1999 Annual Report

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Cover Photographs

Front Cover - Farmer's Field of Sorghum Hybrid NAD-1 in Niger

Back Cover - Variability of Pearl Millet Head Size

INTSORMIL

1999 Annual Report

Executive Summary

Fighting Hunger with Research . . . A Team Effort

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

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INTSORMIL Publication 99-8

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Introduction and Program Overview

Presently, worldwide, more than 800 million people do not get enough to eat or have access to a balanced diet to be healthy. At the World Food Summit in 1996, the United States of America (USA) and 185 other countries pledged to reduce the number of malnourished people by one half by 2015. It is shocking that about 33% of preschool children in developing countries will be stunted due to malnutrition by the year 2000. The number of stunted children in Africa alone has increased significantly from 35 million in 1980 to 45 million in 1995 and is predicted to reach 49 million in 2005. Increased production of cereals, which are crucial sources of food energy and other nutrients, is necessary to reduce world hunger.

Sorghum and millet are two major cereal grains, particularly in semi-arid regions. In 1999, 65.8 million tons of sorghum were produced worldwide, of which 19.7 million tons were produced in Africa, mainly for direct consumption by humans, and 14.7 million tons were produced in the USA, mainly for livestock feed to produce meat for human consumption. In the crop year 1997-1998, the USA exported 5.3 million tons of grain sorghum mainly for livestock feed, and in 1998, U.S. grain sorghum exports were worth $531 million. Large areas are planted to sorghum each year. For example, in 1999, sorghum was produced on 44.8 million hectares (ha, or 173,036 square miles, [sq mi]) worldwide, 23 million ha (88,728 sq mi) in Africa, and 3.4 million ha (13,278 sq mi) in the USA. About 500 million people worldwide depend upon sorghum for food, and most of these people are in developing countries where droughts and famine are common occurrences. Clearly, sorghum production and its utilization as food and feed are vitally important to developing countries and to the USA.

Millets, which include several types such as pearl millet, finger millet and proso millet, are cereal crops even more well adapted to arid ecosystems than is sorghum. Pearl millet, like sorghum, is a staple for 500 million people worldwide. Most of these people are in countries where malnourishment is a persistent problem. In 1999, 37.2 million ha (143,793 sq mi) of millets were harvested worldwide, of which 19.7 million ha (76,170 sq mi) were harvested in Africa, and 120,000 ha (463 sq mi) were harvested in the USA. In 1999, the amount of millets harvested worldwide was 29 million tons, of which 12.9 million tons were harvested in Africa and 180 thousand tons were harvested in the USA. Millets are crops used mainly for direct consumption by humans in developing countries, and the millets are used mainly for feeding livestock, particularly poultry, in developed countries. Pearl millet is an important cereal crop which provides food energy and other nutrients to hundreds of millions of people in areas which currently suffer from malnutrition, particularly Africa and southern Asia. The USA and all other participants in the World Food Conference have a stake in promoting the production and utilization of pearl millet to help end hunger, particularly in Africa.

In October, 1999, the International Food Policy Research Institute (IFPRI) noted that in both developed and developing countries, the rate of increase in cereal yields is slowing from the days of the Green Revolution, partly due to reduced use of inputs like fertilizer and partly due to low levels of investment in agricultural research and technology. In *World Food Prospects: Critical Issues for the Early Twenty-First Century*, IFPRI points out that "without substantial and sustained additional investment in agricultural research and associated factors, it will become more and more difficult to maintain, let alone increase, cereal yields in the longer term. The gap in average cereal yields between the developed and developing countries is slowly beginning to narrow, but it is widening considerably within the developing world as Sub-Saharan Africa lags further and further behind the other regions . . . ."

Agricultural research provides benefits not only to producers of agricultural products but also to processors and consumers of agricultural products. Agricultural research has proven itself continuously as providing improvements which yield products of greater quantity and quality, as well as improved health to consumers and broad-based economic growth which goes beyond producers and consumers. In the U.S. Action Plan on Food Security – *Solutions to Hunger, published in March 1999*, the United States government states that one of the ways that the USA plans to contribute to the global effort to reduce hunger is by the USA's continuing commitment to support international agricultural research through the Collaborative Research Support Programs.

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 to mobilize 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 eight CRSPs currently in operation.

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The Sorghum and Millet Collaborative Research Support Program (INTSORMIL CRSP) conducts collaborative research using partnerships between U.S. university scientists and scientists of the NARS, 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 USA. ***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 United States of America and Less Developed Countries (LDCs).*** Collaborating scientists in NARS developing countries and the USA jointly plan and execute research that mutually benefits all participating countries, including the USA.

INTSORMIL takes a regional approach to sorghum and millet research in western, southern, and eastern Africa, and in Central America. INTSORMIL focuses resources on prime sites in the four regions supporting the general goals of building NARS institutional capabilities, creating human and technological capital to solve problems constraining sorghum and millet production and utilization. INTSORMIL's activities are aimed at achieving 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. What were formerly referred to as "host" countries are now referred to as "collaborating" countries to indicate the closer and more collaborative relationships that have developed between the USA and those countries as a result of all that has been accomplished during the first twenty years of the INTSORMIL CRSP.

Because 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 have a distinctly competitive advantage to yield more grain than other cereals. As wheat and rice products have been introduced to urban populations in developing countries, traditional types of sorghum, because of some quality characteristics, have not been able to effectively compete with the wheat and rice products. However, as a result of research by INTSORMIL researchers and others, improved, food-quality sorghums produce grain that can be used for special ethnic and dietary products as well as for traditional food products. Special, white sorghums developed by INTSORMIL collaborative research in Mali have improved characteristics which allow preparation of high-value food products which can compete successfully with wheat and rice products in village and urban markets. 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 also becoming an important feed source in poultry feeds in the southeastern USA. Improved varieties and hybrids of pearl millet, like improved lines of sorghum, can be grown in developing countries, as well as the USA, and have great potential for processing into high-value food products which can be sold in villages and urban markets, competing successfully with imported wheat and rice products. These developments are results of the training and collaborative, international scientific research that INTSORMIL has supported both in the USA and collaborating countries.

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, improved processing of sorghum and millet, and strengthening the capabilities of NARS scientists to do research on constraints to production and utilization of sorghum and millet.

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 countries. The results include institutional strengthening, development of collaborative research networks, promoting and linking to technology transfer and dissemination infrastructure development, and enhancing national, regional, and global communication linkages. ***A major innovative aspect of the INTSORMIL focus is to maintain continuing relationships with collaborating country scientists upon return to their research posts in their countries. They become members of INTSORMIL research teams composed of American 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 their national agricultural research systems and regional networks in which they collaborate.***

- **Conserving biodiversity and natural resources:** Research results of the collaborative research teams include development and release of enhanced germplasm, development and improvement of sustainable production systems, development of sustainable technologies to conserve biodiversity and natural resources and to enhance society's quality of life and to enlarge the range of agricultural and environmental choices. Thus, INTSORMIL promotes conservation of millet and sorghum germplasm, natural control of arthropod pests and diseases of sorghum and millet,

resource-efficient cropping systems, integrated pest management programs, and cultivars with improved nutrient and water use efficiencies. INTSORMIL also evaluates impacts of sorghum/millet technologies on natural resources and biodiversity.

- **Developing research systems**: Collaboration in the regional sites has been strengthened by using U.S. and NARS multi-disciplinary research teams focused on common objectives and unified plans. INTSORMIL scientists provide global leadership in biotechnology research on sorghum and pearl millet. The output from these disciplinary areas of research are linked to immediate results. Molecular biology 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 to 10 years. New technologies are then extended to farmers' fields in developing countries and the USA through partnerships with NGOs, research networks, extension services and the private sector. In addition, INTSORMIL plays a part in initiating consideration of economic policy and processing constraints to increasing the competitiveness of sorghum and pearl millet as basic food staples.

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

The INTSORMIL program addresses the continuing need for agricultural production technology development for the developing world, especially the semiarid tropics. There is international recognition by the world donor community that the developing country agricultural research systems must assume ownership of their development problems and move toward achieving resolution of them. The 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 and presents a win win situation for international agricultural development.

Administration and Management

The University of Nebraska (UNL) is the Management Entity (ME) for the Sorghum/Millet CRSP and is the primary grantee of USAID. UNL subgrants are made to the participating U.S. Universities for the research projects between U.S. scientists and their collaborating country counterparts. A portion of the project funds, managed by the ME and U.S. participating institutions, support regional research activities. 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 country coordination, budget management, and review.

Several major decisions and accomplishments of INTSORMIL during the past year occurred in the USA and collaborating countries.

- USAID appointed Dr. John Swanson as Project Officer for INTSORMIL.

- Dr. Richard R. Hahn was appointed to the EEP as the utilization/marketing member.

- USAID appointed Stephen Mason as Scientific Liaison Officer with CIAT.

- The 1999-2000 Technical Committee was elected. Its members are Dr. Gary Peterson, Chair, Texas A&M University; Dr. John Sanders, Vice Chair, Dr. John Axtell, Dr. Gebisa Ejeta, Dr. Bruce Hamaker, Purdue University; Dr. Stephen Mason, University of Nebraska; Dr. Henry Pitre, Mississippi State University; Dr. Medson Chisi, Department of Agricultural Re-

search, Zambia; and, Dr. Aboubacar Touré, Institut de Economie Rurale, Mali.

- INTSORMIL, INRAN, ICRISAT and other sponsors held a Regional Hybrid Sorghum and Pearl Millet Seed Workshop in Niger, September 28 - October 2, 1998.

- INTSORMIL and the Sorghum and Millet Improvement Program (SADC/ICRISAT/SMIP) signed a Memorandum of Understanding, providing the institutional framework to strengthen INTSORMIL collaborative research in Southern Africa.

- INTSORMIL PIs, Program Director and Associate Program Director participated in the CRSP Symposium at the annual meeting of the American Society of Agronomy in Baltimore, MD, October 18-22, 1998.

- INTSORMIL and the University of Pretoria held the Sorghum Grain End Use Quality Assessment Workshop in Pretoria in Pretoria, South Africa, December 1-4, 1998.

- INTSORMIL played a major role in preparing a photographic exhibit on the CRSPs at USAID headquarters in Washington, D.C., September through December, 1998. A virtual tour of the exhibit is available at the CRSPs gateway web site.

- The INTSORMIL EEP conducted its five-year, in-depth review of INTSORMIL activities in West and Southern Africa and in the Horn of Africa.

- INTSORMIL helped organize and participated in a USAID-sponsored Lessons without Borders Conference entitled "Global Agriculture and the American Midwest: A Win-Win Exchange," in Ames, Iowa, March 18-19, 1999

- The Grant Renewal Proposal Committee was named and visioning statements for INTSORMIL from 2001 to 2006 were obtained from both inside and outside INTSORMIL.

- Principal Investigators and the Program Director participated in regional sorghum and millet research network meetings in Africa.

- New initiatives were proposed for a multi-CRSP training activity in Mozambique and for a multi-CRSP research activity in the Amhara province of Ethiopia.

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

  * Publication 98-4: 1998 Annual Report
  * Publication 98-5: 1998 Annual Report Executive Summary
  * Publication 98-6: "Inside INTSORMIL Newsletter"
  * Publication 99-1: Proceedings of the Global Conference on Ergot of Sorghum
  * Publication 99-2: INTSORMIL Policy & Procedures Manual
  * Publication 99-3: 1998 INTSORMIL Bibliography
  * Publication 99-4: 1999 INTSORMIL Directory

Training

Within INTSORMIL's regions of collaborative research, training of collaborating country scientists contributes to the capability of each collaborating country research program to stay abreast of economic and ecological changes which alter the balance of sustainable production systems. The strengthening of collaborating country research institutions contributes to their capability to predict and be prepared to meet the challenges of economic and ecological changes which affect production and utilization of sorghum and millet. A well balanced agricultural research institution must prioritize and blend its operational efforts to conserve and efficiently utilize its natural resources while meeting economic needs of the population in general and the nutritional needs of both humans and livestock. To this end, training is an extremely valuable component of development assistance.

During 1998-99, there were 51 students from 23 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. This was a decrease of four students from the previous year. Approximately 75% of these students came from countries other than the USA, which illustrates the emphasis placed on collaborating country institutional development. INTSORMIL also places importance on training women which is reflected in the fact that 25% of all INTSORMIL graduate students were women.

The number of students receiving 100% funding by INTSORMIL in 1998-99 totaled 20. An additional 12 students received partial funding from INTSORMIL. The remaining 19 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 has dropped from a high of 71 in 1986 down to a low of 17 in 1993-94, then 21 in 1995-96 and

now 20 in 1998-99. 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 collaborating country scientists. Several collaborating country scientists were provided the opportunity to upgrade their skills in this fashion during 1998-99.

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 (WCAMRN/ROCAFREMI WCASRN/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 multi-location testing of breeding materials), promote germplasm and information exchange, and facilitate impact evaluation of new technologies.

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

Over the years, established networking activities have been maintained with ICRISAT in India, East Africa, Mali, Niger, and Zimbabwe; ASARECA, SAFGRAD, WCASRN/ ROCARS, WCAMRN/ROCAFREMI, and SMIP/SMINET in Africa; CLAIS and CIAT of Central and South America and SICNA and the U.S. National Grain Sorghum Producers Association 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 co-sponsoring workshops and conferences, and for coordination of research and long term training. INTSORMIL currently cooperates with the ICRISAT programs in East, Southern, and West Africa, with WCASRN/ROCARS and WCAMRN/ROCAFREMI in West/Central Africa and with SMIP/SMINET in Southern Africa. Sudanese collaborators have provided leadership to the Pan African *Striga* Control Network. INTSORMIL collaboration with WCAMRN/ROCAFREMI in West Africa is allowing INTSORMIL utilization scientists to collaborate regionally. WCAMRN/ ROCAFREMI is a good mechanism for promoting millet processing at a higher level than has been seen before in West Africa. During the last two years, INTSORMIL, the Bean/Cowpea CRSP and World Vision International have been working with NARS researchers and farmers in five countries, creating and using a technology-transfer network in West Africa. INTSORMIL will continue to promote free exchange of germplasm, technical information, improved technology, and research techniques.

Benefits to Collaborating Countries

Regional Activities and Benefits

The four regions of INTSORMIL collaboration include five prime sites where INTSORMIL resources were focused over the past year. These prime sites are Mali and Niger in West Africa, Ethiopia in the Horn of Africa, Botswana in Southern Africa, and Honduras in Central America.

West Africa

In Mali in Year 20, INTSORMIL completed its 15th year of collaboration with IER. The sorghum breeding program in Mali is large and diverse. It includes extensive crossing and intercrossing among elite introductions, improved non-guinea and guinea derived breeding lines, and elite local cultivars. It utilizes genetically diverse germplasm from around the world resulting in much genetic diversity in the breeding program. Extensive use is made of lines developed by ICRISAT and elite lines from the USA. INTSORMIL's collaborative breeding program in Mali focuses on developing lines of sorghum which are highly resistant to head bug and grain mold and which are tan plant types having high-quality grain for human consumption. INTSORMIL's collaborative pearl millet breeding in Mali aims at developing hybrid lines of pearl millet using a breeding technique which utilizes the difference in timing between stigma exsertion and receptivity and pollen production on the same panicle to achieve crossing. Local plant pesticides (biological pesticides derived from local plants) were found to be effective in controlling covered smut and will soon be released to farmers for seed dressing products.

In Niger, a long-term effort to improve nutrition and incomes of Nigerien citizens through the use of hybrid sorghum is coming to fruition. In the mid-1980s a Nigerien graduate student being trained in plant breeding by the INTSORMIL program began to experiment with hybrid sorghum in Niger. During the course of his M.S. and Ph.D. studies, he worked with his professors to develop parents of a sorghum hybrid which was designated NAD-1. This hy-

brid, which has grain quality acceptable for local food preparations, is well-adapted to drought and has consistently high yields, compared to local varieties. Yield results of NAD-1 in on-farm demonstrations have ranged from 3000 to 4500 kg ha^{-1} with adequate moisture to 1200 to 1500 kg ha^{-1} on dryland, where the national average is around 270 kg ha^{-1}. In October, 1998, INTSORMIL co-sponsored a regional conference with INRAN and ICRISAT in Niger, entitled "Regional Hybrid Sorghum and Pearl Millet Seed Workshop." The workshop was attended by scientists, government officials and business people from countries throughout West Africa, as well as the USA, Europe and India. At the workshop, which included oral presentations as well as trips to the field, the benefits of hybrid crops were discussed, experiences in starting hybrid sorghum seed industries in developing, as well as developed, countries were shared, and philosophy, strategy and tactics for developing a hybrid sorghum industry in Niger were discussed. As a result, commercial production of hybrid sorghum seed is now under way in Niger. This production of hybrid sorghum seed and the resulting increases in sorghum production will help Niger provide food security and is already resulting in higher incomes for those associated with the production and sale of the hybrid sorghum, NAD-1. INTSORMIL scientists both in the USA and in Niger continue to develop new, improved parents for hybrid sorghum seed production in Niger and continue to work with the private sector and government to assure that each plays its crucial role in developing the hybrid sorghum industry. The success of the nascent hybrid sorghum seed industry in Niger is, in large part, due to commitment of INTSORMIL to train Nigerien scientists and conduct collaborative research in Niger over the long term.

Horn of Africa

The Horn of Africa Regional Program follows a productive collaborative research program with the Agricultural Research Corporation in Sudan. From that collaboration, extensive raw and improved sorghum germplasm were identified, assembled, and catalogued for the benefit of agriculture in Sudan and the USA. Sudanese scientists were trained at INTSORMIL institutions in the USA, and U.S. scientists traveled to Sudan to work with their counterparts. The present, regional program has only recently been undertaken, and has as its prime site, Ethiopia. Eritrea, Kenya, Uganda and Sudan also participate in INTSORMIL's Horn of Africa regional program, although participation of Eritrea and Sudan is limited by political issues and current conflict in the region. Major regional constraints to production of sorghum and millet were identified during the past year. According to sorghum and millet scientists in the region, "the major sorghum and millet production and utilization constraints are generally common to all countries." These constraints include lack of improved germplasm, drought, *Striga*, insects and diseases (anthracnose, leaf blight, grain molds, smuts, ergot, blast, and downy mildew). Lack of moisture and soil nutrients and poor husbandry are primary constraints of sorghum and millet production in the Horn of Africa. Research conducted by participating scientists of NARS in the Horn of Africa is primarily applied research.

Southern Africa

In Southern Africa, INTSORMIL activities last year occurred in Botswana (the prime site), Namibia, Zambia, and Zimbabwe. The Southern Africa program is organized in six collaborative research projects in the following areas: development of pearl millet hybrids, using Namibian and Zambian varieties; sorghum disease management by identification and use of resistance; sorghum food quality research; integrated pest management research in Botswana and South Africa, with emphasis on sugarcane aphid; identification of factors limiting commercial production and marketing of sorghum in Botswana; and control of sorghum ergot. An area of collaborative research of major benefit to both the USA and South Africa deals with control of sorghum ergot, a disease which has plagued South Africa for many years and which entered the USA in 1997. INTSORMIL scientists from Southern Africa and the USA are working together to develop a multi-variate model which will incorporate as many of the relevant variables affecting ergot severity in hybrid sorghum seed production systems. The study is being conducted over a range of areas representative of climatic zones including four areas in South Africa and production areas in Zimbabwe and Zambia.

Central America

During the past year, the Central American program has been evolving from a program focused mainly in Honduras to one which is more inclusive of scientists from other countries in the region. The program has extensive ties with the private industry in Central America. A Memorandum of Understanding signed by INTSORMIL and the Nicaraguan Institute of Agricultural and Livestock Technology in May, 1998, made possible collaboration in sorghum breeding by sorghum breeders at INTA and Texas A&M University. During the past year, discussions were held with representatives of two Nicaraguan Universities (the National Agrarian University and the National Autonomous University of Nicaragua) and the Center for Agricultural, Livestock and Forestry Technology in El Salvador. Memoranda of Understanding are being prepared to provide the institutional framework to support collaborative research on sorghum by scientists of these three institutions with scientists of INTA, EAP and universities participating in INTSORMIL in the USA. Collaborative research on breeding sorghum varieties resistant to sorghum midge in Nicaragua was initiated this past year. Long-term research on the "langosta" complex of lepidopterous pests of sorghum and maize resulted in publication of a guide on how to manage these crops to minimize damage from the insects. In 1998, eighteen commercial sorghum hybrids were evaluated by INTSORMIL scientists working with scientists at national agricultural research systems throughout Central America

and the Dominican Republic. This annual activity of INTSORMIL provides useful information to seed companies, growers, and breeders throughout the region. Collaborative grain quality research conducted by Honduran and American scientists produced useful information on sorghum tortilla quality traits such as appearance (color), taste, aroma, texture (mouthfeel)) and rollability by a taste panel. This information is being used by sorghum breeders to improve traits of food sorghums.

Regional Benefits by Technical Thrust

Germplasm Enhancement and Conservation

Germplasm exchange, movement of seeds in both directions between the USA and collaborating countries, involves populations, cultivars, and breeding lines carrying resistance to insects, diseases, *Striga*, drought, and soil acidity. INTSORMIL plant breeders also develop 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 collaborating country use include the following.

- Improved yield (for all collaborating countries)
- Improved drought tolerance (Africa and drier areas of Latin America)
- Acid soil tolerance
- *Striga* resistance (West, Eastern Africa, and Southern Africa)
- Midge and greenbug resistance (Latin America)
- Downy mildew resistance (Latin America and Botswana)
- Anthracnose resistance (Latin America and Mali)
- Charcoal rot and lodging resistance (Africa and drier areas of Latin America)
- Head smut and virus resistance (Latin America)
- Foliar disease resistance (for all collaborating countries)
- Improved grain quality characteristics for food and industrial uses (for all collaborating countries)

INTSORMIL has been working since the mid-1980s to help Niger develop a hybrid seed industry. Beginning with initial experiments with hybrid sorghum in the 1980s, INTSORMIL scientists of Niger and the USA have collaboratively developed a line of hybrid sorghum, NAD-1, which is well adapted to conditions in Niger, yields higher than most local varieties and has acceptable qualities for consumers. A Hybrid Seed Workshop for W. Africa, was held in Niamey, Niger on September 28 through October 2, 1998. The purpose of the workshop was to acquaint West African sorghum and millet research scientists about the benefits of hybrid seed for West Africa. Speakers discussed relevant hybrid seed experiences in their own developing countries, including India, Zambia, Sudan, and Brazil. The goal was to explore opportunities for development of sorghum and pearl millet hybrids for W. Africa and to assist the development of a private sector seed industry which brings many benefits to farmers in W. Africa. The Workshop consisted of approximately 150 participants from 15 countries including: United States of America, Niger, Ghana, Mali, Cote d'Ivoire, India, Burkina Faso, Kenya, Chad, Egypt, Senegal, France, Nigeria, Zimbabwe, and Zambia. Following the workshop, our private-sector partners, with the cooperation and support of the public sector, in Niger have made significant progress in the production of NAD-1 hybrid sorghum seed. First, a private seed company has purchased the government seed farm at Lossa. Dr. Salifou, who was trained at Mississippi State in seed technology several years ago, is leading the development of a private sector seed industry for Niger. INRAN and the Government of Niger is supportive of this private seed sector activity. NAD-1 will be the first hybrid seed produced and marketed by this company. Second, several hybrid sorghum seed producers in Niger have formed a seed producers association. This association recognizes INRAN as an honorary member, but is intent on controlling the seed association outside of the formal structure of the government. We think this is an encouraging development which we will nurture. Third, the demand for hybrid seed far exceeds the supply even though the seed is sold at approximately eight times the price of grain. The important distinction between seed and grain is now recognized in Niger. We estimate that 60 tons of hybrid seed will be produced this year in Niger. A great deal of this seed production will be on small farms.

Building on the results of INTSORMIL research in the USA, the potential of brown midrib sorghum sudangrass in W. Africa is being explored through collaboration with an INTSORMIL scientist in Niger. The value of forage in West Africa is high, and there is a chronic shortage of good quality forage which we believe can be partially alleviated by brown midrib sorghum sudangrass hybrids. At this point in time, there has been extensive cultivation of brown midrib sorghum hybrids in Pakistan and in some Asian countries. The potential value in India has been recognized since India is now the largest milk producer in the world and they are heavily investing in research on brown midrib forage cereals. As we enter the next decade of the "meat revolution" forage crops will increase in importance.

The mutable pericarp color gene designated as "candystripe" was first identified in Sudan. Collaborative research has now identified and cloned this mutable gene in

sorghum. The transposon is a very high molecular weight element with all the characteristic properties of other transposable elements. The unique feature of these elements is that they can be used to identify agronomically important genes in sorghum. The probes are just now available which will allow us to isolate important genes for such important traits as drought resistance and to study them in other plant systems and other gene expression systems. This is an important step forward in the identification of important genes from sorghum which can now be studied in greater depth.

Collaborative research of an INTSORMIL team is proving useful to sorghum breeders worldwide. The use of DNA-based markers for genetic analysis and manipulation of important agronomic traits is becoming increasingly useful in plant breeding. In a recent study 190 sorghum accessions from the five major cultivated races, namely *bicolor*, *guinea*, *caudatum*, *kafir*, and *durra*, were sampled from the world collection maintained by ICRISAT. Genetic variation was detected using RAPD primers. Only 13% of the total genetic variation was attributable to divergence across regions, but South African germplasm exhibited the least amount of genetic diversity, while the genetic diversity within the West African, Central African, East African and Middle Eastern regions was high among the 190 samples from the world collection. This research showed that molecular markers can be used to help identify suitable germplasm for introgression into breeding stocks. Selecting the most divergent accessions for introgression may increase the probability of extracting suitable inbred lines to improve the yields of varieties and hybrids.

The commitment of INTSORMIL to integrated pest management of insect pests and pathogens has produced new lines of sorghum useful to commercial breeders and seed companies for both marketing hybrids and developing more advanced hybrids. Germplasm obtained and evaluated for resistance to economically important insect pests was used to combine insect resistance with other favorable plant traits. Sorghum germplasm was identified for advanced testing with resistance to several stresses and will contribute to production of more widely adapted, high yielding hybrids. Techniques of molecular biology are being used to help understand the inheritance of resistance to greenbug. Results from molecular mapping of sorghum are being used in marker-assisted selection studies for greenbug resistance and post-flowering drought tolerance.

Producing improved seed that seed companies and farmers can use, INTSORMIL researchers collaborated with LDC scientists to develop improved, high yielding varieties and hybrids. Progeny were identified that combine several needed favorable traits into a single genotype. Advanced selections are in evaluation in on-farm trials to measure performance. As research continues to generate new technology, the importance of testing on-farm, and soliciting producer input on research activities will increase. Technology (germplasm) developed by this project has been adopted by private industry and used in hybrid production or breeding programs. Impact assessment studies have consistently shown a high rate of return on investment from research conducted by this project.

Sustainable Production Systems

An INTSORMIL study focusing on the impact of household and agricultural technologies on women in Burkina Faso showed the importance of household and agricultural technologies independent of decision-making in the household. Many new technologies, especially new seeds and inorganic fertilizers, increase the demand for labor and therefore result in female and male household members working more on the commonly farmed area and less on their private plots. This has been shown to reduce the income received by women. As technology introduction proceeds, however, increasing within-family contention over the new income streams would be expected, with an evolution towards the conflict and cooperation of bargaining household decision-making. As the bargaining position of women improved, there was a substantial, combined effect of the two types of technology on the potential income of women. With bargaining, agricultural technologies increase the income of women by 29% and the combined agricultural and household technologies by 68%. Policy recommendations are to accelerate the introduction of technological change onto the commonly farmed areas while also increasing the bargaining power of women.

In West Africa, INTSORMIL's main collaborative, agronomic research activities have been focused in Mali and Niger. INTSORMIL participates in the West and Central African Sorghum and Millet Research Networks. This year, INTSORMIL signed a Memorandum of Understanding with the national agricultural research system of Burkina Faso, IN.ERA, and collaborative research was begun. In research conducted during the past year, it was determined that high-yielding grain sorghum genotypes that are tall or have high vertical leaf area distribution can be more competitive with weeds and, therefore, be a useful component of integrated weed management programs. Studies on management of late-maturing Maiwa pearl millet in southern Niger were initiated. Because this variety of pearl millet tillers profusely, it provides a unique opportunity to integrate grain production for human consumption and forage production to support livestock. Initial results that tillers can be harvested 65 to 85 days after planting for use as livestock feed without reducing grain or stover yield point to development of a more economically rewarding cropping system for millet farmers in the Sahel.

Research in Mali by WCAMRN/ROCAFREMI showed that pearl millet grain production increased 10 to 19% of when millet was rotated with cowpea or peanut across West and Central Africa, while yield increases of pearl millet grain production due to other production practices appeared to be more site-specific. The highest grain yields required application of inorganic fertilizer or combined application of inorganic and organic fertilizer.

In Niger, several collaborative studies of INTSORMIL scientists from Niger, India and the USA were finalized. The results of the research are now being prepared for publication by INTSORMIL scientists at the University of Nebraska. The on-farm trials in Niger were inconclusive in 1998 due to adverse environment, but tended to show the value of NAD-1 and tied ridges for conserving moisture. In addition to preparing manuscripts, a visiting INTSORMIL scientist has conducted greenhouse studies at UNL to strengthen the field results from Niger. A former INTSORMIL graduate student has returned to Ghana to begin collaborative research under the new memorandum of understanding recently signed by INTSORMIL and the Savannah Agricultural Research Institute (SARI) of Ghana. INTSORMIL has provided him with a new computer and chlorophyll meter, and will also provide operating funds in 1999.

In Mali, studies on the effect of previous crop on sorghum yields showed that sorghum following corn or cowpea was better than sorghum after peanuts, pearl millet or dolichos. Sorghum following sorghum resulted in the poorest yields. Responses were modified positively and linearly by N application up to 60 kg ha^{-1}. Application of Malian rock phosphate also increased sorghum yield about 9%.

Sustainable Plant Protection Systems

INTSORMIL's approach to developing sustainable plant protection systems is integrated pest management (IPM). Two key elements of IPM for sorghum and millet which are central to INTSORMIL plant protection research are genetic resistance of sorghum and millet to insect pests, pathogens, and the parasitic weed, *Striga*, and practices to control insects and pathogens with minimal use of chemical pesticides. INTSORMIL entomologists and plant pathologists work closely with plant breeders, agronomists and food scientists to develop more effective means to manage pests of sorghum and millet in order to provide higher yields of higher quality grain per unit area cultivated. Intensification of agricultural production, which can help remove pressure on fragile ecosystems, depends on many factors; sustainable, plant protection is essential to increase production of food and feed from sorghum and millet in economically and ecologically sustainable ways. 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 researchers from the USA and Africa are accelerating the progress in developing biological defenses to the attack on sorghum by the parasitic weed, *Striga*. Advanced techniques have been developed to rapidly screen lines of sorghum by testing the sorghum seed in order to determine whether these lines have any of several specific modes of resistance to *Striga*. The extended agar assay involves artificially germinating sorghum seeds in the presence of *Striga* seeds to determine which lines of sorghum produce little or no germination stimulant. The paper roll assay is used to determine which sorghum lines inhibit the penetration of *Striga*. Using these techniques, INTSORMIL researchers not only select sorghum lines with specific resistances to *Striga*, but also are learning more about the complex interactions between sorghum and the parasite. The use of these laboratory techniques is rapidly accelerating the selection and breeding of *Striga*-resistant lines of sorghum which can be used to improve the resistance of varieties and hybrids of sorghum in Africa where *Striga* is a major factor in causing famine throughout the continent. Research on the agroecology and biotechnology of stalk rot pathogens of sorghum and millet resulted in increased understanding of sexual reproduction of *Fusarium*, a fungal pathogen of both sorghum and millet.

Ergot, or *Claviceps africana*, is a fungal pathogen of sorghum which prevents pollination of the sorghum plant's ovaries if the ergot enters the ovary before pollination occurs, resulting in a sticky exudate and no grain formation. Ergot infestation of grain sorghum was a problem in Africa and Asia before 1996 when the disease was first detected in Argentina and Brazil. In 1997, ergot spread to Colombia, Honduras, Mexico, many islands in the Caribbean, and major sorghum-producing states in the USA (Kansas, Nebraska, and Texas). Losses due to ergot can include reduction in grain yield, loss of export markets of seed and feed grains to countries where ergot has not been reported, and loss of germplasm and hybrid seed increases in winter nurseries where ergot has been detected and quarantine regulations prohibit return of the grain to the USA. INTSORMIL researchers during the past year have focused their efforts on many aspects of the biology and ecology of ergot. These efforts have been collaborative and international, involving scientists in the USA, Central and South America, Africa, Asia, and Europe.

Important findings include:

- Sorghum accessions susceptible to *Claviceps africana* include *S. bicolor*, *S drummondii*, *S virgatum*, *S. arundinaceum*, and *S. halepense*. Ergot symptoms were not observed on *S. verticilliflorum* and *S. drummondii*. Other economically important plant species surveyed which were observed to be not affected by ergot include finger millet, pearl millet, proso millet, foxtail millet, big bluestem, Osage indiangrass, switchgrass, maize and Canadian wild rye.

- An extremely high incidence of ergot was reported in grain sorghum over a several-week period in February 1997 on many islands of the Caribbean, probably due to an airborne spore shower. It is believed that Hurricane Mitch was the primary carrier of spores of ergot in the Caribbean region during its existence in 1998.

- In late 1998, *C. africana* demonstrated that it is a well-established, recurrent pathogen of Mexico and Texas with the capacity to survive under extended, unfavorable, dry environments and has the ability to quickly reach epidemic proportions over vast regions upon a return to favorable, wet, cool environments.

- The obvious honeydew exuded from parasitic sphacelia of ergot on sorghum is only one source of conidia. Any surface coated with honeydew (e.g., leaves, seeds, or soil) may also be a source.

- There is a marked effect of temperature on the survival of conidia, with storage of sphacelia at higher temperatures resulting in more rapid loss of viability, compared to storage at lower temperatures.

- Sorghum ergot caused by *C. africana* was observed to persist in an active phase predominantly on feral grain sorghum in Mexico and as far north as Corpus Christi, TX through February 1998. Feral and ratooned grain and forage sorghum and johnsongrass within fields and along roadsides were infected by large outbreaks of ergot in December 1998 due to a wet, cool environment.

- Experiments using a fungicide showed that it can be used to effectively prevent germination of ergot sphacelia and sclerotia, leading to the conclusion that sclerotia and sphacelia in seed treated with the fungicide should not be considered a potential source of the inoculum.

Each growing season, sorghum and maize are attacked by soil inhabiting insects, stem borers and panicle feeding insects that contribute to reduced yields of both crops on subsistence farms in Honduras, as well as other countries in Central America. However, the major insect pest constraint to production of these grain crops in Honduras is foliage feeding insects, whereas, the sorghum midge is the principal insect pest constraint to sorghum production on large commercial fields on the coastal plains of Nicaragua. A complex of defoliators annually damages or destroys the sorghum and maize crops in Honduras resulting in yield losses or replanting. Subsistence farmers may not have the resources to replant. The pest complex has been identified by INTSORMIL scientists to consist principally of three armyworm species and a grass looper.

Soil inhabiting insect pests contributing to sorghum seed and seedling losses in Honduras have been identified and insecticide control methods determined. Although slash-and-burn agricultural practices are used by subsistence farmers to assist in insect control, this cultural practice had limited influence on fall armyworm and neotropical cornstalk borer infestations. The pests were attracted to luxuriant plant growth in burned fields. Seed treatment with insecticide limited damage to seed and seedlings by soil inhabiting insects. Neotropical cornstalk borer attacked sorghum in monoculture at greater infestation 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.

Aspects of the biology, ecology, behavior and population dynamics of the armyworm species in the defoliator complex in Honduras and the sorghum midge in Nicaragua have been investigated. This information has contributed to the successful conduct of entomological research designed to evaluate ecological relationships of the pest insects with crop and noncrop plants within various cropping systems, crop planting and management strategies, host plant resistance, influence of insecticides on pest and natural enemy populations, and roll of naturally occurring beneficial agents in regulation of pest populations. Insect pest management tactics have been investigated as independent control practices, as well as in integrated systems on subsistence farms in southern Honduras. Recommendations for planting dates, weed control and insecticide applications to manage soil inhabiting insect pests and the lepidopterous defoliators have been developed and disseminated.

The information obtained in these INTSORMIL studies on sorghum and maize will assist subsistence farmers in Honduras and commercial farmers in Nicaragua and surrounding areas with similar insect pest constraints in their production of grain crops to increase yield at minimum cost for pest control with reduced risk to human health and the environment. The extension of INTSORMIL entomological research into Nicaragua has expanded the scope of entomological activities in this ecogeographic zone.

Sorghum diseases are, and remain, important factors reducing the potential yield of sorghum. Ergot continues to threaten the seed industry worldwide. Grain mold and anthracnose resistance traits have been mapped and other useful loci to aid in the pyramiding resistance genes for more durable resistance is progressing.

Acremonium wilt of sorghum has recently become a problem in the Konni area of Niger with the introduction of improved cultivars and hybrids. In order to determine the effect of plant pathogenic nematodes in the infection of sorghum by Acremonium wilt, INTSORMIL scientists conducted a nematicide trial near Konni on a farmer's field to determine whether two nematicides would be effective in controlling pathogenic nematodes, especially of *Pratylenchus spp.* For the susceptible hybrid, NAD-1, the presence of nematodes is not necessary for disease development. With the landrace Mote, the level of infection increases as the nematode number increases. In the presence of nematodes, Mota becomes susceptible to *A. strictum*. The nematicide treatments did not significantly affect the incidence of Acremonium wilt of sorghum either in 1997 (a drought year) or 1998.

In Mali, INTSORMIL scientists from the USA and Mali are developing IPM strategies for insect pests, especially panicle-feeding bugs and sorghum midge, that attack traditional and improved insect-resistant and susceptible sorghums.

In Southern Africa, collaborative research relationships were re-established between INTSORMIL scientists in the USA, Botswana and the Republic of South Africa. Research will be directed toward developing and evaluating sugarcane aphid-resistant sorghums adapted to the southern African region. During this reporting period, 50 sorghum lines were evaluated in the laboratory but not in the field because of severe drought.

Progress was made toward developing a "Millet Head Miner (MHM) Warning System" model to forecast the probability of MHM outbreaks in areas of West Africa so that appropriate measures can be implemented to control the pest before it damages pearl millet. A graduate student from Mali continued writing his dissertation from field studies begun in year 17 on MHM immature stage mortality, adult MHM biology and fecundity, and MHM biology on alternate host plants. His work will form the basis for reporting in 2000. Another graduate student completed and defended his thesis, and returned to Niger in August, 1999. Results from these students' research will be used to construct a stage-specific life table, 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. Using the database available on agro-climatic conditions in the Sahel, and research data from this and other research on MHM, improved approaches to managing MHM will be possible. This is an example of how research done by graduate students from developing countries can contribute significantly to long-term solutions to problems of production and utilization of sorghum and pearl millet.

Crop Utilization and Marketing

In a study of urban consumption patterns in Mali, INTSORMIL researchers showed the substitution potential between imported rice and the traditional cereals, sorghum and millet. With the reduction of import tariffs and devaluation, the net effect was an increase in the traditional cereal price relative to rice. Sorghum and millet were shown to be substitutes for imported rice, but not for domestic rice. Traditional cereals are still cheaper than rice in absolute terms with devaluation, and devaluation has an income reducing effect even if cereal prices do not increase. Income effects apparently encouraged a small increase in consumption of sorghum and millet.

This past year, INTSORMIL cereal chemists have developed rapid screening techniques for breeders to use which assesses the new high digestibility trait recently discovered in germplasm of sorghum. A new rapid screening technique, which measures disappearance of alpha kafirin in sorghum grain has been developed by INTSORMIL scientists from the USA and Niger. The test is rapid and readily distinguishes between normal sorghum and the highly digestible sorghum cultivars. A Kenyan scientist has tested this technique across several environments and found that it is accurate and yet simple enough to be applied to large populations of breeding materials. He is determining the mechanism of inheritance of the high digestibility trait. This technique is being used to accelerate the selection of lines of sorghum which have grain of high digestibility. Further research is being done to improve the assay by way of using microtiter plates to decrease sample size and increase sample throughput per day.

With the hire of a food technologist, in Niger using INTSORMIL regional funds, the couscous project has advanced substantially. The process has been optimized and is waiting for our planned purchase of a decorticator and hammer mill to improve flour quality. This is a critical step in achieving a consistent, high quality final couscous product. There is a good deal of interest both within Niger and in neighboring countries about the potential of commercializing couscous made from sorghum and millet.. The WCAMRN-ROCAFREMI processing project has also focused on this opportunity. In Burkina Faso, where INRAN carried the couscous unit for demonstration, there was a very good response. American and Cameroonian INTSORMIL collaborating scientists will address economic considerations regarding commercial couscous processing. The couscous processing unit designed by CIRAD may not be the most economical, however, there is indication that it probably produces the most consistent, high quality product available from a small-scale process. Consumer acceptability tests showed that the couscous made from the INRAN unit was highly acceptable. Market testing has yet to be done, but is still planned for the upcoming year.

Stronger collaboration should result with the INTSORMIL food scientist in Ethiopia due to INTSORMIL's upcoming purchase of a decorticator and hammer mill for their cereal technology laboratory. With this equipment, there are plans to develop high quality flours that can be used in local Ethiopian industries.

The WCAMRN/ROCEFREMI participation has much potential in allowing INTSORMIL utilization scientists to collaborate regionally. So far ROCEFREMI-WCAMRN appears to be a very good mechanism for facilitating collaboration in millet processing research to a greater extent than has been seen before among the West African NARS.

INTSORMIL research on processing of sorghum has yielded significant results over the past year. Extensive multi-location, multi-year trials to evaluate the abrasive milling properties and factors affecting dry milling of sorghum were conducted. Conclusions are:

- The milling properties of sorghum are affected by hybrid and environmental conditions.

- Sorghums with purple or red plant color produce highly-colored, stained grits when the grain weathers during and after maturation; tan plant color reduces discoloration.

- The food sorghums released have about the same grit yields as cream hybrids, but the grit color is much better, especially when weathering occurs.

- The tan plant red sorghum hybrids produced about the same yields of grits; the grit color was much improved.

- Waxy sorghums have slightly lower density, test weights are generally low, and milling yields are lower.

- ATx635 hybrids all had significantly improved yields of grits with excellent color. The density and test weights were highest for ATx635 grains at all locations.

- It is possible to select for improved milling properties.

White food sorghum flour can be substituted for 50% of the wheat flour in Mexican cookie formulae. The effect of particle size and sandiness of sorghum flour were reduced by using 5% pregelatinized corn starch with 95% sorghum flour in cookies. The texture was equivalent to wheat flour cookies. Pregelatinized sorghum could be used as well.

Noodles from 100% sorghum flour were similar to rice noodles but the dry matter losses during cooking were higher. A noodle making procedure that could be used to make nonwheat noodles for special gluten free diets was devised. Factors affecting noodle quality of sorghum were determined. Heterowaxy sorghum grain has advantages for use in tortillas and baked snacks to improve the texture. Waxy grain has excellent functional properties but grain yields are low. Anti-fungal proteins may be related to grain mold resistance in sorghum. A molecular linkage map for sorghum kernel characteristics, milling properties and mold resistance is nearing completion.

Two Ph.D., two B.S. and one short-term trainee completed work on sorghum and joined the food industry in Mexico, USA and Nicaragua. Three new graduate students joined the INTSORMIL research team at Texas A&M. Research in Honduras demonstrated that food sorghums produced acceptable tortillas. This work was conducted by a Honduran scientist using the commissary tortilleria at EAP and is used as part of increased educational activities in food technology.

A Sorghum Quality Assessment Workshop organized by the University of Pretoria, CSIR, and Texas A&M University, took place in Pretoria, South Africa. More than 36 participants from the food industry, university and research institutes in Southern Africa interacted during the 3.5 day workshop. It included tours to a Sorghum Brewery and the ARC Summer Grains Institute in Potchefstroom. Students participated who are enrolled in the Southern African Regional M.S. degree program at the University of Pretoria.

Work in Mali continued to demonstrate the high qualities of flour from N'Tenimissa sorghum in baked and other products. Progress can be made if identity-preserved grains of consistent quality can be obtained for processing. The bland flavor and light color of white food type sorghums are superior to maize in composite baked products.

Benefits to the USA

Germplasm Enhancement and Conservation

Several seed companies in the USA are now producing seed of brown midrib sorghum sudangrass commercially. Response of livestock producers has been excellent due to improved digestibility and significantly improved palatability. Dairy farmers are the first to see the benefits of the improved nutritional quality in increased milk production. There are approximately 5 million acres of sorghum sudangrass in the USA at the present time, compared with 9 million acres of hybrid sorghum for grain production. Estimating that eventually 50% of the sorghum sudangrass acreage in the USA will be planted to brown midrib cultivars, $42.84/acre value added per acre times 2.5 million acres is equal to $107.1 million additional value to the farmer each year.

The sorghum and pearl millet breeders in Nebraska have taken lines from world wide sources in crosses with U.S. stocks to produce new hybrid parents for the USA, and elite germplasm for selection in developing country programs. Breeding techniques, researched in the project are enhancing the millet breeding programs in Namibia, Zambia and Mali, and the sorghum program in Botswana.

Plant biotechnology has become a powerful tool to complement the traditional methods of plant breeders in plant improvement. During the past year, INTSORMIL researchers have developed a protocol for sorghum transformation using a bacterium, *Agrobacterium tumefaciens*. It demonstrates that Agrobacterium-mediated transformation is a feasible technique for the genetic transformation to improve sorghum. Key factors were the co-cultivation medium, the use of a genotype and an explant with good tissue culture response, and the addition of Pluronic F-68 to the inoculation medium. Sorghum transformation via *Agrobacterium* is still not a routine technique, but it seems to have good potential to improve the characteristics of sorghum once the protocol is further refined and improved.

Both applied and basic research were conducted in both crops. In pearl millet INTSORMIL bred and tested new hybrid parents, many in two cytoplasms, A_1 and A_4, and some

with white grain, that gave higher yielding hybrids (trial mean yield at Mead, University of Nebraska Research Center, was 4.3 t ha^{-1}) with better lodging resistance. Detailed research, in conjunction with an ICRISAT visiting scientist at the University of Nebraska-Lincoln compared isonuclear hybrids in A_1 A_4 and normal (non sterile) cytoplasm. Evidence of cytoplasmic nuclear interaction was found, which means certain hybrids are best in one cytoplasm, others in another, and may be better in sterile cytoplasm than normal. The implication for other crops like maize for instance, is that a hybrid may be better if made by CMS than by detasseling. A_4 hybrids had better seed set at low temperatures, fertility restoration is better, and inheritance is simple and clear. Three further male sterile cytoplasms, A_5 A_{cgp} and A_{av} are being incorporated into the isonuclear parent set to permit further studies. A visiting scientist from Namibia for six months working on hybrid breeding also studied direct effects of pollination on hybrid seed. In inbreds, male parent pollen directly increased seed size in pollinated heads relative to selfed pollinated seed. This means that in hybrid seed production fields some male parents can significantly increase yield, through increased seed size, on seed parents. Similarly, pollination of one hybrid with another slightly increased seed size, but not significantly.

INTSORMIL scientists found large differences between pearl millet genotypes for ability to germinate in cool soils - which would be useful in the Midwest. It is, therefore, possible to breed for this ability. INTSORMIL scientists tested food quality sorghum hybrids from a new generation of parental lines synthesized from earlier project germplasm; yields of the best hybrids were up to 18% better than commercial checks. Tests in 1999 with more extensive combinations produced in the winter nursery should lead to five or six new seed parents and two early male parents. Releases in the germplasm category (advanced lines) are also planned for 1999.

Sustainable Production Systems

During the past year INTSORMIL research has shown that pearl millet has potential as an alternate grain crop in dry, short growing season regions of the Great Plains of the USA. Planting date studies indicate a recommended date of June 1, but there is a wide window of planting dates from May 15 through July 15 for which there is minimal yield loss. This wide window of planting dates in the Great Plains is a characteristic which makes pearl millet feasible as an emergency crop or as a double crop.

Damage to young millet plants occurs for a variety of reasons. When 10 cm was mowed off of 25-day- old plants to simulate damage, increased tillering resulted. In early plantings later maturing varieties compensated well in terms of yield, while in later plantings, when yields from undamaged plants is lower, later varieties actually gave higher yields after mowing, demonstrating pearl millets' remarkable ability to rapidly switch resources to new tillers.

This years results of a multi-year study to determine recommended planting date and row spacing for dwarf pearl millet hybrids was continued on a sandy soil site in Ogallala, NE and a silty clay loam site in Mead, NE, and expanded to include a loam soil site in Sidney, NE, which has low rainfall and a short growing season. At the Sidney site, efforts are being made to intensify wheat -fallow production systems by incorporating a summer annual crop. Averaged over eight environments, narrowing row spacing increased yield of both pearl millet and grain sorghum by 12 to 15%. Pearl millet produced the higher yield when planted on June 1, but yield declines were small when planting as early as May 15 and as late as July 15, while grain sorghum had a narrower window for planting. Averaged over environments, grain sorghum produced approximately 0.4 Mg ha^{-1} more grain than pearl millet, but at planting dates after July 1, pearl millet often produced higher yield. Since pearl millet has a lower base temperature than grain sorghum, further study of planting dates in early May in the Great Plains is merited.

Research of INTSORMIL scientists on weed interference in grain sorghum production showed that velvetleaf (*Abutilon theophrasti* Medic.) is less successful in competing with sorghum hybrids of tall height, compared to the hybrids of medium height. The use of tall grain sorghum hybrids with high vertical leaf area distribution would be a useful component of an integrated weed management program.

Sustainable Plant Protection Systems

INTSORMIL research on *Striga*, the parasitic weed of sorghum which is widespread in Africa and which invaded a small, now quarantined, area in the USA is providing valuable fundamental information about the chemical signals exchanged between crop plants and parasitic weeds. The components of biological resistance of sorghum to *Striga* which are being discovered by INTSORMIL research in the USA and collaborating countries are allowing the USA to build defenses against *Striga* while helping collaborating countries deal with the widespread yield losses of sorghum in Africa.

Ergot, *Claviceps africana*, which attacks sorghum was first observed in the USA in 1997. This fungus decreases sorghum yields by preventing pollination of the female flower of the sorghum plant and can make harvesting difficult by preventing machinery from operating normally due to sticky "honeydew" secreted by the fungus. Non-tariff barriers to importation of U.S. grain sorghum to Mexico and other countries could have become a significant problem once ergot had been identified in U.S. sorghum fields, so INTSORMIL researchers responded to the need for scientific information on which to base international agreements for importation of U.S. sorghum. During this past year, a visiting scientist from Zimbabwe conducted research on several epidemiological and biological aspects of *C. africana* in Mexico and the USA. Sclerotia of *C. africana*

developed from within sphacelia, so sclerotia always have some sphacelial tissue present. Sphacelia and sclerotia of *C. africana* should be thought of as different tissues of the same structure rather than entirely independent structures. Captan fungicide greatly reduced conidial germination associated with fresh sphacelia but did not penetrate far into the sphacelia. Temperature and relative humidity clearly interact to affect survival of conidia of *C. africana*. Several cumulative factors reduce presence and survival of *C. africana* in seed making seedborne ergot a negligible source of initial inoculum for infection in the field, especially in regions where ergot is already a recurrent pathogen. A four page pamphlet was prepared which outlined the prominent features of sphacelia and sclerotia. A well-illustrated manual "A laboratory guide to the identification of *Claviceps purpurea* and *Claviceps africana* in grass and sorghum seed samples" was also prepared in collaboration with Oregon scientists and utilized as part of a training workshop for Mexican seed inspectors at Sanidad Vegetal in Mexico City. Both publications are available in English and Spanish. The biological knowledge determined during the course of this project and the associated publications and training workshops are promoting the establishment of more scientifically-based import/export regulations for the international seed trade in sorghum.

Collaboration of INTSORMIL entomologists was successful with INTSORMIL sorghum breeders and molecular biologists to develop, evaluate, and deploy insect-resistant sorghums and add to the information database to increase resistance durability and identify the role of insect-resistant sorghums in integrated pest management (IPM) systems for the USA. New insect-resistant parental lines and hybrids were evaluated from selections and crosses made the previous year. Data collected will result in release of sorghum midge-resistant lines. Data were collected and good progress was made in advancing greenbug biotype I- and K-resistant parental lines for anticipated release. Insect resistance technology will contribute to better and more environmentally sound sorghum IPM.

INTSORMIL research is the basis for IPM of sorghum insect pests in the USA, especially in Texas. The information from INTSORMIL entomological research in Texas is used extensively by extension personnel, private agricultural consultants and farmers. A "Questionnaire on the Importance of IPM" was administered to Board members and Extension Agents-Pest Management at the Texas Pest Management Association Mid-year Board of Directors' Meeting held 2 October 1998 in El Paso, and a "Questionnaire on Pest Management Practices by Crop Consultants" was handed out at the Texas Association of Agricultural Consultants' Annual Conference and Exhibition held 14-16 December 1998 in Lubbock, and returned by mail. All farmers said they benefit from using IPM, a method of pest control which is central to INTSORMIL research and INTSORMIL's outreach partnerships in the USA and developing countries. To farmers and consultants, respectively, IPM means considering pesticides only when needed (100%), multiple pest management tactics (95 and 92%), natural enemies (90 and 92%), and practices to prevent/avoid pests (95 and 84%). Most farmers (68%) said IPM greatly lessens risks. Reduced farming risks (79%), less harm to the environment (79%), less trouble or complication than current practices (79%), and making money (74%) were very important to farmers when considering implementing new IPM practices. Most farmers (74%) and most consultants (72%) think IPM can greatly improve environmental quality. Ninety percent of farmers believe preserving environmental quality is very important and that their farming practices do not harm the environment.

During the past year, INTSORMIL plant pathologists have worked closely with INTSORMIL sorghum breeders to select lines of sorghum resistant to sorghum head smut, an important soil-borne fungal disease which appears at the seedling stage and results in complete inability of the plant to produce grain. In Mississippi, INTSORMIL entomologists evaluated the efficacy of insecticides applied to sorghum for control of fall armyworm and sorghum midge. This information is useful in providing recommendations to farmers for control of fall armyworm and sorghum midge on sorghum in the USA.

Crop Utilization and Marketing

The digestibility of sorghum is a trait which can be improved by plant breeding. INTSORMIL cereal chemists were this year developing an improved rapid screening assay based on a turbidity measurement for the high protein digestibility trait. This was done with a buy-in to the INTSORMIL project from the Texas Grain Sorghum Board. INTSORMIL food scientists at Purdue are still working on further improving the assay by way of using microtiter plates to decrease sample size and increase sample throughput per day. This rapid assay will enable sorghum breeders to more rapidly screen and select lines of sorghum with high digestibility, so that highly digestible sorghum can be commercially produced sooner to benefit both the livestock industry and producers of food for humans.

Sorghum food products are becoming more available in the USA, because some commercial hybrid seed companies have expanded their efforts to produce white, tan plant, food-type sorghum. Food-type sorghums are being segregated in storage to preserve their food-quality characteristics. INTSORMIL food scientists analyzed commercial food sorghums grown in 1997 and 1998, and they found that the protein and fat content of food type sorghums averaged 10.7 and 3.4%, respectively. The advantages of food type sorghums over red grain include color more acceptable to consumers and higher yield of decorticated grain. During this last year, INTSORMIL food scientists have worked closely with INTSORMIL sorghum breeders to incorporate the best quality characteristics into new cultivars and parents of new hybrids. Several inbreds that produce white, tan-plant sorghum hybrids with excellent food and feed pro-

cessing quality have been released. These cultivars produce well in dry climates, but these sorghums need more resistance to molds and weathering to be grown in hot humid areas, for example, in the Coastal Bend of Texas.

Future Directions

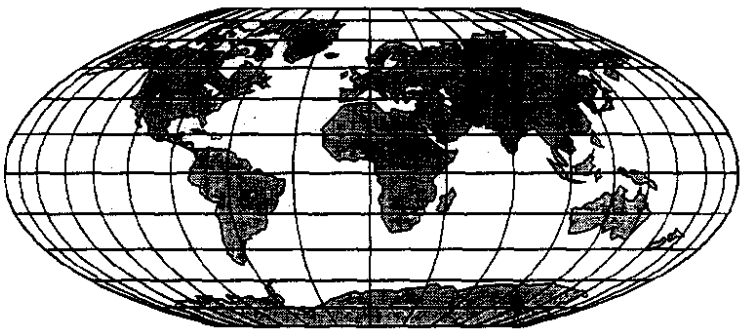
Based on its achievements, the INTSORMIL team is well positioned to contribute even more effectively to ending hunger and raise incomes. With its increasing strength of scientific expertise in developing countries, INTSORMIL is now able to more effectively reduce constraints to production and utilization of sorghum and millet to the mutual benefit of developing countries and the USA. Advances in sorghum and millet research over INTSORMIL's first 20 years, INTSORMIL scientists in the USA, Africa and Central America are now able to jointly plan and execute collaborative research which will have increased benefits to developing countries and the USA. 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 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.

In the past, INTSORMIL focused a major part of its resources on graduate student training and generating research particularly useful within the scientific community. The INTSORMIL agenda for the future continues to include graduate student training and generation of scientific knowledge and information to scientists, but will be more focused and directed toward users of the technology generated by INTSORMIL research. Future strategies of INTSORMIL will maintain INTSORMIL's current, highly productive momentum, build on its record of success, and accomplish a new set of goals. INTSORMIL's strategies for the future 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

Central America

South America



Horn of Africa

West Africa

Southern Africa

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

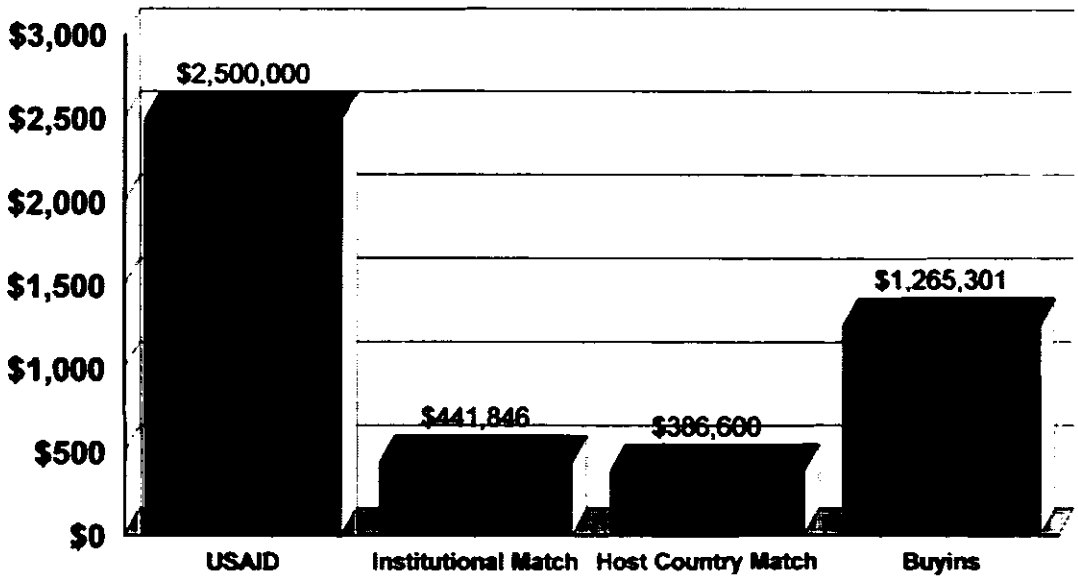
Outcomes

- 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

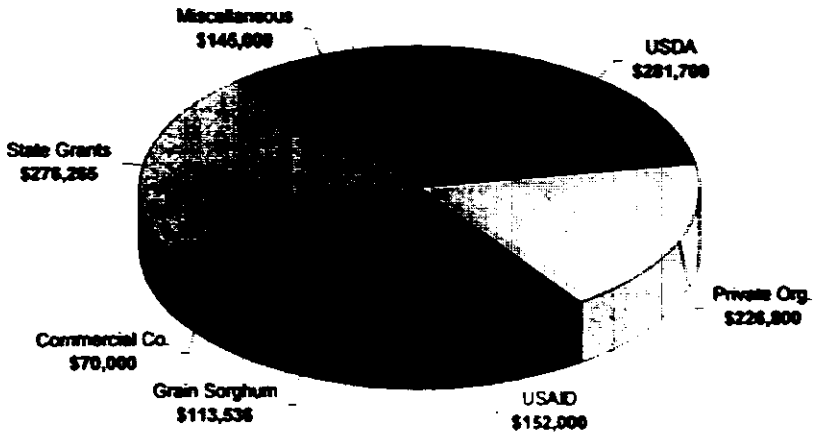
Networking
Communication
TechnologyTransfer

Farmers

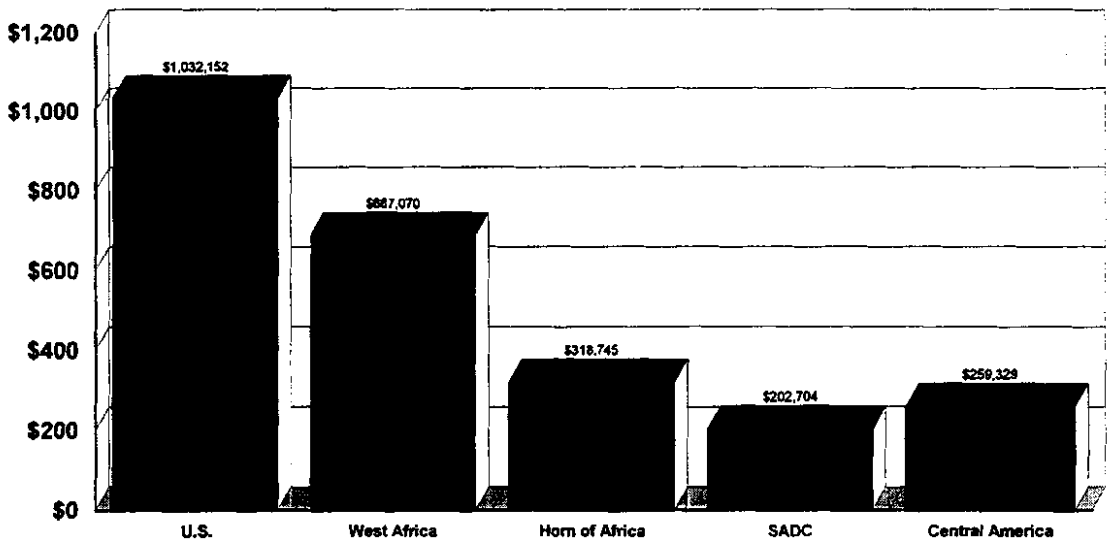
INTSORMIL FY 99 Source of Funding
Total Year 20 - $ 4,593,747



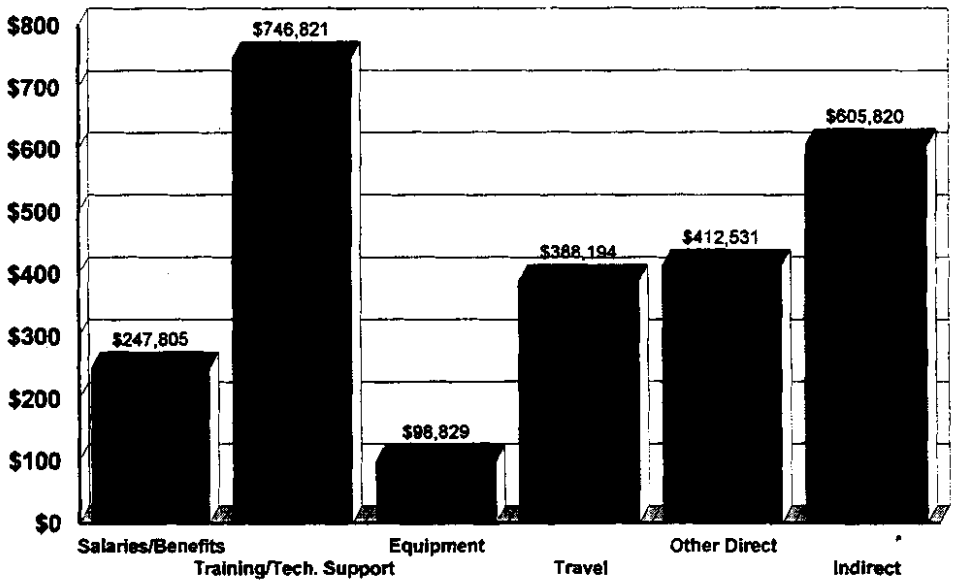
Breakdown of Buy-Ins
$ 1,265,301



INTSORMIL Budget Analysis - Year 20 - FY 99
Functional - $ 2,500,000

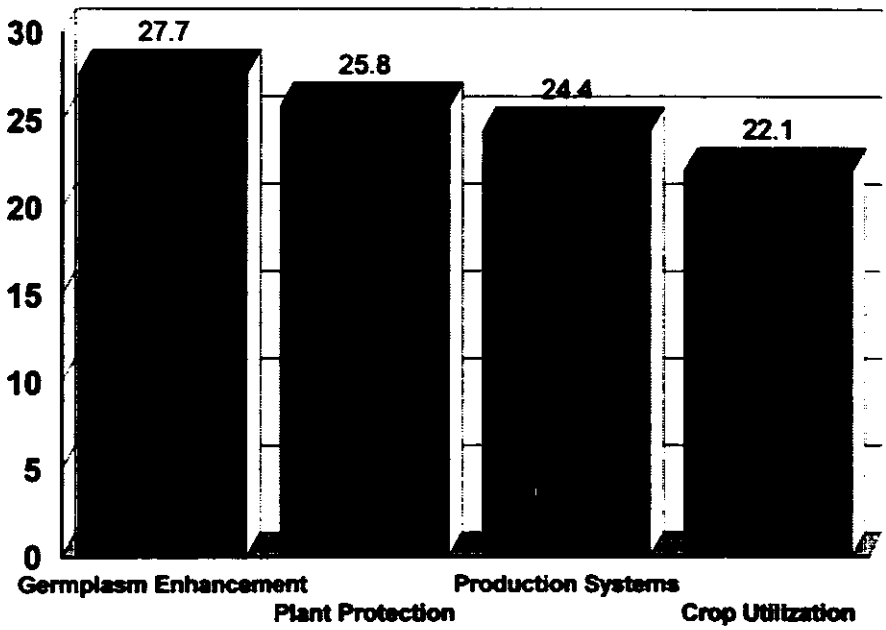


By Region

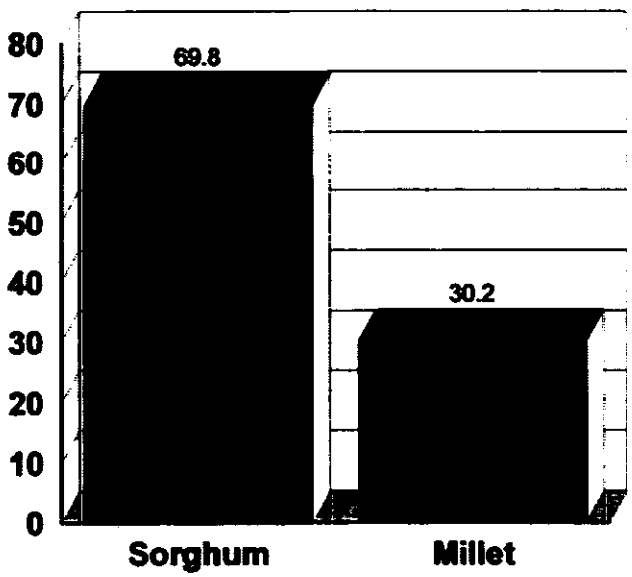


By Line Item

INTSORMIL FY 99 Technical Budget Analysis
Year 20 - $ 1,925,000



Technical Thrusts - By Percentage



Crops - By Percentage

Table 1. USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY 80) through 20 (FY 99) for all Collaborative Research and Management Entity.			
Budget Line Items	**Years 1 - 19 FY 80 - 98**	**Year 20 FY 99**	**Totals FY 80 - 99**
Salaries and Benefits	$ 22,840,078	$ 994,626	$ 23,834,704
Equipment and Facilities	2,523,499	98,829	2,622,328
Travel	6,011,426	369,194	6,380,620
Other Direct Costs	5,642,239	411,531	6,053,770
Networking	605,090	20,000	625,090
LDC Special Projects	4,357,186		4,357,186
Mission Buyin	100,000		100,000
Indirect Costs	12,621,364	605,820	13,227,184
Total	**$ 54,700,882**	**$ 2,500,000**	**57,200,882**

Table 2. Management Entity Office Budget Details for Years 1 (FY 80) through 20 (FY 99).			
Budget Line Item	**Years 1-19 FY 80 - 98**	**Year 20 FY99**	**Total**
Salaries	$ 3,273,699	$ 280,560	$ 3,554,259
Equipment	53,534	1,300	54,834
Travel	897,556	35,700	933,256
Consultants	44,600		44,600
Other Direct Costs	474,671	27,300	501,971
Indirect Costs	1,926,966	145,140	2,072,106
Total	**$ 6,671,026**	**$ 490,000**	**$ 7,161,026**
Workshops	151,000		151,000
EEP	260,000	35,000	295,000
Special Projects	377,800	50,000	427,800
ME Total	**$ 7,459,826**	**$ 575,000**	**$ 8,034,826**

Table 3. Summary of Non-Federal Matching Contributions by U.S. Institutions - Grant Years 1 (FY 80) through 20 (FY 99).			
U.S. Institution	**Years 1-19 FY 80 - 98**	**Year 20 FY 99**	**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	1,844,584	$ 22,500	1,867,084
Mississippi State University	958,619	17,500	976,119
University of Nebraska	2,304,802	74,345	2,379,147
Purdue University	2,970,931	113,185	3,084,116
Texas A&M University	4,660,701	192,610	4,853,311
University of Illinois - Urbana-Champaign	13,832	21,706	35,538
Total	**$ 13,142,326**	**$ 441,846**	**$ 13,584,172**

Table 4. USAID-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research. Year 20 (FY 99), July 1, 1998 - June 30, 1999. USAID Grant LAG-G-00-96-90009-00.

	IL	KS	MS	NE	PR	TX	Inst. Total	ME Spec.Proj.	ME HC	ME	Total
Salary	$ 35,140	$ 38,842	$ 29,792	$ 102,915	$ 224,885	$ 206,777	$ 638,351		$ 75,715	$ 280,560	$ 994,626
Equipment	4,480		2,515	35,488		21,706	64,189		33,340	1,300	98,829
Travel	8,520	25,975	13,000	23,409	57,520	101,250	229,674	$ 76,000	46,820	35,700	388,194
ODC	530	4,304	4,900	49,511	149,382	75,479	284,106	9,000	92,125	27,300	412,531
Indirect	21,330	20,879	19,793	58,677	170,213	169,788	460,680			145,140	605,820
Total	**$ 70,000**	**$ 90,000**	**$ 70,000**	**$ 270,000**	**$ 602,000**	**$ 575,000**	**$ 1,677,000**	**$ 85,000**	**$ 248,000**	**$ 490,000**	**$ 2,500,000**

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, 51 students from 23 different countries were enrolled in an INTSORMIL advanced degree program. Approximately 74% of these students come from countries other than the USA 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 1998-99, 25% of all INTSORMIL graduate participants were female. Twenty of the total 51 students received full INTSORMIL scholarships. An additional 12 students received partial INTSORMIL funding and the remaining 19 students were funded from other sources as shown in Figure 3.

All 51 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 1998-1999 there are 18.

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. Four post doctoral scientists and five visiting host country scientists were provided the opportunity to upgrade their skills in this fashion during 1998-1999.

The following table is a compilation of all INTSORMIL training activities for the period July 1, 1998 through June 30, 1999.

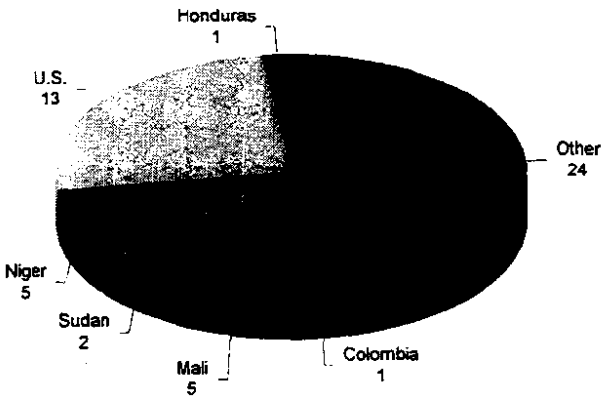


Figure 1. Participants by Country

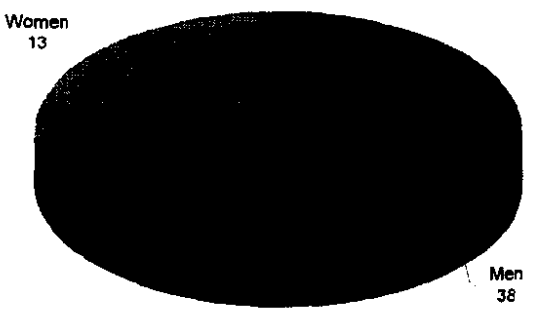


Figure 2. Participants by gender

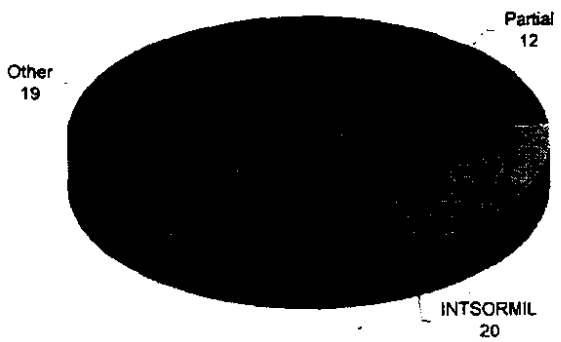


Figure 3. Source of Funding

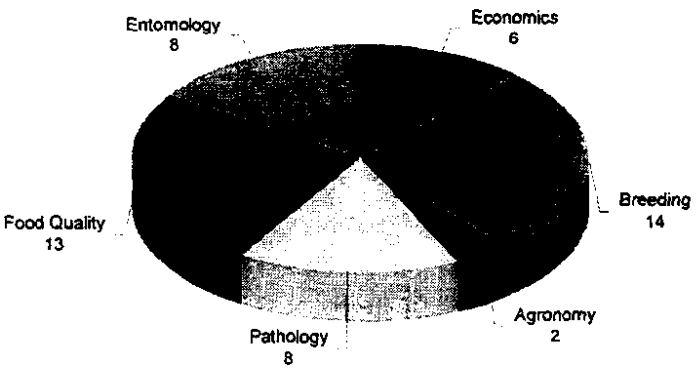


Figure 4. Discipline Breakdown

Year 20 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Regassa, Teshome	Ethiopia	M	Agron/Physiol	Maranville	PHD	M	O
Traore, Samba	Mali	UNL	Agronomy	Mason	PHD	M	P
Carvalho, Carlos H.S.	Brazil	PRF	Genetics/BioTech	Axtell	PHD	M	P
Kapran, Issoufou	Niger	PRF	Breeding	Axtell	PHD	M	I
Ndulu, Lexingtons	Kenya	PRF	Breeding	Axtell	PHD	M	I
Gunaratna, Nilupa	U.S.	PRF	Breeding	Ejeta	MSC	F	I
Ibrahim, Yahia	Sudan	PRF	Breeding	Ejeta	PHD	M	I
Mohammed, Abdalla	Sudan	PRF	Breeding	Ejeta	PHD	M	P
Phillips, Felicia	U.S.	PRF	Breeding	Ejeta	MSC	F	O
Rich, Patrick	U.S.	PRF	*Striga* Biology	Ejeta	PD[2]	M	I
Coulibaly, Sidi Bekaye	Mali	TTU	Breeding	Rosenow/Peterson	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	P
Setimela, Peter	Botswana	UNL	Breeding	Andrews	PHD	M	O
Tiryaki, Iskender	Turkey	UNL	Breeding	Andrews	MSC	M	O
Ndjeunga, Jupiter	Cameroon	UIUC	Economics	Nelson	PD[2]	M	P
Coulibaly, Bakary	Mali	PRF	Economics	Sanders	MSC	M	O
Kazianga, Harounan	Burkina Faso	PRF	Economics	Sanders	PHD	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
Gorena, Roberto Luis	U.S.	TAM	Entomology	Peterson/Teetes	PHD	M	P
Boire, Soualika	Mali	TAM	Entomology	Gilstrap/Teetes	PHD	M	I
Kadi Kadi, Hame	Niger	TAM	Entomology	Gilstrap/Teetes	MSC	M	I
Carrillo, Mario	Argentina	MSU	Entomology	Pitre	MSC	M	I
Johnson, Zeledon	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Jensen, Andrea	U.S.	TAM	Entomology	Teetes	PHD	F	I
Katsar, Catherine Susan	U.S.	TAM	Entomology	Peterson/Teetes	PHD	F	P
Lingren, Scott	U.S.	TAM	Entomology	Teetes	PHD	M	O
Aboubacar, Adam	Niger	PRF	Food Quality/Util	Hamaker	PD[1]	M	O
Bugusu, Betty	Kenya	PRF	Food Quality/Util	Hamaker	MSC	F	I
Mix, Nadege	France	PRF	Food Quality/Util	Hamaker	MSC	F	I
Zhang, Genyi	China	PRF	Food Quality/Util	Hamaker	PHD	M	P
Awika, Joseph Mobutu	Kenya	TAM	Food Quality/Util	Rooney/Waniska	MSC	M	I
Barron, Marc	U.S.	TAM	Food Quality/Util	Rooney	BSC	M	O
Leach, Michelle	U.S.	TAM	Food Quality/Util	Rooney	BSC	F	O
Leon-Chapa, Martha	Mexico	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P
Medina, Jorge	Nicaragua	TAM	Food Quality/Util	Rooney/Waniska	VS[1]	M	I
Miranda-Lopez, Rita	Mexico	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Rodriguez-Herera, Raul	Mexico	TAM	Food Quality/Util	W.Rooney/Waniska	PHD	M	O
Quintero-Fuentes,Ximena	Mexico	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Zelaya, Nolvia	Honduras	F	Food Quality/Util	Rooney/Waniska	MSC	F	I
Narvaez, Dario	Colombia	KSU	Pathology	Claflin	PHD	M	O
Jurgenson, Jim	U.S.	KSU	Pathol/Genetics	Leslie	VS[1]	M	O
Hanson, Amy	U.S.	KSU	Pathol/Genetics	Leslie	MSC	F	O
Salah, Amgad	Egypt	KSU	Pathology	Leslie	PHD	M	O
Silva, Gabriella	Uruguay	KSU	Genetics	Leslie	VS[1]	F	O
Zeller, Kurt P.	U.S.	KSU	Pathology	Leslie	PD[2]	M	O
Kollo, Issoufou	Niger	TAM	Pathology	Frederiksen	PHD	M	I
Torres-Montalvo, Jose H.	Mexico	TAM	Pathology	Frederiksen	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
UIUC University of Illinois at Urbana-Champaign
UNL = University of Nebraska - Lincoln

INTSORMIL Buyins
FY 99 - Year 20

Project No.	Buyin	Amount	Total
KSU-210A	Kansas Agricultural Experiment Station	$ 19,000	
	Ivy Laboratories	36,800	
	USAID/Egypt	75,000	
	American Society for Microbiology	20,000	
	USDA/Food Safety Panel	60,000	
	USDA/National Scab Research Iniative	35,000	
KSU-210B	USDA/Epidemiology/Etiology	15,200	**$ 261,000**
PRF-203	Purdue University - Department of Agronomy	1,000	
	Purdue University - Department of Agriculture	30,000	
	Rockefeller Foundation	20,000	
	Winrock/McKnight Foundation	50,000	
PRF-207	Purdue University - Department of Agronomy	1,000	
PRF-212	Texas Grain Sorghum Board	40,000	
PRF-213	Purdue University - Department of Agronomy	1,000	
PRF-209	Niger Country Program		
	Rockefeller Foundation	20,000	
	INRAN	10,000	
	ROCARS	10,000	
	ICRISAT	10,000	
	ROCAFREMI	10,000	
	World Bank Niger	10,000	
	McKnight Foundation	20,000	**233,000**
TAM-222	Sorghum Biotech Partnership	10,000	
	USDA-NRI	15,000	
	USDA-ARS	6,000	
	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	USAID	70,000	
	USDA/Germplasm Evaluation	6,500	
	USDA/CSREES	25,000	
	USDA/FAS	30,000	
TAM-225	Texas Grain and Grain Gene Iniative	35,027	
	Texas Dept. of Agriculture & Texas Pest Management Assoc.	19,659	
TAM-226	Hatch 6789	35,000	
	Hatch 7134	70,000	
	Hatch H-8472	40,000	
	Texas Grain Sorghum Producers Board	50,000	
TAM-228	USDA-ARS	59,000	
	USDA/CSREES	30,000	**690,765**
UNL-213	Nebraska Grain Sorghum Board	2,700	
	SPARC/USAID	7,000	
UNL-214	Pioneer Hi-Bred International, Inc.	20,000	
UNL-218	Nebraska Grain Sorghum Board	20,836	
	Mahyco Seed Company, India	30,000	**80,536**
	Total Buyins - June 30, 1998 to July 1, 1999 - Fy 99 - Year 20		**$ 1,265,301**

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.	Global Conference on Ergot of Sorghum	Sete Lagoas MG Brazil	6/97
50.	Conference on the Status of Sorghum Ergot in North America	Corpus Christi, Texas	6/98
51.	Principal Investigators Meeting and Impact Assessment Workshop	Corpus Christi, Texas	6/98
52.	Regional Hybrid Sorghum and Pearl Millet Seed Workshop	Niamey, Niger	9/98
53.	INTSORMIL End Use Quality Assessment Workshop	Pretoria, South Africa	12/98

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Other

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