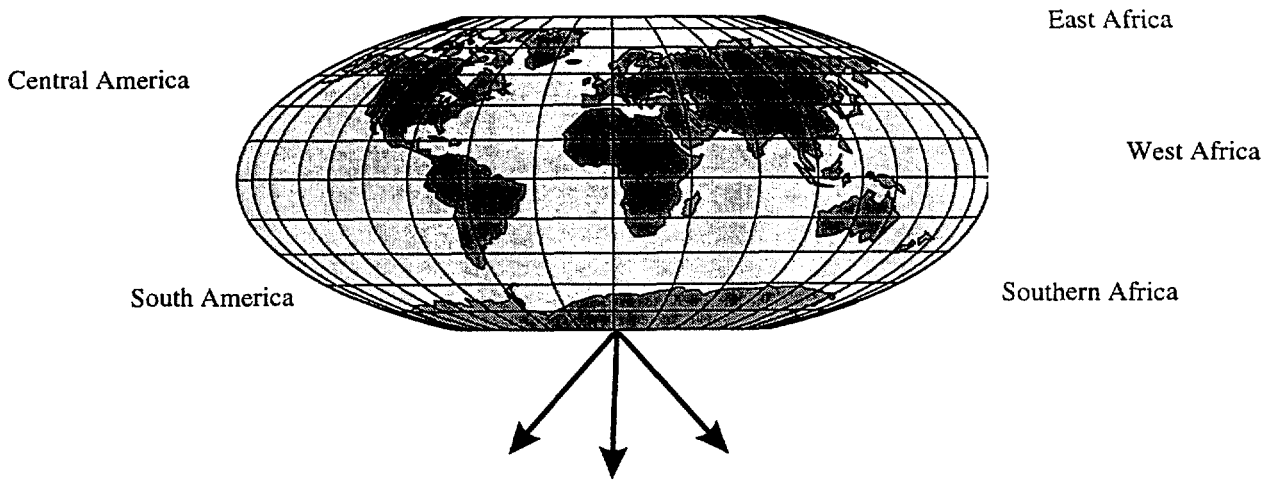
The adverse effects of molds and weathering on sorghum quality significantly limit the use of sorghum for foods in many areas. Major progress to understand the factors affecting grain deterioration has been made. Work continues to secure mold resistant sorghum cultivars. New information on the role of antimicrobial proteins is being developed.

The structure and processing properties of pearl millet has been evaluated. A white pearl millet grain had excellent acceptance when cooked like rice. The milling properties of pearl millet were mainly affected by kernel size, shape and hardness. Parboiled pearl millet did not develop the off-flavor that occurs in pearl millet products.

Future Directions

INTSORMIL will continue to jointly plan and execute collaborative research that benefits developing countries and the United States. These collaborative relationships are keys to INTSORMIL's success and will continue as fundamental approaches to meeting the INTSORMIL mission. In the future, INTSORMIL will target NARS collaborative ties that reflect regional needs for sorghum and/or millet production. These ties are envisioned to be in the sorghum and millet agroecological zones of western, eastern, and southern Africa, and Central America. By concentrating collaboration in selected sites, INTSORMIL optimizes its resources, builds a finite scientific capability on sorghum and millet, and creates technological and human capital that has a sustainable and global impact. INTSORMIL will use five specific strategies to maintain its current momentum, build on its record of success, and accomplish a new set of goals. These strategies are (1) sustainable research institutions and human capital development, (2) conservation of biodiversity and natural resources, (3) research systems development with focus on relevant technology generation, (4) information and research networking, and (5) demand driven processes.

INTSORMIL Global Plan



Constraints

Education

Programs

- Post-secondary Education
- Short-term training
- Post-doctoral assignments
- Seminars, Workshops, Conferences

Research

Technical Thrusts

- Germplasm Enhancement
- Sustainable Production Systems
- Sustainable Plant Protection Systems
- Crop Utilization and Marketing

← Mentoring →

Educational Outcomes

- Institutional Strengthening
- Collaborative Research Networks
- Technology Transfer and Dissemination Infrastructure
- National, Regional and Global Communication Linkages

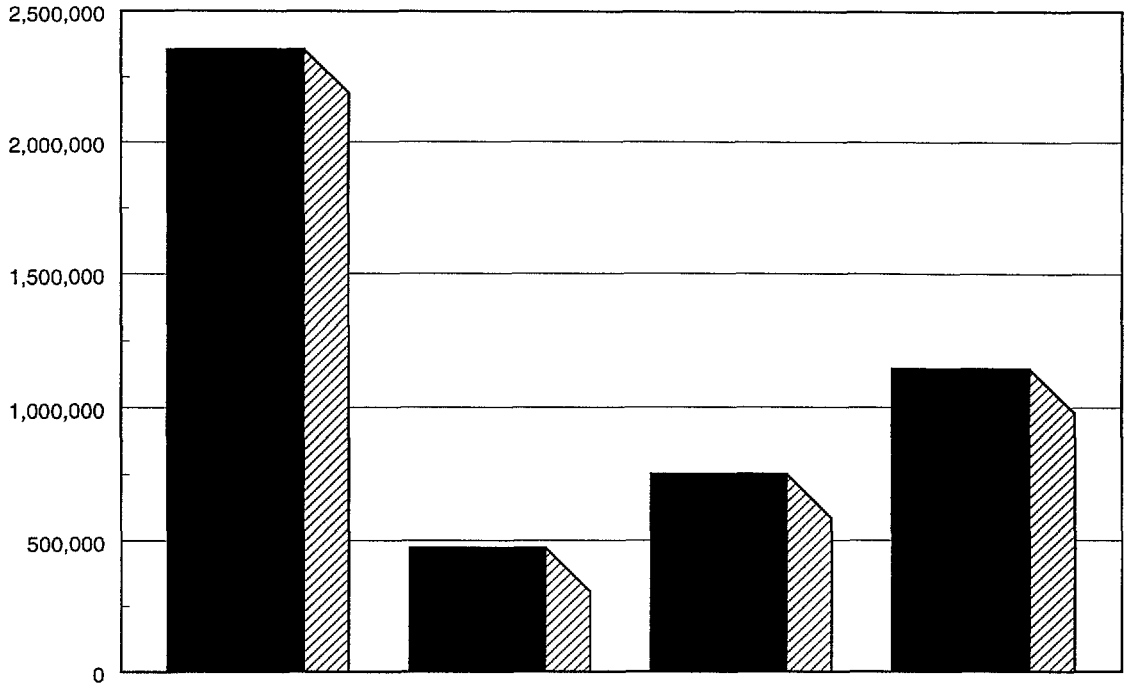
Research Outcomes

- Development and Release of Enhanced Germplasm
- Development and Improvement of Sustainable Production Systems
- Development of Economic Models for Prioritization of Research and Farm-level Industry Evaluation
- Development of Sustainable Food Technology, Processing and Marketing Systems

Networking Communication

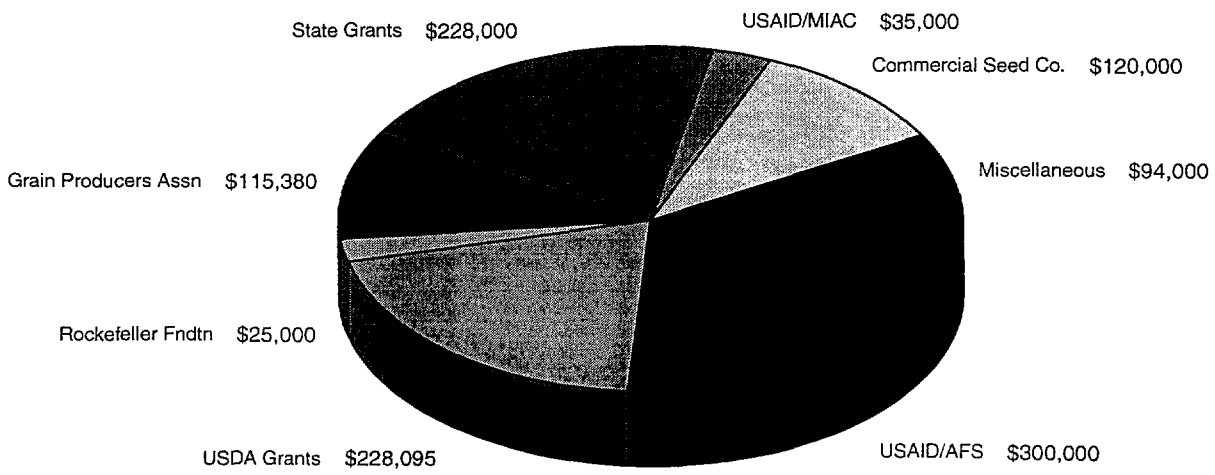
Farmers

INTSORMIL FY 96 Source of Funding
Total Year 17 - $ 4,722,831

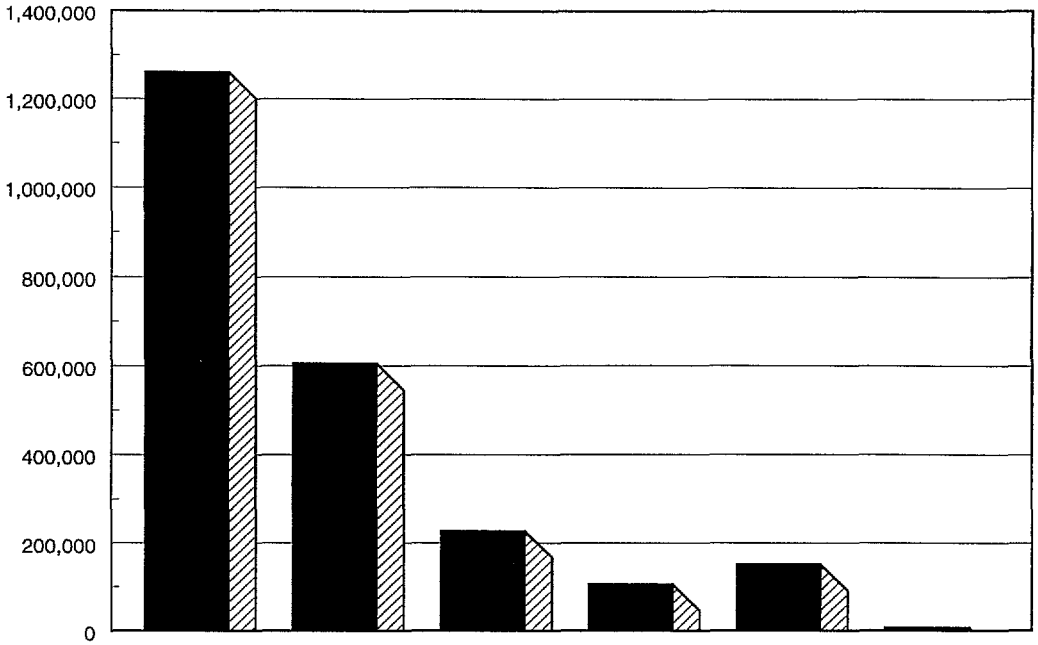


USAID/AFS	Institutional Match	Host Country Match	Buyins
$2,355,000	$471,456	$750,900	$1,145,475

Breakdown of Buyins
$ 1,145,475

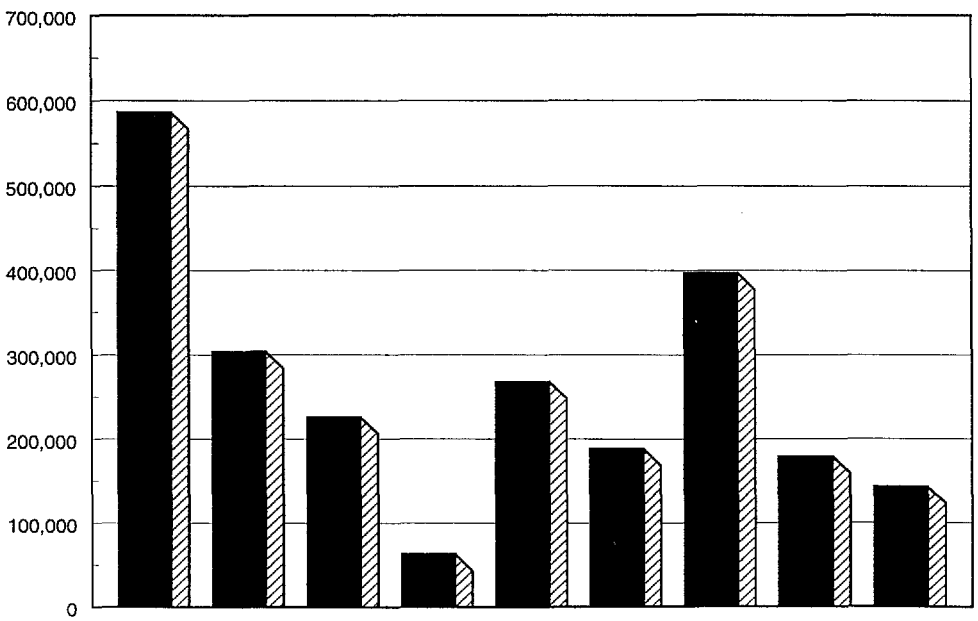


INTSORMIL Budget Analysis - Year 17 - FY 96
Functional - $2,355,000



U.S.	West Africa	Horn of Africa	Southern Africa	Central America	Other
$1,260,260	$605,069	$227,162	$105,139	$150,845	$6,525

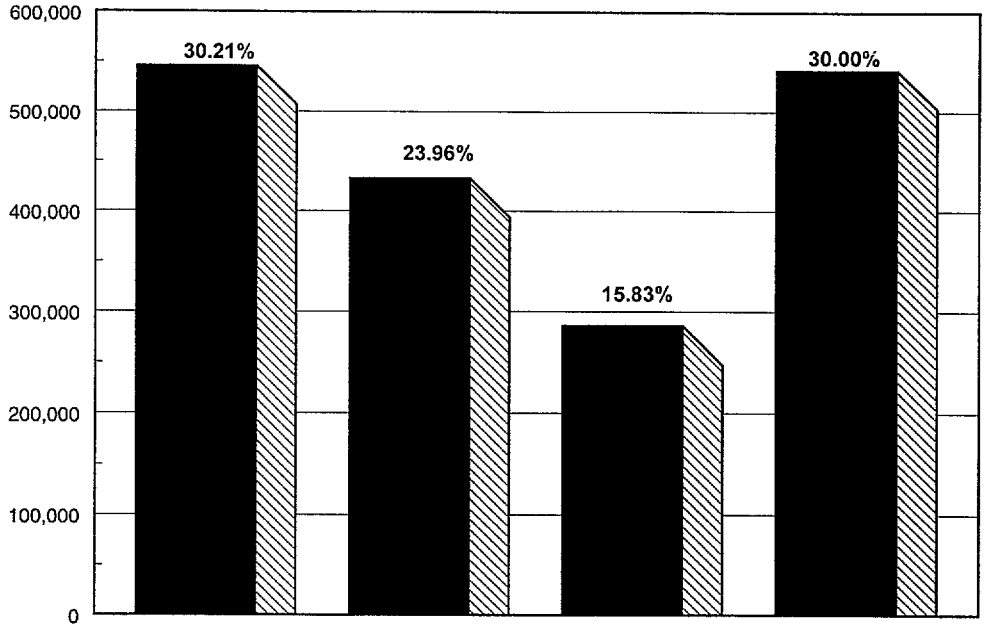
By Region



Indirect Costs	Other Salaries	Univ. Staff	Equipment	Grad Students	Other Direct	Travel	Supplies	Post Doc/Tech
$586,349	$303,692	$226,262	$63,415	$267,900	$188,521	$397,050	$178,851	$142,960

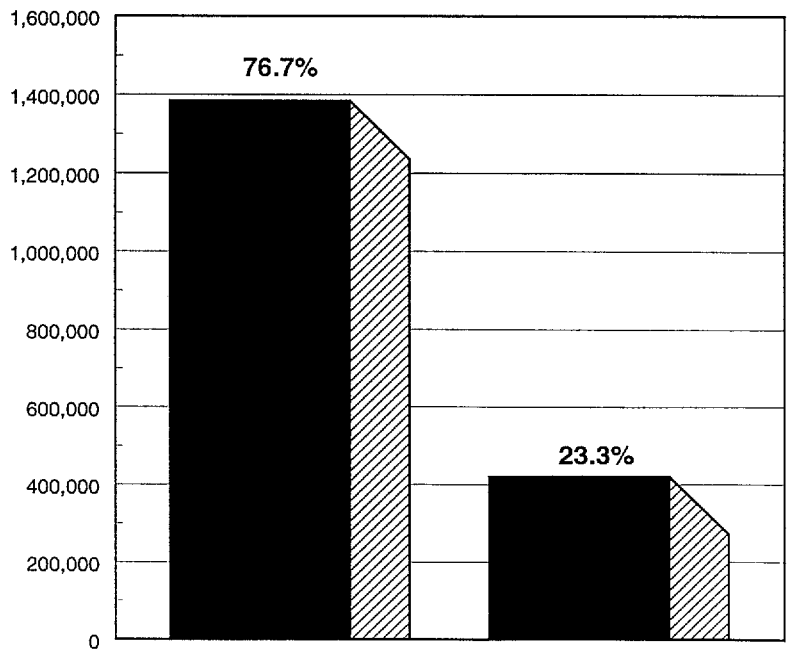
By Line Item

INTSORMIL FY 96 Technical Budget Analysis
Year 17 - $ 1,805,000



Production Systems	Plant Protection	Crop Utilization	Germplasm Enhancemen
$545,290	$432,478	$285,732	$541,500

By Technical Thrusts



Sorghum	Millet
$1,384,435	$420,565

By Crop

Table 1. USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY80) through 17 (FY96) for all Collaborative Research and Management Entity.

Budget Line Items	FY 80-85 Years 1-6	FY 86-90 Years 7-11	FY 91-95 Year 12-16	FY 96 Year 17	FY 80-96 Totals
Salaries & Benefits	$ 7,604,987	$ 6,237,598	$ 5,851,714	$ 940,814	$ 20,635,113
Equipment & Facilities	1,292,255	634,996	295,885	63,415	2,286,551
Travel	1,862,258	1,572,005	1,437,680	296,050	5,167,993
Other Direct Costs	1,018,921	1,518,436	1,912,097	353,372	4,802,826
Technical Assistance	341,290	57,000	146,800	25,000	570,090
LDC Special Projects	2,160,955	1,357,725	748,506	90,000	4,357,186
Mission Buyin				100,000	100,000
Indirect Costs	3,869,334	3,353,940	3,477,318	586,349	11,286,941
Total	$ 18,150,000	$ 14,731,700	$ 13,870,000	$ 2,455,000	$ 49,206,700

Table 2. USAID-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research, U.S. Institutions (Florida A&M University, University of Arizona, Kansas State University, University of Kentucky, Mississippi State University, University of Nebraska, Purdue University, Texas A&M University), and the Management Entity.

Budget Line Items	FL	AZ	KY	KS	MS	NE	PR	TX	Institutional Total	ME Budget	ME TA-LDC	Total Grant
Years 1 - 6 (FY 80-85) A.I.D. Grant - AID/DSAN/XII-G-0149												
Salary & Benefits	85,270	191,675	287,013	896,270	828,186	1,622,402	1,224,363	1,833,520	6,968,699	636,288		7,604,987
Equipment & Facilities	35,500	41,529	4,600	134,655	34,968	159,889	129,863	726,750	1,267,754	24,501		1,292,255
Travel	14,500	27,523	136,390	276,950	177,094	233,533	216,753	435,559	1,518,302	343,956		1,862,258
Other Direct Costs	7,500	5,670	55,271	142,027	112,537	148,359	217,751	242,370	931,485	87,436		1,018,921
Technical Assistance											341.290	341,290
LDC											2,160,955	2,160,955
Indirect Costs	35,106	58,283	165,476	397,575	447,465	762,315	661,080	894,215	3,421,515	447,819		3,869,334
TOTALS	$ 177,876	$ 324,680	$ 648,750	$ 1,847,477	$ 1,600,250	$ 2,926,498	$ 2,449,810	$ 4,132,414	$ 14,107,755	$ 1,540,000	$ 2,502,245	$ 18,150,000
Years 7 - 11 (FY 86-90) A.I.D. Grant -AID/DAN-1254-G-SS-5065-00												
Salary & Benefits			100,954	754,097	532,584	1,044,184	1,324,037	1,718,681	5,474,537	763,061		6,237,598
Equipment & Facilities			800	90,817	79,347	170,837	95,802	185,210	622,813	12,183		634,996
Travel			27,684	165,613	131,996	199,309	353,523	405,880	1,284,005	288,000		1,572,005
Other Direct Costs			17,213	116,960	148,757	202,525	366,378	483,008	1,334,841	161,595	22,000	1,518,436
Technical Assistance											57,000	57,000
LDC											1,265,525	1,265,525
Discontinued Projects/ Grad Student Support											92,200	92,200
Indirect Costs			54,999	319,538	265,566	544,370	811,010	901,296	2,896,779	457,161		3,353,940
TOTALS			$ 201,650	$ 1,447,025	$ 1,158,250	$ 2,161,225	$ 2,950,750	$ 3,694,075	$ 11,612,975	$ 1,682,000	$ 1,436,725	$ 14,731,700
Years 12 - 16 (FY 91-95) USAID Grant -AID/DAN-1254-G-00-0021-00												
Salary & Benefits				453,872	531,446	895,661	1,277,525	1,648,760	4,807,264	1,044,450		3,851,714
Equipment & Facilities				21,438	12,094	91,736	39,800	122,467	287,535	8,350		295,885
Travel				76,572	107,035	162,144	301,389	505,040	1,152,180	285,500		1,437,680
Other Direct Costs				97,466	159,748	230,396	787,053	478,694	1,753.357	158,740		1,912,097
Technical Assistance											146,800	146,800
LDC/Special Projects*											748,506	748,506
Indirect Costs					252,327	454,813	931,733	1,038,039	2,904,114	573,204		3,477,318
TOTALS				$ 876,550	$ 1,062,650	$1,834,750	$3,337,500	$ 3,793,000	$10,904,450	$ 2,070,244	$ 895,306	$13,870,000
Year 17 (FY96) USAID Grant - AID/DAN-1254-G-00-0021-00 (July 1, 1995 - June 30, 1996)												
Salary & Benefits				23,869	23,130	139,165	249,646	209,185	644,995	238,500		883,495
Equipment & Facilities					2,130	11,085		14,200	27,415	1,500		28,915
Travel				26,500	8,000	17,900	76,500	86,150	215,050	33,000		248,050
Other Direct Costs				4,804	6,500	30,833	145,705	73,849	261,691	31,500		293,191
Networking											25,000	
LDC Special Projects*											390,000	
Indirect Cost				24,827	15,240	71,017	183,149	161,616	455,849	130,500		586,349
TOTALS				$ 80,000	$ 55,000	$ 270,000	$ 655,000	$ 545,000	$ 1,605,000	$ 435,000	$ 415,000	$ 2,455,000
GRAND TOTALS	**$ 177,876**	**$ 324,680**	**$ 850,400**	**$ 4,251,052**	**$ 3,876,150**	**$ 7,192,473**	**$ 9,393,060**	**$ 12,164,489**	**$38,230,180**	**$5,727,244**	**$ 5,249,276**	**$ 49,206,700**

*LDC and Special Projects/External Evaluation Panel, Mali/Niger Country Projects

Table 3. Management Entity Office Budget Details.

Budget Line Items	FY 80-85 Years 1-6	FY 86-90 Years 7-11	FY 91-95 Years 12-16	FY 96 Year 17	Totals FY 80-96 Years 1-17
Salaries & Benefits	$ 636,288	$ 763,061	$ 1,040,450	238,500	$ 2,678,299
Equipment & Facilities	24,501	12,183	8,350	1,500	46,534
Travel	339,956	257,000	200,500	33,000	830,456
International				10,000	
Domestic				7,000	
Board of Directors				6,000	
Technical Committee				10,000	
Consultants	6,600	22,000	16,000		44,600
Other Direct Costs	84,836	144,595	146,740	31,500	407,671
Indirect Costs	447,819	457,161	573,204	130,500	1,608,684
Total	$ 1,540,000	$ 1,656,000	$ 1,985,244	435,000	$ 5,616,244
P.I. Conference		16,000	25,000	20,000	61,000
External Evaluation Panel		10,000	170,000		180,000
Special Projects			138,400	95,000	233,400
ME Total Costs	$ 1,540,000	1,682,000	$ 2,318,644	$ 550,000	$ 6,090,644

Table 4. Sorghum/Millet CRSP Summary of Non-Federal Matching Contributions by U.S. Institutions - Grant Years 1 (FY 80) through 17 (FY 96).

U.S. Institution	FY 80-95 Years (1-16)	FY 96 Year 17	FY 80-96 Totals
University of Arizona	$ 149,310	$	$ 149,310
Florida A&M University	23,898		23,898
University of Kentucky	215,649		215,649
Kansas State University	1,769,021	20,000	1,789,021
Mississippi State University	909,869	13,750	923,619
University of Nebraska	2,075,832	64,420	2,140,252
Purdue University	2,497,602	168,887	2,666,489
Texas A&M University	4,138,573	204,399	4,342,972
Total	$ 11,779,754	$ 471,456	$ 12,251,210

TRAINING

INTSORMIL gives high priority to training host country scientists who will have major responsibilities for sorghum and millet research in their home countries. Training is also provided for young U.S. scientists who plan for careers in international development work.

The most frequently used mode of training is graduate study for advanced degrees, with the students' research forming an integral part of an INTSORMIL project. During the year covered by this report, 57 students from 18 different countries were enrolled in an INTSORMIL advanced degree program. Approximately 77% of these students come from countries other than the U.S. which shows the emphasis placed on host country institutional development (Figure 1).

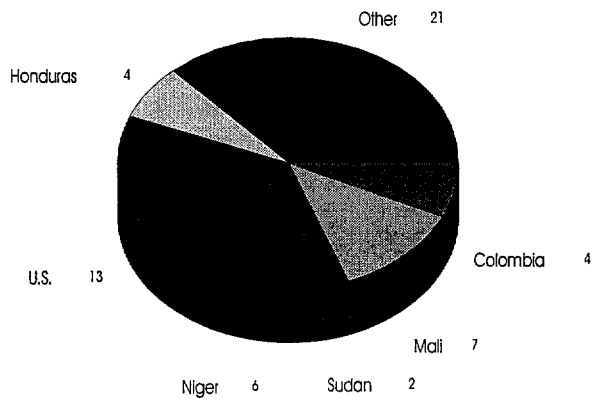


Figure 1. Training analysis - country breakdown.

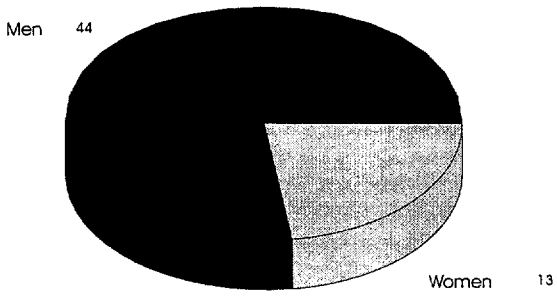


Figure 2. Training analysis - gender breakdown.

INTSORMIL also places a high priority on training women which is reflected in Figure 2. In 1996, 23% of all INTSORMIL graduate participants were female. Twenty-One of the total 57 students received full INTSORMIL scholarships. An additional 16 students received partial INTSORMIL funding and the remaining 20 students were funded from other sources as shown in Figure 3.

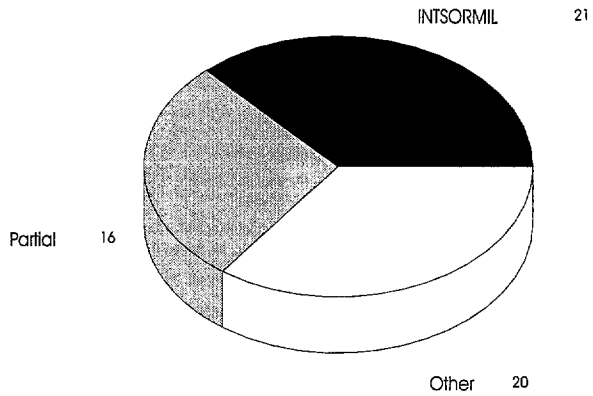


Figure 3. Training analysis - source of funding.

All 57 students worked directly with INTSORMIL principal investigators on INTSORMIL projects. These students are enrolled in graduate programs in six disciplinary areas, agronomy, breeding, pathology, entomology, food quality, and economics.

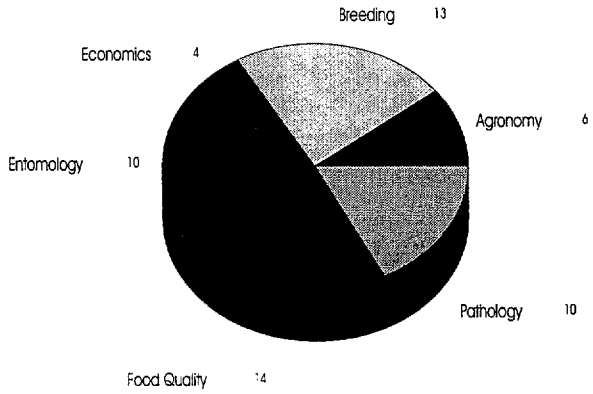


Figure 4. Training analysis - discipline breakdown.

Total student numbers decreased in 1995-96 as compared to 1994 and 1995. The number of INTSORMIL funded students has decreased gradually over the years. This is related to decreases in program budget and the loss of U. S. Principal Investigators. In 1993-1994 there were 25 U.S. PIs with the program and in 1995-1996 this had decreased down to eighteen.

In addition to graduate degree programs, short term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Three visiting host country scientists and four post doctoral scientists were provided the opportunity to upgrade their skills in this fashion during 1995-1996.

The following table is a compilation of all INTSORMIL training activities for the period July 1, 1995 through June 30, 1996.

Year 17 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Gutierrez, Patricio F.	Ecuador	UNL	Agronomy	Clegg	PHD	M	I
Masi, Cassim	Zambia	UNL	Agronomy	Maranville	PHD	M	O
Traore, Abdoulaye	Mali	UNL	Agronomy	Maranville	PHD	M	I
Maman, Nouri	Niger	UNL	Agronomy	Mason	M.S	M	I
Stockton, Roger	U.S.	UNL	Agronomy	Mason	PHD	M	P
Traore, Samba	Mali	UNL	Agronomy	Mason	PHD	M	O
Carvalho, Carlos H.S.	Brazil	PRF	Breeding	Axtell	PHD	M	P
Kapran, Issoufou	Niger	PRF	Breeding	Axtell	PHD	M	I
Ndulu, Lexingtons	Kenya	PRF	Breeding	Axtell	PHD	M	I
Ibrahim, Yahia	Sudan	PRF	Breeding	Ejeta	PHD	M	I
Mohammed, Abdalla	Sudan	PRF	Breeding	Ejeta	PHD	M	P
Tuinstra, Mitchell	U.S.	PRF	Breeding	Ejeta	PHD	M	I
Stewart, Klint G.	U.S.	TAM	Breeding	Peterson	MSC	M	O
Katsar, Catherine Susan	U.S.	TAM	Breeding	Peterson/Teetes	PHD	F	P
Crasta, Oswald	India	TTU	Breeding	Rosenow	PHD	M	P
Munera, Alvaro	Colombia	TTU	Breeding	Rosenow	MSC	M	P
Rodriguez, Raul	Mexico	TAM	Breeding	Rosenow/Rooney	PHD	M	P
Teme, Niaba	Mali	TTU	Breeding	Rosenow	MSC	M	I
Jeutong, Fabien	Cameroon	UNL	Breeding	Andrews	PHD	M	O
Coulibaly, Bakary	Mali	PRF	Economics	Sanders	MSC	M	O
Dembele, Issiaka	Mali	PRF	Economics	Sanders	VS[1]	M	O
Kebe, Demba	Mali	PRF	Economics	Sanders	VS[1]	M	O
Lilja, Nina	U.S.	PRF	Economics	Sanders	PHD	F	O
Sidibe, Mamadou	Senegal	PRF	Economics	Sanders	PHD	M	O
Vitale, Jeff	U.S.	PRF	Economics	Sanders	PHD	M	I
Boire, Soualika	Mali	TAM	Entomology	Gilstrap	PHD	M	I
Kadi Kadi, Hame	Niger	TAM	Entomology	Gilstrap	MSC	M	I
Calderon, Pedro	Honduras	MSU	Entomology	Pitre	MSC	M	P
Cordero, Roberto	Honduras	MSU	Entomology	Pitre	MSC	M	I
Vergara, Oscar	Honduras	MSU	Entomology	Pitre	MSC	M	I
Diarisso Yaro, Niamoye	Mali	TAM	Entomology	Teetes/Peterson	PHD	F	O
Jensen, Andrea	U.S.	TAM	Entomology	Teetes	PHD	F	I
Lingren, Scott	U.S.	TAM	Entomology	Teetes	PHD	M	O
Magallenes, Ricardo	Mexico	TAM	Entomology	Teetes	PHD	M	P
Mott, Dale Allen	U.S.	TAM	Entomology	Teetes	MSC	M	O
Aboubacar, Adam	Niger	PRF	Food Quality/Util	Hamaker/Axtell	PHD	M	I
Buckner, Becky	U.S.	PRF	Food Quality/Util	Hamaker	PHD	F	O
Itapu, Suresh	India	PRF	Food Quality/Util	Hamaker	PD[2]	M	O
Mamadou, Lewamy	Niger	PRF	Food Quality/Util	Hamaker	MSC	M	O
Oria, Maria P.	Spain	PRF	Food Quality/Util	Hamaker	PHD	F	I
Weaver, Charlotte	U.S.	PRF	Food Quality/Util	Hamaker	MSC	F	O
Zhang, Genyi	China	PRF	Food Quality/Util	Hamaker	MSC	M	I
Acosta, Harold	Colombia	TAM	Food Quality/Util	Rooney/Waniska	PHD	M	P
Asante, Sam	Ghana	TAM	Food Quality/Util	Rooney/Waniska	PHD	M	P
Bueso, Francisco Javier	Honduras	TAM	Food Quality/Util	Rooney/Waniska	MSC	M	I
Floyd, Cherie	U.S.	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Guajardo-Flores, Sara	Mexico	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	I
Kunetz, Christine	U.S.	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Seetharaman, Koushik	India	TAM	Food Quality/Util	Rooney/Waniska	PHD	M	P
Suhendro, Elly	Indonesia	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Diourte, Mamourou	Mali	KSU	Pathology	Claflin	PHD	M	O
Lu, Ming	China	KSU	Pathology	Claflin	PHD	M	O
Muriithi, Linus M.	Kenya	KSU	Pathology	Claflin	PHD	M	O
Narvaez, Dario	Colombia	KSU	Pathology	Claflin	MSC	M	O
Nzioki, Henry S.	Kenya	KSU	Pathology	Claflin	MSC	M	O
Xu, Xiude	China	KSU	Pathology	Claflin	VS[1]	M	O
Amoah, Ben	Ghana	KSU	Pathology	Leslie	PD[2]	M	I
Arjula, Vaishal	India	KSU	Pathology	Leslie	MSC	F	O
Salleh, Baharuddin	Malaysia	KSU	Pathology	Leslie	PD[2]	M	O
Zeller, Kurt P.	U.S.	KSU	Pathology	Leslie	PD[2]	M	O
Kollo, Issoufou	Niger	TAM	Pathology	Frederiksen	PHD	M	I
Osorio, Jairo	Colombia	TAM	Pathology	Frederiksen	PHD	M	O
Rosewich, Ute L.	Germany	TAM	Pathology	Frederiksen	PHD	F	I
Torres-Montalvo, Jose H.	Mexico	TAM	Pathology	Frederiksen	PHD	M	P

* I = Completely funded by INTSORMIL
P = Partially funded by INTSORMIL
O = Other source

[1]VS = Visiting Scientist
[2]PD = Post Doctoral

KSU = Kansas State University
MSU= Mississippi State University
PRF = Purdue University
TAM= Texas A&M University
TTU = Texas Tech University
UNL = University of Nebraska - Lincoln

INTSORMIL Buy-Ins through FY 96

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
KSU-106	Kansas Sorghum Board	1985	6 years	17,500	105,000
	Kansas Agric. Exp. Station	1989	3 years	19,000	57,000
	Kansas Agric. Exp. Station	1989	3 years	13,333	40,000
	Kansas Sorghum Board	1991	4 years	15,334	61,338
	Kansas Agric. Exp. Station	1990	3 years	19,000	57,000
	EPA/Univ. of Nebraska	1990	2 years	32,518	65,036
					$ 385,374
KSU-108	Kansas Sorghum Board	1985	9 years	18,482	166,338
	Kansas Corn Commission	1988	3 years	16,845	50,535
	Kansas Sorghum Commission	1989	1 year	7,166	7,166
	Kansas Sorghum Commission	1989	1 year	6,500	6,500
	EPA	1990	3 years	39,523	118,569
	Kansas Agric. Exp. Station	1991	3 years	19,000	57,000
	USDA/ARS	1992	1 year	14,400	14,400
					$ 420,508
KSU-108B	Myco Pharmaceuticals	1993	3 years	30,000	90,000
	Kansas Agric. Exp. Station	1993	3 years	17,500	52,500
	USDA/Pioneer Seed Co.	1994	2 years	75,000	150,000
	USDA/Pioneer Seed Co.	1994	2 years	30,000	60,000
	No. Central Biotechnology Initiative	1994	2 years	65,000	130,000
	USDA/CSRS	1995	2 years	62,000	124,000
					$ 606,500
MSU-104	MIAC/Kenya	1990	2 years	115,725	231,450
	MIAC/Kenya	1992	3.5 years	142,000	497,000
	USAID/MIAC	1992	5 years	35,000	175,000
					$ 903,450
MSU-105	FAO	1992	3 years	2,245	**$ 6,735**
MSU-111	Fedearroz	1990	5 years	10,000	50,000
	El Alcaravan Foundation	1990	2 years	200,000	400,000
	Fenalce	1991	1 year	5,000	5,000
					$ 455,000
PRF-103A	AID/Program Support Grant	1988	2 years	7,500	15,000
	Agric. Exp. Station	1988	2 years	6,000	12,000
	Purdue Agronomy Dept.	1989	2 years	1,000	2,000
	McKnight Foundation	1989	3 years	250,000	750,000
	Corporation for Science & Tech.	1991	1 year	10,000	10,000
	Pioneer Hi-Bred Intern.	1992	3 years	33,900	101,693
	Purdue Agronomy Dept.	1992	1 year	1,000	1,000
	McKnight Foundation	1992	3 years	250,000	750,000
	Midwest Biotechnology Consortium	1993	1 year	32,627	32,627
	Purdue Agronomy Dept.	1994	2 years	1,000	2,000
	Pioneer Hi-Bred	1994	2 years	30,000	60,000
					$ 1,736,320
PRF-103B	USDA Training	1989	3 years	15,000	45,000
	AFGRAD Training	1989	4 years	9,000	36,000
	NAAR Project	1991	1 year	3,000	3,000
					$ 84,000
PRF-104B & 104C	USAID PSG	1989	2 years	7,500	15,000
	Rockefeller Foundation	1989	3 years	23,067	69,200
	USAID/PSTC	1990	4 years	37,450	150,000
	USAID PSG	1991	2 years	10,000	20,000

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
	Purdue Research Foundation	1991	1 year	2,800	2,800
	Pioneer Seed Co.	1991	3 years	40,000	120,000
	PSTC/USAID	1991	3 years	50,000	150,000
	Pioneer Seed Co.	1991	2 years	30,000	60,000
	NSF	1992	1.5 years	173,333	260,000
	Pioneer Seed Co.	1993	2 years	13,600	27,192
	Dept. of Energy	1993	2 years	56,780	113,560
	Rockefeller Foundation	1993	2 years	45,000	90,000
	USAID/PSTC	1994	2 years	50,000	100,000
	McKnight Foundation	1994	1 year	85,000	85,000
	National Science Foundation	1994	1 year	85,000	85,000
	USDA	1995	1 year	4,275	4,275
	ASA/Sorghum Crop Advisory	1995	1 year	10,000	10,000
					$ 1,362,027
PRF-105	USAID PSG	1989	4 years	5,000	20,000
	USAID PSG	1989	3 years	5,000	15,000
	World Bank	1989	2.5 years	10,000	25,000
	World Bank/IDA	1989	1 year	4,500	4,500
	USAID/Bean-Cowpea CRSP	1990	1 year	27,000	27,000
	EMBRAPA	1992	1 year	10,000	10,000
	USAID/AFT/ARTS	1992	1 year	20,000	20,000
	USAID/AFT/ARTS	1994	2 years	150,000	300,000
	USDA/SCS	1995	1 year	27,820	27,820
					$ 449,320
PRF-107	Purdue Agronomy Dept.	1988	1 year	1,500	1,500
	State of Indiana	1990	1 year	7,000	7,000
	McKnight Foundation	1990	3 years	20,632	61,896
	USAID PSG	1990	2 years	14,000	28,000
	McKnight Foundation	1990	3 years	22,000	66,000
	Pioneer Seed Co.	1991	2 years	30,000	60,000
	State of Indiana	1991	1 year	1,200	1,200
	Rockefeller Foundation	1992	3 years	33,335	100,000
					$ 325,596
PRF-109	USDA Grant	1990	2 years	60,000	**$ 120,000**
PRF-112	Purdue Agronomy Department	1994	1 year	12,000	12,000
	USDA	1993	3 years	17,000	51,000
	Mahyco Research Foundation	1995	2 years	40,000	80,000
					$ 143,000
TAM Joint	USAID/TAMU	1989	3 years	15,000	45,000
	USAID/TAMU	1991	3 years	15,000	45,000
					$ 90,000
TAM-122	State of Texas Grant	1989	2 years	20,000	40,000
	USAID/TAMU	1990	2 years	10,000	20,000
	USAID/TAMU	1990	3 years	13,000	39,000
	Texas Higher Coordinating Board	1991	2 years	27,000	54,000
	USDA	1991	2 years	7,500	15,000
	USAID/TAMU	1992	2 years	28,000	56,000
					$ 224,000
TAM-123	Texas Grain Sorghum Producers	1990	5 years	50,000	250,000
	USAID/TAMU	1990	1 year	17,000	17,000
	USAID/TAMU	1991	1 year	28,000	28,000
	TAES	1993	2 years	22,500	45,000
	USDA/Sorghum Advisory Committee	1994	1 year	5,000	5,000
					$ 345,000
TAM-124	USDA	1989	3 years	10,000	30,000

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
	Texas Advanced Research	1989	1 year	75,000	75,000
	TAES/ERA	1989	2 years	32,000	64,000
	Texas Advanced Research	1990	3 years	15,000	45,000
	Rockefeller Foundation	1990	2 years	30,000	60,000
	Texas Advanced Research	1992	2 years	10,000	20,000
	Rockefeller Foundation	1992	2 years	7,000	14,000
	Rockefeller Foundation	1994	3 years	25,000	75,000
	Pioneer Seed Company	1994	2 years	30,000	60,000
	TAES	1994	2 years	50,000	100,000
	Texas Sorghum Board	1995	2 years	22,500	45,000
					$ 588,000
TAM-125	TAMU/PSG	1989	2 years	45,000	90,000
	Industry Grant	1989	2 years	10,000	20,000
	USDA/CRSP	1989	1 year	15,000	15,000
	USDA/APHIS	1989	2 years	15,000	30,000
	USDA/APHIS	1989	1 year	14,000	14,000
	Texas Agric. Exp. Station	1990	2 years	7,000	14,000
	USDA/APHIS	1990	3 years	23,734	71,202
	USDA/CSRS	1990	2 years	59,819	119,638
	TAMU/Program Support Grant	1990	2 years	18,638	37,276
	TAMU/Program Support Grant	1990	2 years	30,000	60,000
	Texas Grain Sorghum Producers	1990	2 years	50,000	100,000
	USDA/APHIS	1991	1 year	13,200	13,200
	TAMU/Program Support Grant	1990	3 years	27,000	81,000
	Texas Grain Sorghum Producers	1993	5 years	25,000	125,000
	TAES Ag Research Station	1994	2 years	10,000	20,000
	Texas Grain Sorghum Prod.	1994	2 years	40,000	80,000
					$ 890,316
TAM125-B	TAES	1993	2 years	29,000	58,000
	USDA/APHIS	1993	4 years	32,500	130,000
	USDA/CSRS-SR	1993	2 years	45,000	90,000
	USDA/APHIS	1993	4 years	15,000	60,000
	USDA/APHIS	1994	2 years	25,000	50,000
	TAES	1994	2 years	5,000	10,000
	USDA/CSRS	1995	1 year	7,000	7,000
					$ 405,000
TAM-126	Texas Center for Energy	1989	1 year	14,500	14,500
	TAMU/Program Support Grant	1989	3 years	10,000	30,000
	Texas Agr. Exp. Station	1989	5 years	50,000	250,000
	TAES/ERA	1990	2 years	25,000	50,000
	HATCH	1990	4 years	35,000	140,000
	Texas Sorghum Producers	1990	1 year	15,000	15,000
	Grain Sorghum Producers	1991	3 years	10,300	30,900
	TAMU/Hatch	1992	5 years	31,184	155,920
	TAES/ERA	1990	2 years	19,000	38,000
	Grain Sorghum Producers	1992	2 years	20,000	40,000
	Texas Grain Sorghum Board	1994	2 years	20,000	40,000
	Pioneer Seed Co.	1994	2 years	30,000	60,000
	TAMU/HATCH	1995	3 years	35,000	105,000
	TAMU/HATCH	1995	5 years	55,000	275,000
	TAMU/Program Support Grant	1995	2 years	17,000	34,000
					$ 1,278,320
TAM-128	TAES	1993	2 years	10,000	**$ 20,000**
TAM-131	USAID/Honduras PL480	1990	1 year	111,395	111,395
	USAID/Honduras PL480	1991	1 year	120,000	120,000
	USAID/Honduras PL480	1992	1 year	88,704	88,704
	USAID/Honduras PL480	1993	1 year	88,704	88,704
	Commercial Seed Co.	1992	1 year	7,000	7,000
	EEC/IICA/PRAIG	1992	3 years	9,260	27,780
	EEC/IICA/PRAIG	1993	3 years	10,975	32,920
					$ 476,503

University/ Project No.	Buy-In	Year	Life of Buy-In	Annual Amount	Total
UNL-113	Rockefeller Foundation	1988	3 years	8,333	25,000
	Ministry of Science (Leave)	1991	1 year	25,000	25,000
	Nebraska Foundation	1994	2 years	15,000	30,000
					$ 80,000
UNL-114	German Acad.Exchange Serv.	1993	2.5 years	11,000	$ 27,500
	FAO/IAR/Ethiopia	1994	.5 year	14,900	14,900
	Zambia/World Bank	1994	1 year	13,000	13,000
					$ 55,400
UNL-115 & 118	Michigan State/Senegal Agric.	1989	3 years	46,700	140,000
	USAID/Dakar	1992	5 years	70,000	350,000
	Nebraska Grain Sorghum Board	1994	1 year	20,900	20,900
	Nebraska Grain Sorghum Board	1993	3 years	15,600	45,500
	Nebraska Grain Sorghum Board	1994	2 years	6,500	13,000
					$ 569,400
UNL-116	Elliott Grant	1986	4 years	17,250	69,000
	USDA/OICD	1989	3 years	14,667	44,000
	Nebraska Sorghum Board	1990	3 years	24,00	72,000
	USAID/OICD	1990	3 years	43,000	129,000
	USAID/OICD	1990	1 year	4,000	4,000
					$ 318,000
UNL-123	USAID/PSTC Grant	1989	3 years	50,000	150,000
	USDA/ARS	1986	5 years	22,669	113,345
	USDA/ARS	1991	5 years	24,356	121,780
					$ 385,125
M.E.	INTSORMIL/Egypt/NARP Nebraska/Kansas St.	1991	3 years	156,727	$ 470,183
	SADC/ICRISAT/INTSORMIL Training	1990	5 years	1,280,400	6,402,039
	AID/CROSS CRSP Activities	1990	1 year	100,000	100,000
	USAID/Botswana/DAR	1990	1 year	35,860	35,860
	USAID/Khartoum/ARC	1990	1 year	80,000	80,000
	Social Science Research Workshop	1991	1 year	31,600	31,600
	Adaptation of Plants to Soil Stress Workshop	1992	1 year	25,000	25,000
	Rockefeller Foundation-Conference	1993	1 year	6,500	6,500
	FAO/IAR Ethiopia Training	1994	1 year	20,000	20,000
	Niger Mission Inter/CRSP Support	1995	1 year	100,000	100,000
					$ 7,271,182
Total Buy-Ins					**$ 19,994,076**

INTSORMIL Sponsored and Co-Sponsored Workshops 1979 - 1996

	Name	Where	When
1.	International Short Course in Host Plant Resistance	College Station, Texas	1979
2.	INTSORMIL PI Conference	Lincoln, Nebraska	1/80
3.	West Africa Farming Systems	West Lafayette, Indiana	5/80
4.	Sorghum Disease Short Course for Latin America	Mexico	3/81
5.	International Symposium on Sorghum Grain Quality	ICRISAT	10/81
6.	International Symposium on Food Quality	Hyderabad, India	10/81
7.	Agrimeteorology of Sorghum and Millet in the Semi-Arid Tropics	ICRISAT	1982
8.	Latin America Sorghum Quality Short Course	El Batan, Mexico	4/82
9.	Sorghum Food Quality Workshop	El Batan, Mexico	4/82
10.	Sorghum Downy Mildew Workshop	Corpus Christi, Texas	6/82
11.	Plant Pathology	CIMMYT	6/82
12.	Striga Workshop	Raleigh, North Carolina	8/82
13.	INTSORMIL PI Conference	Scottsdale, Arizona	1/83
14.	INTSORMIL-ICRISAT Plant Breeding Workshop	CIMMYT	4/83
15.	Hybrid Sorghum Seed Workshop	Wad Medani, Sudan	11/83
16.	Stalk and Root Rots	Bellagio, Italy	11/83
17.	Sorghum in the '80s	ICRISAT	1984
18.	Dominican Republic/Sorghum	Santo Domingo	1984
19.	Sorghum Production Systems in Latin America	CIMMYT	1984
20.	INTSORMIL PI Conference	Scottsdale, Arizona	1/84
21.	Primer Seminario National Sobre Produccion y Utilizacion del Sorgo	Santo Domingo, Dominican Republic	2/84
22.	Evaluating Sorghum for Al Toxicity in Tropical Soils of Latin America	Cali, Colombia	4/84
23.	First Consultative and Review on Sorghum Research in the Philippines	Los Banos, Philippines	6/84
24.	INTSORMIL Graduate Student Workshop and Tour	College Station, Texas	6/84
25.	International Sorghum Entomology Workshop	College Station, Texas	7/84
26.	INTSORMIL PI Conference	Lubbock, Texas	2/85
27.	Niger Prime Site Workshop	Niamey, Niger	10/85
28.	Sorghum Seed Production Workshop	CIMMYT	10/85
29.	International Millet Conference	ICRISAT	4/86
30.	Maicillos Criollos and Other Sorghum in Middle America Workshop	Tegucigalpa, Honduras	12/87
31.	INTSORMIL PI Conference	Kansas City, Missouri	1/87
32.	2nd Global Conference on Sorghum/Millet Diseases	Harare, Zimbabwe	3/88
33.	6th Annual CLAIS Meeting	San Salvador, El Salvador	12/88
34.	International INTSORMIL Research Conference	Scottsdale, Arizona	1/89
35.	INTSORMIL Graduate Student Workshop and Tour	College Station, Texas	7/89
36.	ARC/INTSORMIL Sorghum/Millet Workshop	Wad Medani, Sudan	11/89
37.	Workshop on Sorghum Nutritional Grain Quality	West Lafayette, Indiana	2/90
38	Improvement and Use of White Grain Sorghums	El Batan Mexico	12/90
39.	Sorghum for the Future Workshop	Cali, Colombia	1/91
40.	INTSORMIL PI Conference	Corpus Christi, Texas	7/91
41.	Social Science Research and the CRSPs	Lexington, KY	6/92
42.	Seminario Internacional Sobre los Cultivos de Sorgo y Maiz sus Principales Plagas y Enfermedades	Colombia	1/93
43.	Workshop on Adaptation of Plants to Soil Stresses	Lincoln, NE	8/93
44.	Latin America Workshop on Sustainable Production Systems for Acid Soils	Villavicencio, Colombia	9/93
45.	Latin America Sorghum Research Scientist Workshop (CLAIS Meeting)	Villavicencio, Colombia	9/93
46.	Disease Analysis through Genetics and Biotechnology: An International Sorghum and Millet Perspective	Bellagio, Italy	11/93

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