1998 Annual Report

INTSORMIL

Sorghum/Millet Collaborative Research Support Program (CRSP)

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Cover Photographs

Front cover

Food scientists in Mali have tested value-added processing of cereals grown locally with women such as these in a village near Cinzana The work is important because the cereals grown in Mali are difficult to process through conventional means and the quality of the traditional, ultimate products is poor With improved processing comes better quality food and increased profits for local farmers The research pays off in the United States, too, as the genes identified through International Sorghum/Millet CRSP collaboration with Malian scientists also are being used to improve sorghum here Photo courtesy of Dr Lloyd Rooney, Texas A&M University, College Station, TX

Back cover

International Sorghum/Millet CRSP pearl millet breeders, such as this one at the University of Nebraska, are producing an early-maturing, drought-tolerant alternative grain crop option Pearl millet grain hybrids, now being tested by 20 farmers in six states, can give yields of 50-70 bushels per acre, sometimes as high as 100 bushels per acre, in warm, low-rainfall or short-season areas in the United States Two American seed companies are producing four acres of hybrid seed of these early grain hybrids Genetic material in these U S hybrids was obtained from CRSP researchers' work in Asia and Africa Food-quality pearl millet grain is of interest to the U S because of its premium feed grain value and export potential to countries where pearl millet is consumed in such forms as flat bread, porridge, a popcorn-like food, opaque beer and weaning food Photo courtesy of Professor David Andrews, University of Nebraska, Lincoln, NE

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INTSORMIL

1998 Annual Report

Executive Summary

Fighting Hunger with Research .. A Team Effort

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

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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

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University of Illinois at Urbana - Champaign
Kansas State University
Mississippi State University
University of Nebraska - Lincoln
Purdue University
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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 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 is one of nine CRSPs currently in operation

The Sorghum and Millet Collaborative Research Support Program (INTSORMIL CRSP) conducts collaborative research using partnerships between U S university scientists and scientists of the National Agricultural Research Systems, IARCs, PVOs and other CRSPs INTSORMIL is programmatically organized for efficient and effective operation and captures most of the public research expertise on sorghum and pearl millet 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 agriculture in the U S and Less Developed Countries (LDCs)*** Collaborating scientists in NARS developing countries and the U S jointly plan and execute research that mutually benefits all participating countries, including the United States

INTSORMIL takes a regional approach to sorghum and millet research in the agroecological zones of western, southern, and eastern Africa, and in Central America INTSORMIL resources focus on these prime sites in these five regions supporting 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 six universities currently active in the INTSORMIL CRSP are the University of Illinois 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, and, in their area of adaptation, sorghum and millet cannot be sustainably substituted by other cereals The development of food sorghums and feed sorghums with improved properties such as increased digestibility and reduced tannin content has contributed to sorghum becoming a major feed grain in the U S and 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 food products that can effectively compete with wheat and rice products Pearl millet also has great potential for processing into high-value food products which can be sold in villages and cities markets, competing 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 serves, population growth rates continue to exceed rates of increase of cereal 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

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 promotes educational outcomes in collaborating host countries The outcomes include strengthening agricultural research institutions, developing collaborative research networks, promoting and linking to technology transfer and dissemination infrastructure 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 After earning their graduate degrees, host country scientists become***

peer 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, and development of sustainable technologies to conserve biodiversity and natural resources INTSORMIL's emphasis on conserving biodiversity and natural resources enhances society's quality of life and enlarges the range of agricultural and environmental choices in developing countries and in the United States 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 the eco-geographical regional sites has been strengthened by using U S and NARS multidisciplinary research teams focused on common objectives and unified plans INTSORMIL scientists provide global leadership in biotechnology research on sorghum and millets The outputs 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 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 research sites within the region 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 product 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 analyses for prioritization of research, 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 and millet for food Research products transferred to the farm will seek to spur rural economic growth and provide direct economic benefits to consumers INTSORMIL economists and food scientists assess consumption shifts and socioeconomic policies for reducing effects of price collapses, and address methods to more efficiently process 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 INTSORMIL 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, presenting a win-win situation for international agricultural development

Administration and Management

The Management Entity (ME) for the Sorghum/Millet CRSP is at the University of Nebraska - Lincoln (UNL) 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 A portion of the project funds, managed by the ME and U S participating institutions, flow to regional programs 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 ME employed Dr Thomas Crawford of Sioux Falls, South Dakota as the Associate Director for INTSORMIL effective July 1, 1997

- The Board of Directors established a new policy statement regarding publishing of the Annual Report Effective July 1, 1998 all annual reports are due by August 1 and Regional/Country program reports are due by August 15 All projects will be penalized 5% of their budgets if not submitted on time and an additional 10% beginning September 1 and each month there after until the report has been received by the ME

- Dr Carl Nelson, an agricultural economist at the University of Illinois, was awarded a subgrant through the end of the current grant to do research on sorghum,millet marketing/economics (Project UIUC-205)

- The 1998-99 Technical Committee (TC) was elected The TC members are Dr Stephen Mason, Chair, University of Nebraska, Dr Bruce Hamaker, Vice Chair, Purdue University, Dr Henry Pitre, Secretary, Mississippi State University, Dr Gary Peterson, Texas A&M University, Dr John Axtell, Purdue University, Dr Darrell Rosenow, Texas A&M University, Dr Sidi Bekaye Coulibaly, IER/Mali, and Dr Medson Chisi, Mt Makulu Research Station, Zambia

- The Technical Committee and the Board of Directors approved the Five Year In-Depth EEP review schedule commencing in September 1998, and finishing in August 1999

- Dr Walter DeMilliano, Novartis Seeds, Amsterdam, Holland was approved by the BIFAD and USAID to succeed Dr Merle Shepard on the EEP Dr DeMilliano will represent the crop protection disciplines and will serve a five-year term

- Dr Richard Hahn has been nominated by INTSORMIL to succeed Dr Joseph Hulse on the EEP Dr Hahn will represent the processing/utilization discipline and will serve a five-year term

- INTSORMIL entered into a Memorandum of Agreement with the Instituto Nicaraguense De Technologia Agropecuaria (INTA) of Managua, Nicaragua on May 8, 1998

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

  - * Publication 97-1 INTSORMIL Policy and Operating Procedures
  - * Publication 97-2 U S CRSP P I s (All CRSPs)
  - * Publication 97-3 "Inside INTSORMIL Newsletter"
  - * Publication 97-4 INTSORMIL CRSP Directory
  - * Publication 97-5 Proceedings of the International Conference on Genetic Improvement of Sorghum and Pearl Millet
  - * Publication 98-1 1997 Annual Report
  - * Publication 98-2 1997 Annual Report Executive Summary
  - * Publication 98-3 "Inside INTSORMIL Newsletter"

- To increase recognition of INTSORMIL research among the general public, Congress and USAID, the INTSORMIL ME established an information site on the world wide web at http //www ianr unl edu/intsormil/ and an informational site for all Collaborative Research Support Programs at http //www ianr unl edu/crsps/ In addition, the ME responded to the news media with information about INTSORMIL that was published by the Association Liaison Office, that represents 2,200 institutions of higher learning in the U S Other articles were published in the popular press highlighting INTSORMIL research

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 economics, 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 1997-98, there were 55 students from 23 different countries enrolled in advanced degree programs that were advised by one or more INTSORMIL principal investigators This was a decrease of two students from the previous year Approximately 78% 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 17% of all INTSORMIL graduate students were women

The number of students receiving 100% funding by INTSORMIL in 1997-98 totaled 23 An additional 15 students received partial funding from INTSORMIL The remaining 17 students were funded from other sources but are working on INTSORMIL projects These students are enrolled in graduate programs in six disciplinary areas, agronomy, breeding, pathology, entomology, food quality, and economics The number of students receiving 100% funding from INTSORMIL dropped from a high of 71 in 1986 to a low of 17 in 1993-94, then increased to 21 in 1995-96 and is now up to 23 in 1997-98 The reduction in total students being trained from INTSORMIL funds 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 1997-98

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, ROCARS, ASARECA, 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 multilocation testing of breeding materials), promote germplasm and information exchange, and facilitate impact evaluation of new technologies

- Develops regional research networks, 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, WCASRN, WCAMRN, ROCAFREMI, EARSAM of ICRISAT, ICRISAT/Mexico, CIAT and CLAIS of Central and South America for the purpose of coordinating research activities to avoid duplication of effort and to promote the most effective expenditures of research dollars There also has been excellent collaboration with each of these programs in cosponsoring 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 (Reseau 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 collaboration with ROCAFREMI in West Africa has much potential in allowing INTSORMIL utilization scientists to collaborate regionally ROCAFREMI is a good mechanism for promoting millet processing over a wider geographic extent than has been seen before in West Africa 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 resistance 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, East,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 × K1567), for this country The female line Tx623 was used due to its wide adaptation, high yield potential and drought resistance Hageen Dura-1 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 ATx623 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 × Tortillero), and Sureño [(SC423 × 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, that have been distributed 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 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 filling 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 × 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^{-1} on-station, ten times the average yield of the farmer in Niger (273) In 1993, the farm level plots showed the average farmer yield for the Konni and Jirataoua region was 2365 kg ha^{-1} for NAD-1 In 1994, NAD-1 yielded an estimated 1725 kg ha^{-1} (Say), 3500 kg ha^{-1} (Jirataoua), 3800 kg ha ^{1} (Cerasa), and 4600 kg ha ^{1} (Konni) for an overall farmer yield of more than 3000 kg ha ^{1} This is compared to the national average of 273 kg ha ^{1} 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 ^{1} compared to 1 1 t ha ^{1} 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 develop superior hybrids from their research INRAN has made a substantial contribution in producing NAD-1 seed on an interim basis INRAN/INTSORMIL is encouraging private farmers/organizations (farmer cooperatives) to take up seed production The numbers of interested parties is rapidly expanding across the southern part of Niger Private seed production (1997-98) now significantly exceeds that of INRAN Training has become an important component of assisting those interested in hybrid seed production This training aspect should be expanded to provide hands on experience, seminars, small workshops on special topics for a range of concerned individuals/organizations, i e , bankers, NGOs, government officials, as well as seed producers INRAN is effectively assuming lead responsibility for the production and availability of foundation seed At the present time demand for seed of NAD-1 exceeds supply and since 1995 NAD-1 seed has sold for 700-800 CFA/kg which is 4-8 times the price of grain

While new sorghum hybrids are being developed by INRAN/INTSORMIL collaboration, pearl millet hybrid researchers continue to improve pearl millet hybrids INTSORMIL scientists at IER/Mali and from the United States are collaborating with scientists at the ICRISAT Sahelian Center in the hybrid pearl millet programs

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 has been 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 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 A major accomplishment in 1997-98 has been the development of a rapid screening assay for the high protein digestibility trait This has been a joint effort of INTSORMIL and the Texas Grain Sorghum Board

There is considerable interest in Niger and neighboring countries about the potential of commercializing couscous, a processed food, made from sorghum and millet flour The INRAN/INTSORMIL couscous project has advanced substantially The process for making couscous has been optimized as a result of collaborative INTSORMIL research, this optimization of the process is a critical step in achieving a consistent, high-quality couscous product Consumer acceptibility tests show that the couscous made from the INRAN/INTSORMIL unit was highly acceptable Market testing will be taking place during 1998-1999

A *Striga* resistant variety, SRN-39, was identified as promising and released for production in Sudan SRN-39 and other possible sources of resistance to *Striga* are now 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 those *Striga* resistant food quality sorghums were tested on field stations or in farmers fields, or both, in the following countries Ghana, Senegal, Mali, Niger, Sudan, Rwanda, Mozambique, and Eritrea Based upon field results of this germplasm and a mix of cultural practices that alleviate the *Striga* problem, an integrated *Striga* control project combining host plant resistance, fertilizers, and cultural practices was initiated in 1997 for on-farm testing in Northern Ethiopia as a joint project between INTSORMIL, Global 2000, and the Ethiopian Agricultural Research Organization Discussions have also been held with other NARS in the Horn of Africa Region regarding the possibility of conducting the same project on a regional basis

During the 1997-98 program year, INTSORMIL collaborated with the sorghum program of IER/Mali and ROCARS to grow, increase and characterize the Mali sorghum collection This endeavor collected all sorghum accessions of Mali origin from the U S , ICRISAT, CIRAD, and Mali The project was very successful From this it was recommended that in the future, more emphasis should be placed on breeding for drought resistance, especially in northern Mali, and that work should be cooperative with drought breeding efforts in Niger

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 × 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 In 1998, the food processing unit of IER/Sotuba Station, Bamako, Mali has contracted with one village to produce 10 tons of the N'tenimissa grain which will be sold to the GAM, the major biscuit manufacturer in Mali They will use that grain to blend at a 20/80 ration with wheat for biscuit production This is a major step for increased use of sorghum in food industry utilization and value-added product development for sorghum The PVO, World Vision, distributed N'tenimissa to 20 on farm trials in 1997/98 In Northern Mali, CARE is cooperating with IER and testing new sorghum cultivars at about 20 sites INTSORMIL has introduced N'tenimissa to the Bean/Cowpea CRSP/INTSORMIL/Worldvision West Africa NRM Inter-CRSP Project which covers sites in Niger, Mali, Ghana, Chad and Senegal

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, 1993, 1994, and 1995 respectively, while application of 40 kg ha^{-1} 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 removing mineral nutrients from the soil at rates faster than they were being replenished 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^{1} N and 40 kg ha^{1} N, respectively, in monoculture and 64% and 66% for 20 kg ha^{1} N and 40 kg ha^{1} N, respectively, in millet-cowpea rotation Crop rotation (millet-cowpea) alone without N increased millet grain yield by 74% The legume effect appears to be worth 30 to 40 kg N/ha This information, developed by collaborative INTSORMIL research of Malian and American scientists, 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^{-1} 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^{-1} better than the other cultivars Increasing the fertilizer rate to the highest level (15 t ha^{-1} manure plus 100 kg ha^{-1} N) increased grain yield from 1246 to 2475 kg ha^{-1} and stover yield from 3178 to 5067 kg ha^{-1} 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 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 larval and adult populations of head bugs vary naturally from year to year 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 traits Cultivars with previously identified specific and general resistance to the three major foliar diseases (leaf blight, anthracnose, and sooty stripe) maintained their resistance under variable disease pressure in nurseries across the SADC region Some entries in these nurseries are being utilized in sorghum improvement programs in Zambia and Zimbabwe Progress was made on several ergot objectives including additional information on the efficacy of triazole fungicides to control sorghum ergot in seed production fields and the necessity of integrating chemicals with other controls like pollen management Investigations for alternate hosts for sorghum ergot continued to indicate that *Sorghum* spp are the only important hosts in nature

Work continues on identification of the most important disease constraints and for design of disease control strategies in Central America 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 principal sorghum production area 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 are 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, and in 1996 they began their graduate degree research at the ICRISAT Sahelian Center Their research objectives and results will build on findings for millet head miner (MHM) biological control reported by INTSORMIL scientists in 1994 and 1995 Annual Report Results from these students' research will be used to construct a stage-specific life table of the MHM, thus providing an understanding of factors that regulate the abundance of MHM These results also can be used to develop an improved plan for managing MHM on pearl millet in West Africa Ultimately, these data will support developing a "Millet Head Miner Warning System" model to forecast the probability of MHM outbreak in a given area so that appropriate measures can be implemented to control the pest before it damages pearl millet 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

In Honduras, insect pest control developed for one species or a complex of pest species of sorghum involves the integration of specific management tactics, possibly 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 (three army worm species) and a grass looper insect Soil inhabiting insect pests contributing to seed and seedling losses in southern Honduras were identified as wireworms, white grubs, and rootworms Slash-and-burn fields were infested with greater populations of these insects than slash-and-mulch fields, with insects attracted to luxuriant plant growth in burned fields Neotropical cornstalk borer attacked sorghum in monoculture at greater infestatation levels than sorghum intercropped with maize Planting sorghum with hybrid maize reduced stalk borer infestations and damage to sorghum compared with sorghum planted with a native maize These investigations have provided the information for design of integrated insect pest management programs for designated crop production areas Recommendations for planting dates, weed control and insecticide applications to manage lepidopterous defoliators have been developed

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 was 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 In 1998 the food processing unit of IER/Souba Station, Bamako, Mali has contracted with one village to produce 10 tons of the N'tenimissa grain which will be sold to the GAM, the major biscuit manufacturer in Mali They will use that grain to blend sorghum at a 20/80 ratio with wheat for biscuit production This is a major step for increased use of sorghum in food industry utilization and value-added product development for sorghum

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 The INRAN/INTSORMIL couscous project has advanced substantially The process for making couscous has been optimized which is a critical step in achieving a consistent, high quality couscous product Consumer acceptibility tests show that the couscous made from the INRAN/INTSORMIL unit was highly acceptable Market testing will be taking place during 1998-1999

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 Gene mapping has shown that genes conferring resistance to different greenbug biotypes are slightly different, but probably control the same resistance process Molecular biology is contributing to understanding of the inheritance of resistance to greenbug Results from molecular mapping are used in marker-assisted selection studies for greenbug resistance and post-flowering drought resistance Good progress is being made for greenbug resistance Parental lines with biotype I- and K-resistance are anticipated to qualify for release

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 Resistance of sorghum to midge 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 were released to other breeders during the fall of 1996 These were 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

During 1997-98, 62 parental lines of sorghum and 7 of grain pearl millet were released by the Nebraska INTSORMIL collaborating breeder Progress is being made with studies on germination and seedling cold and heat tolerance in sorghum

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 (N) 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 CO^2 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 CO^2 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 Twenty farmers in Nebraska, South Dakota, Oklahoma, Colorado, Iowa and Illinois are trying test plots of pearl millet for the first time in 1998

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 development 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

Throughout 1997-98 INTSORMIL continued to function as one of the primary sources for sorghum ergot information as the pathogen spread across Texas, Oklahoma, Kansas and into Nebraska INTSORMIL was one of the organizers of a U S ergot conference held in late June, 1998 in Corpus Christi, Texas Across south Texas sorghum ergot overwintered in an active disease phase predominantly on feral sorghum in abandoned fields and along roadsides or other areas but also on johnson grass Triazole fungicides continued to provide the best control of ergot on sorghum plants in the field but the necessity for good coverage and contact of the head has raised concerns over efficacy of aerial applications

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 INTSORMIL scientists 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

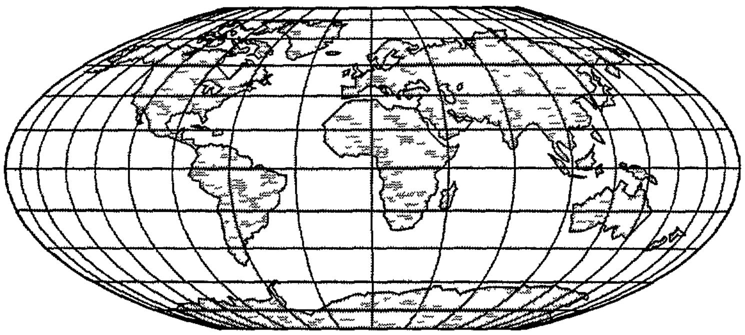
The adverse effects of molds and weathering on sorghum quality significantly limit the use of sorghum for foods in many areas Major progress to understand the factors affecting grain deterioration has been made Work continues to secure mold resistant sorghum cultivars New information on the role of antimicrobial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



Education Strategies

Programs

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

Outcomes

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

Peer ← Collaboration →

Research Strategies to Resolve Constraints

Thrusts

- Conservation
- Developing Research Systems
- Supporting Information Networking
- Promoting Demand Drive Processes

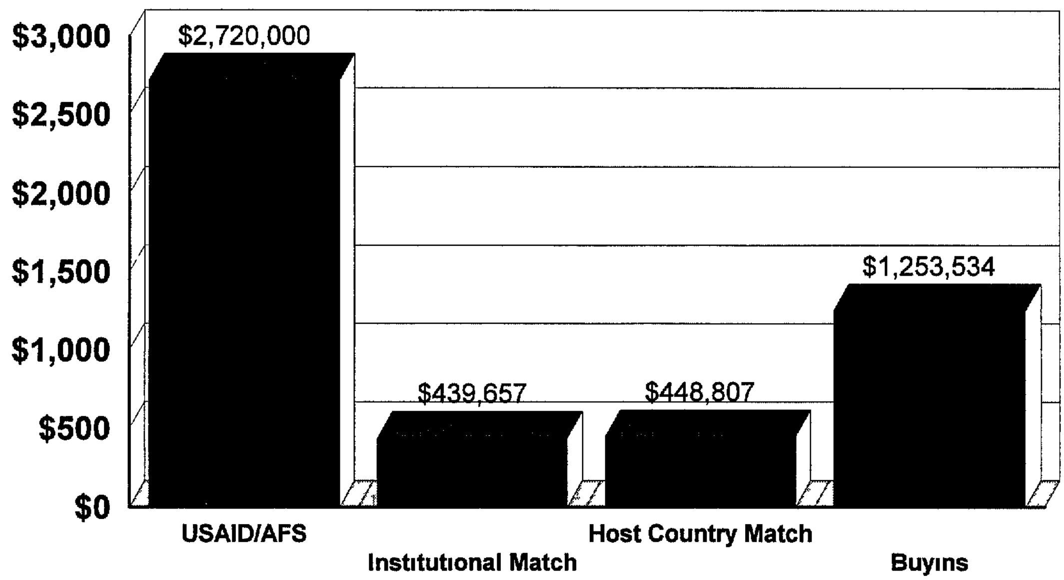
Outcomes

- 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

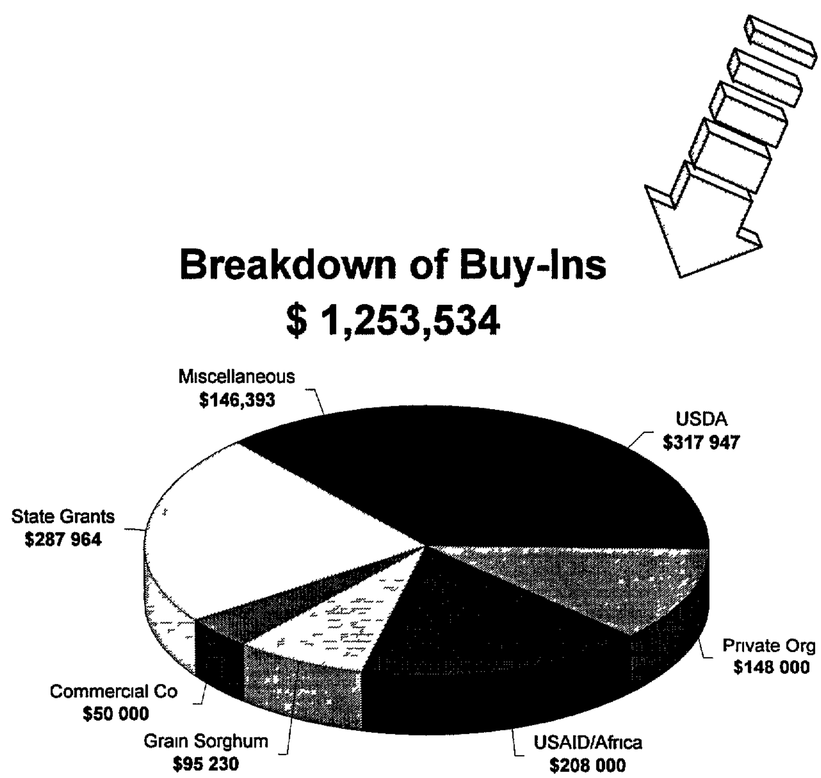
Networking Communication TechnologyTransfer

Farmers

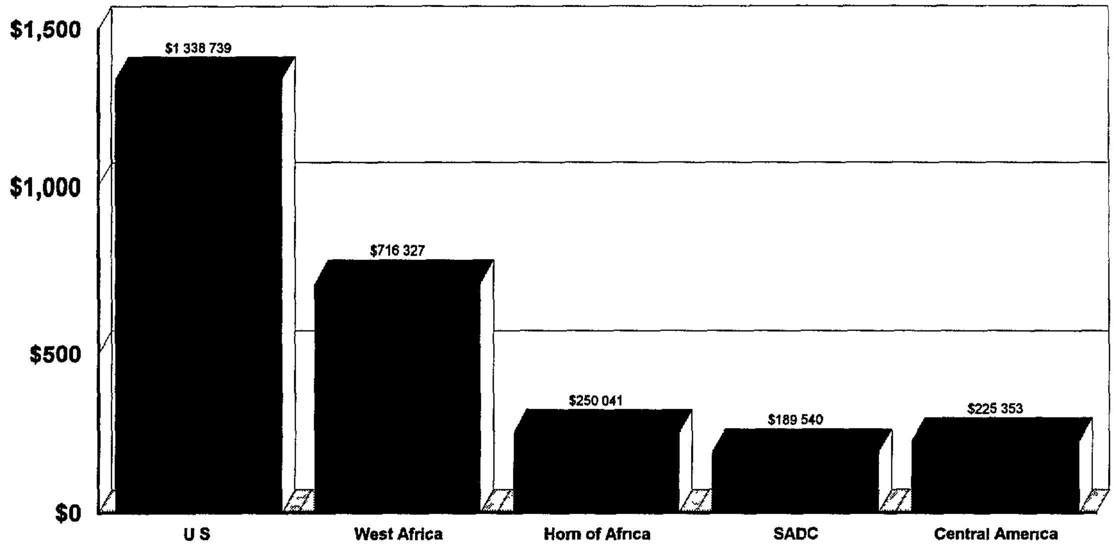
INTSORMIL FY 98 Source of Funding
Total Year 19 -$ 4,861,998



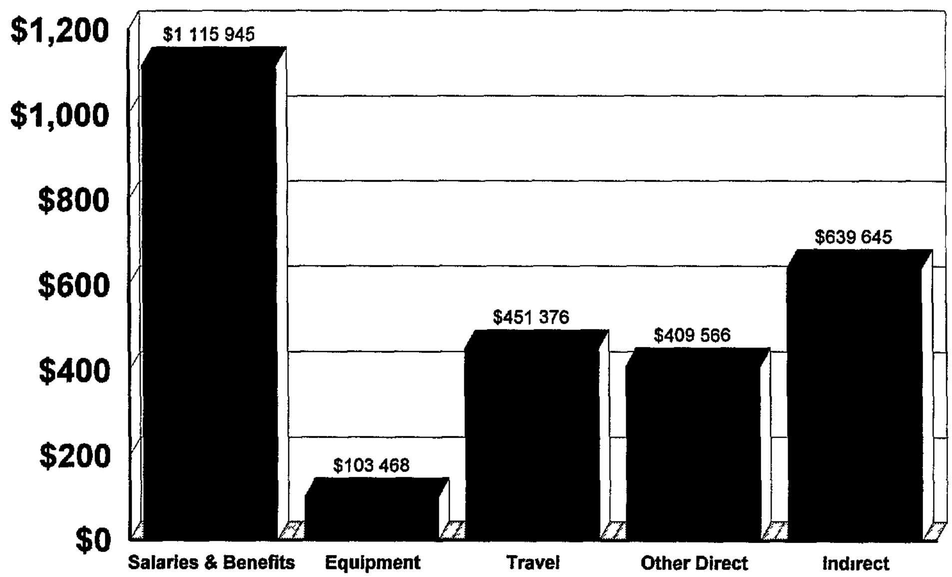
Breakdown of Buy-Ins
$ 1,253,534



INTSORMIL Budget Analysis - Year 19 - FY 98
Functional - $ 2,720,000

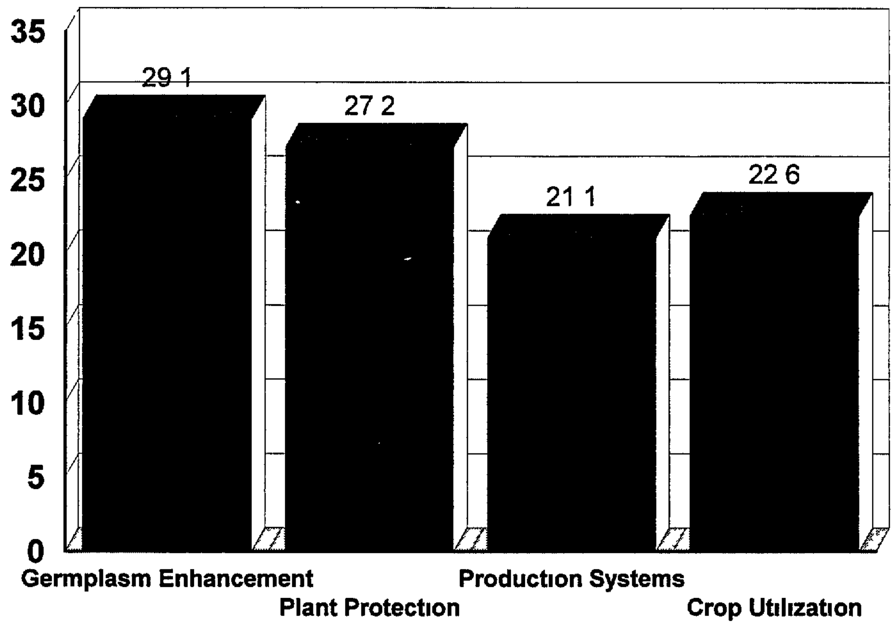


By Region

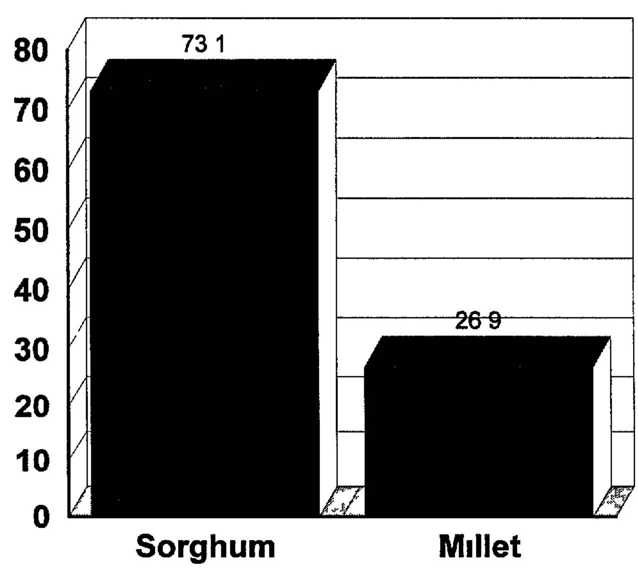


By Line Item

INTSORMIL FY 98 Technical Budget Analysis
Year 19 - $ 1,970,000



Technical Thrusts - By Percentage



Crops - By Percentage

Table 1 USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY80) through 19 (FY98) for all Collaborative Research and Management Entity

Budget Line Items	FY 80 97 Years 1 18	FY 98 Year 19	FY 80 98 Totals
Salaries & Benefits	$ 21 724 133	$ 1 115 945	$ 22 840 078
Equipment & Facilities	2 420 031	103 468	2 523,499
Travel	5,590,850	420 576	6 011 426
Other Direct Costs	5 236 873	405 366	5 642 239
Networking	570,090	35,000	605,090
LDC Special Projects	4,357,186		4,357,186
Mission Buyin	100,000		100,000
Indirect Costs	11,981,719	639,645	12,621 364
Total	$ 51,980,882	$ 2,720 000	$ 54,700 882

Table 2 USAID-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research Year 19 (FY 98), July 1, 1997 - June 30, 1998 USAID Grant LAG-G-00-96-90009-00

	IL	KS	MS	NE	PR	TX	Inst Total	ME Spec Proj	ME HC	ME	Total
Salaries	35 549	38 514	29 288	120 705	232 852	216 677	673 585	24 500	91 860	326 000	1 115 945
Equipment	4 588	3 000	2 239	25 941		22 700	58 468		42 000	3 000	103 468
Travel	8 317	17 000	12 500	21 409	57 200	104 900	221 326	140 550	56 000	33 500	451 376
ODC	628	4 076	6 100	39 211	129 917	60 544	240 476	24 950	114 140	30 000	409 566
Indirect	20 918	27 410	19 873	62 734	171 031	170 179	472 145			167 500	639 645
Total	70 000	90 000	70 000	270 000	591 000	575 000	1 666 000	190 000	304 000	560 000	2 720 000

Table 3 Management Entity Office Budget Details for Years 1 (FY 80) through 19 (FY 98)

Budget Line Item	Years 1-18 FY 80-97	Year 19 FY 98	Total
Salaries and Benefits	$ 2 947,699	$ 326 000	$ 3,273 699
Equipment and Facilities	50,534	3 000	53 534
Travel	864,056	33,500	897,556
Consultants	44,600		44,600
Other Direct Costs	444,671	30,000	474 671
Indirect Costs	1,759,466	167 500	1,926,966
Total	6,111,026	560 000	6 671 026
Workshops	111,000	40 000	151 000
EEP	190 000	70 000	260 000
Special Projects	297,800	80,000	377,800
ME Total	$ 6,709,826	$ 750,000	$ 7,459,826

Table 4 Summary of Non-Federal Matching Contributions by U S Institutions - Grant Years 1 (FY 80) through 19 (FY 98)

U S Institution	Years 1-18 FY 80 97	Year 19 FY 98	Total
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	1 822 084	22 500	1 844,584
Mississippi State University	941 119	17 500	958 619
University of Nebraska	2 231 302	73,500	2,304 802
Purdue University	2 825,650	145,281	2,970,931
Texas A&M University	4 493 657	167 044	4 660,701
University of Illinois	- 0	13 832	13 832
Total	$ 12,702 669	$ 439 657	$ 13,142,326

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, 55 students from 23 different countries were enrolled in an INTSORMIL advanced degree program Approximately 78% of these students come from countries other than the U S which shows the emphasis placed on host country institutional development (Figure 1)

INTSORMIL also places a high priority on training women which is reflected in Figure 2 In 1998, 16% of all INTSORMIL graduate participants were female Twenty-three of the total 55 students received full INTSORMIL scholarships An additional 15 students received partial INTSORMIL funding and the remaining 17 students were funded from other sources as shown in Figure 3

All 55 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

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 1997-1998 this has decreased to seventeen

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 Five post doctoral scientists and seven visiting host country scientist were provided the opportunity to upgrade their skills in this fashion during 1997-1998

The following table is a compilation of all INTSORMIL training activities for the period July 1, 1997 through June 30, 1998

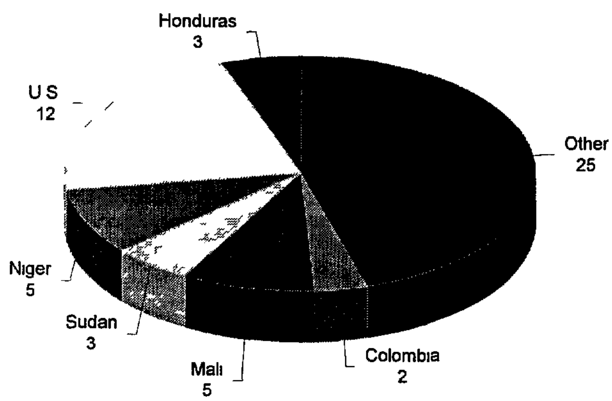


Figure 1 Participants by Country

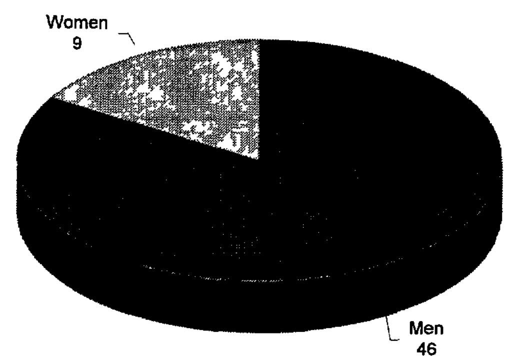


Figure 2 Participants by gender

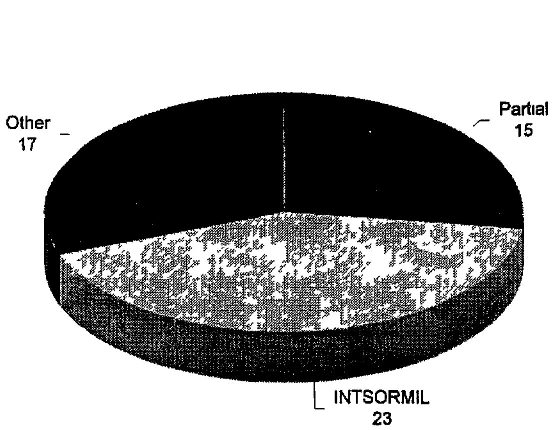


Figure 3 Source of Funding

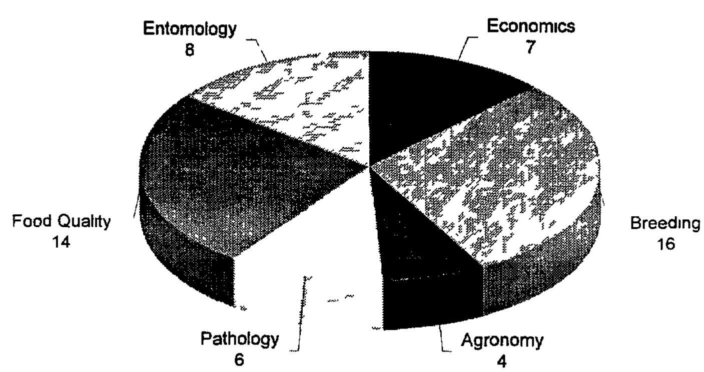


Figure 4 Discipline Breakdown

Year 19 INTSORMIL Training Participants

Name	Country	Univ	Discipline	Advisor	Degree	Gender	Funding*
Traore Abdoulaye	Mali	UNL	Agronomy	Maranville	PHD	M	I
Kim S Young	Korea	UNL	Agron/Physiol	Maranville	MSC	M	O
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
Melakebrhan Admasu	Ethiopia	PRF	Breeding	Ejeta	PD[2]	M	I
Mohammed Abdalla	Sudan	PRF	Breeding	Ejeta	PHD	M	P
Mulatu Tadesse	Ethiopia	PRF	Breeding	Ejeta	MSC	M	P
Rich Patrick	U S	PRF	Breeding	Ejeta	PD[2]	M	I
Tuinstra, Mitchell	U S	PRF	Breeding	Ejeta	PD[2]	M	O
Katsar Catherine Susan	U S	TAM	Breeding	Peterson/Teetes	PHD	F	P
Rodriguez Hererra, Raul	Mexico	TAM	Breeding	Rosenow/Rooney	PHD	M	P
Teme Niaba	Mali	TTU	Breeding	Rosenow	MSC	M	I
Ipinge S A	Namibia	UNL	Breeding	Andrews	VS[1]	M	I
Rai K N	India	UNL	Breeding	Andrews	VS[1]	M	O
Setimela, Peter	Botswana	UNL	Breeding	Andrews	PHD	M	P
Tiryaki Iskender	Turkey	UNL	Breeding	Andrews	MSC	M	P
Ahmed Mohamed M	Sudan	PRF	Economics	Sanders	PD[2]	M	I
Coulibaly Bakary	Mali	PRF	Economics	Sanders	MSC	M	O
Kazianga, Harounan	Burkina Faso	PRF	Economics	Sanders	PHD	M	O
Kebbeh Mohamed M	Gambia	PRF	Economics	Sanders	VS[1]	M	O
Sidibe Mamadou	Senegal	PRF	Economics	Sanders	PHD	M	O
Tahirou Abdoulaye	Niger	PRF	Economics	Sanders	PHD	M	I
Vitale Jeff	U S	PRF	Economics	Sanders	PHD	M	I
Boire Soualika	Mali	TAM	Entomology	Gilstrap/Teetes	PHD	M	I
Kadi Kadi Hame	Niger	TAM	Entomology	Gilstrap/Teetes	MSC	M	I
Calderon Pedro	Honduras	MSU	Entomology	Pitre	MSC	M	O
Cordero Roberto	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Johnson Zeledon	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Vergara, Oscar	Ecuador	MSU	Entomology	Pitre	MSC	M	O
Jensen Andrea	U S	TAM	Entomology	Teetes	PHD	F	I
Lingren Scott	U S	TAM	Entomology	Teetes	PHD	M	O
Aboubacar Adam	Niger	PRF	Food Quality/Util	Hamaker/Axtell	PHD	M	I
Bugusu Betty	Kenya	PRF	Food Quality/Util	Hamaker	MSC	F	I
Zhang Genyi	China	PRF	Food Quality/Util	Hamaker	MSC	M	I
Acosta, Harold	Colombia	TAM	Food Quality/Util	Rooney	PHD	M	P
Asante Sam	Ghana	TAM	Food Quality/Util	Rooney	PHD	M	P
Barron Marc	U S	TAM	Food Quality/Util	Rooney	BSC	M	P
Bueso Francisco Javier	Honduras	TAM	Food Quality/Util	Rooney/Waniska	MSC	M	I
Kunetz Christine	U S	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P
Lee Jae K	Korea	TAM	Food Quality/Util	Rooney/Waniska	VS[1]	M	O
Leon Chapa, Martha	Mexico	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	I
Mateo Rafael	Honduras	TAM	Food Qualtiy/Util	Rooney/Waniska	VS[1]	M	I
Miranda Lopez Rita	Mexico	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Omueti Olusola	Nigeria	TAM	Food Quality/Util	Rooney/Waniska	VS[1]	F	O
Quintero Fuentes Ximena	Mexico	TAM	Food Quality/Util	Rooney	PHD	F	P
Narvaez Dario	Colombia	KSU	Pathology	Claflin	MSC	M	P
Jurgenson Jim	U S	KSU	Pathol/Genetics	Leslie	VS[1]	M	O
Hanson Amy	U S	KSU	Pathol/Genetics	Leslie	MSC	F	O
Zeller Kurt P	U S	KSU	Pathology	Leslie	PD[2]	M	O
Kollo Issoufou	Niger	TAM	Pathology	Fredericksen	PHD	M	I
Torres Montalvo Jose H	Mexico	TAM	Pathology	Fredericksen	PHD	M	O

* 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
FY 98

University/ Project No	Buy-In	Amount
KSU-210A	Ivy Labs	59 063
	USDA/Egypt	30 783
	USDA/Wisconsin	26 831
	American Society for Microbiology	24,500
		$141,177
UNL-214	World Bank	5,000
	Ktibougou University, Mali	3,000
	China Scholarship Council	12 000
UNL-218	Nebraska Grain Sorghum Board	20 230
	Maharastra Hybrid Seed Co India	30,000
	Federal Regional Funds NC501	10,000
		$80,230
PRF-203	McKnight Foundation	10 000
	Purdue University Dean of Agriculture	30 000
	Rockefeller Foundation	20 000
	Winrock/McKnight Foundation	20 000
	World Bank	28 000
PRF-205	USAID/Africa	208,000
	InterCRSP USAID, University of Hawaii	6,000
PRF-207	Purdue University, Department of Agronomy	1 000
PRF-207/213	USDA	37 333
PRF-212	Texas Grain Sorghum Board	40 000
PRF-209	Niger Country Program-World Bank	75,000
		$556,794
TAM-222	Sorghum Biotech Partnership	10 000
	USDA/NRI	15 000
	USDA/ARS	7,500
	Texas Higher Education Coordinating Board	90,000
TAM-222/223	Texas Higher Education Coordinating Board	79 579
TAM-223	Pioneer Hi-Bred International Inc	20 000
TAM-224	USDA/ARS	40 000
	TAMU/TAES	12 000
	USDA/Germplasm Evaluation	6,500
	USDA/CSREES	25 000
	USDA/FAS	30 000
TAM-225	Texas Dept of Agriculture and Texas Pest Mng Assoc	14 699
	Texas Dept of Agriculture and Texas Pest Mng Assoc	19 659
	Texas Grain & Grain Gene Initiative	35 027
TAM-226	Hatch 6789	12 830
	Hatch 8101	15 000
	Texas Grain Sorghum Producers Board	25 000
TAM-228	USDA/ARS	59 000
	USDA/CSREES	30 000
	USDA/FAS/ICD/RSED	10,000
		$556,794
Totals		**$ 1,253,534**

INTSORMIL Sponsored and Co-Sponsored Workshops 1979 - 1999

	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
47	INTSORMIL PI Conference	Lubbock Texas	9/96
48	International Conference on Genetic Improvement of Sorghum and Pearl Millet	Lubbock Texas	9/96
49	Conference on the Status of Sorghum Ergot in North America	Corpus Christi Texas	6/98
50	Principal Investigators Meeting and Impact Assessment Workshop	Corpus Christi Texas	6/98
51	Regional Hybrid Sorghum and Pearl Millet Seed Workshop	Niamey Niger	9/98
52	Sorghum Grain Quality Workshop	Pretoria, South Africa	12/98

INTSORMIL Publications

Abstracts

Aboubacar A and B R Hamaker 1997 Variation in couscous properties among sorghum cultivars Cereal Foods World 42 623

Anderson R M and G L Teetes 1997 Evaluation of insecticides for suppression of sorghum midge on sorghum 1993 Arthropod Management Tests 22 304

Anderson R M G L Teetes and B B Pendleton 1998 Sorghum midge suppression on sorghum 1997 Arthropod Management Tests (in press)

Anderson R M G L Teetes and B B Pendleton 1998 Evaluation of insecticides for suppression of rice stink bug on sorghum, 1997 Arthropod Management Tests (in press)

Anderson, R M , and G L Teetes 1997 Evaluation of insecticides for suppression of sorghum midge on sorghum, 1996 Arthropod Management Tests 22 305

Anderson, R M , G L Teetes, and B B Pendleton 1998 Control of panicle caterpillars on sorghum, 1997 Arthropod Management Tests (in press)

Anderson R M , B B Pendleton, and G L Teetes 1997 Greenhouse evaluation of imidacloprid-treated seed for control of yellow sugarcane aphid on sorghum seedlings 1993 Arthropod Management Tests 22 303

Anderson R M and G L Teetes 1997 Evaluation of insecticides for suppression of rice stink bug on sorghum 1996 Arthropod Management Tests 22 305-306

Buckner R J and B R Hamaker 1997 Sorghum protein digestibility is not affected by artificial dry down Cereal Foods World 42 634

Bueso F R D Waniska W L Rooney 1997 Activity of antifungal proteins against mold in sorghum caryopses in the field AACC 82nd Annual Meeting October 12-16 San Diego CA Cereal Foods World 42(8) 625

Coulibaly A M Bagayoko S Traore and S C Mason 1998 Pearl millet yield and soil properties as influenced by crop residue management Agron Absts , (In Press)

Diarisso Niamoye Yaro 1997 Spikelet flowering time and morphology as causes of sorghum resistance to sorghum midge (Diptera Cecidomyiidae) Annual Plant Resistance to Insects Newsletter 23 37-38

Diarisso N Y B B Pendleton, G L Teetes, G C Peterson and R M Anderson 1997 Relationship between sorghum glume closure and resistance to sorghum midge International Sorghum and Millets Newsletter 38 87-88

Diourte M L E Claflin and B A Ramundo 1997 Infection and colonization of sorghum plants by two Fusarium species involved in the etiology of Pokka Boeng Phytopathology 87 S24

Diourte M , and L E Claflin 1997 Characterization of *Fusarium* isolates from Kansas and Mali Phytopathology 87 S24

Kapran, I J Axtell, G Ejeta, and T Tyler 1997 Expression of Heterosis and Prospects for Marketing of Sorghum Hybrids in Niger Presented at the International Conference on the Exploitation of Heterosis and in Crops, CIMMYT Mexico

Katsar C S A H Paterson, G C Peterson and G L Teetes 1997 Molecular analysis of resistance to greenbug in sorghum p 654-655 In Rosenow et al eds Proc of International Conference on the Genetic Improvement of Sorghum and Pearl Millet Lubbock TX Sep 22-27 1996 INTSORMIL University of Nebraska, Lincoln NE Publ 97-5

Katsar, C S , A H Paterson G C Peterson, and G L Teetes 1997 RFLP analysis of greenbug-resistant sorghum germplasm Annual Plant Resistance to Insects Newsletter 23 39 40

Kunetz C F H Almeida-Dominguez C M McDonough, R D Waniska, and L W Rooney 1997 Cooking characteristics and quality of noodles from food sorghum AACC 82nd Annual Meeting October 12-16 San Diego, CA Cereal Foods World 42(8) 624

Maman N S C Mason and T D Galusha 1997 Genotype and N influence on pearl millet growth and nutrient uptake Agron Absts , p 96

Maman, N S C Mason and S Sirifi 1997 Genotype and fertilizer influence on pearl millet growth and nutrient uptake in Niger Agron Absts , p 96

Maranville, J W , S C Mason and J H Sanders 1998 Improving crop production practices in Sub Saharan Africa INTSORMIL approaches and perspectives Agron Absts , (In Press)

McDonough, C M , K Kunetz, L W Rooney 1997 Structure and texture of sorghum noodles AACC 82nd Annual Meeting, October 12-16, San Diego, CA Cereal Foods World 42(8) 666

Peterson Gary C , Jerry W Jones, George L Teetes Bonnie B Pendleton and Roger M Anderson Grain yield of sorghum midge-resistant sorghum hybrids 1997 Arthropod Management Tests (in press)

Peterson G C G L Teetes, J W Jones R M Anderson, B B Pendleton and K Schaefer 1997 Release of sorghum inbred lines resistant to sorghum midge International Sorghum and Millets Newsletter 38 37-38

Peterson, G C G L Teetes J W Jones R M Anderson B B Pendleton and K Schaefer 1997 Sorghum inbred lines resistant to sorghum midge Annual Plant Resistance to Insects Newsletter 23 36-37

Quintero F X , R D Waniska, and L W Rooney TIA 1998 Effect of amylopectin level on texture during aging of maize and sorghum tortillas 8th Annual TIA Technology Seminar, May 10-14 Dallas TX

Rooney L W D T Rosenow and W L Rooney 1997 Milling properties of sorghums AACC 82nd Annual Meeting, October 12-16 San Diego CA Cereal Foods World 42(8) 629

Rosenow D T C A Woodfin, K Schaefer and L E Clark 1997 Performance of stay green sorghum hybrids under post-flowering soil moisture stress Agronomy Abs p 88

Rosenow D T J A Dahlberg L E Clark and G C Peterson 1998 Sorghum conversion program p 671-672 In Rosenow et al (eds) Proc of International Conference on the Genetic Improvement of Sorghum and Pearl Millet Lubbock TX Sep 22 27 1996 INTSORMIL, University of Nebraska, Lincoln NE Publ 97 5

Stockton R D S C Mason S A Finlayson and P W Morgan 1998 Ethylene effect on grain sorghum germination and early seedling vigor Agron Absts , (In Press)

Suhendro E L , H D Almeida-Dominguez L W Rooney and R D Waniska 1998 An objective measurement of tortilla texture 8th Annual TIA Technology Seminar May 10 14 Dallas TX

Teetes G L G C Peterson R M Anderson K Schaefer and J W Jones 1998 Sorghum midge-resistant hybrids for the 21st century p 677 In Rosenow et al (eds) Proc of International Conference on the Genetic Improvement of Sorghum and Pearl Millet Lubbock, TX Sep 22-27 1996 INTSORMIL, University of Nebraska, Lincoln, NE Publ 97-5

Wiltse, C C , W L Rooney, R A Frederiksen, and D T Rosenow 1997 Survey of anthracnose resistance sorghum germplasm lines to identify additional resistance genes Agronomy Abs p 72

Zhang, G and B R Hamaker 1997 The effect of protein on sorghum starch digestibility Cereal Foods World 42 646

Journal Articles

Bandyopadhyay R D E Frederickson N W McLaren G N Odvody and M J Ryley 1998 Ergot A New Disease Threat to Sorghum in the Americas and Australia Plant Disease 82 356-367

Boora, K S R A Frederiksen and C W Magill 1998 DNA-based markers for a recessive gene conferring anthracnose resistance in sorghum Crop Science In Press

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