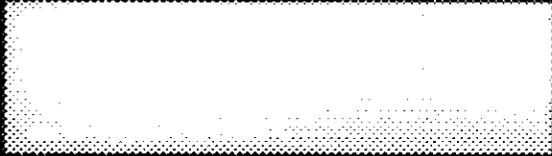
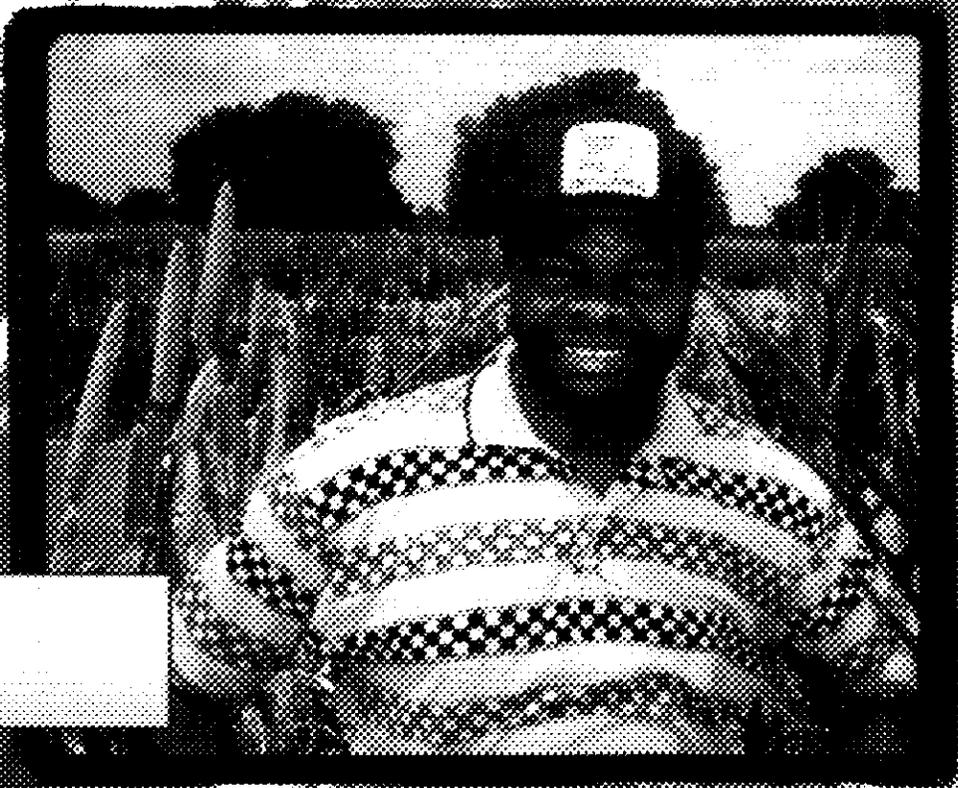


# 2000 Annual Report

PD-ACA-162

EXECUTIVE  
SUMMARY

## PERSONAL Gordon Miller Collaborative Research Support Program (CRSP)



...through the Agency for International Development  
...  
...  
...

## Captions for INTSORMIL Four-Year Report (1996-2000)

Photo on front:

Dr. Medison Chisi, INTSORMIL sorghum breeder from Zambia at the Workshop on Farmer Participation in Pearl Millet Breeding and Farmer-Based Seed Production Systems in Namibia, March 24-26, 1998. Dr. Chisi received his doctorate from Kansas State University and is presently a member of INTSORMIL's Technical Committee.

Photo on back:

A "master farmer" and her child at the InterCRSP workshop on weevil disinfestation and storage techniques near Tamale, Ghana on November 5, 1997. Her t-shirt serves as a means of visually identifying farmers who know the techniques and can teach them to others. This technology transfer workshop is part of the project, "Adaptive Research with InterCRSP Natural Resource Management Technologies for Regional Transfer in West Africa," a collaborative effort of two Collaborative Research Support Programs which developed the technologies — the Bean/Cowpea CRSP and INTSORMIL — in partnership with a non-governmental organization — World Vision International (WVI) — which transfers the technologies to farmers and farm families. The project makes technologies such as improved varieties of sorghum, pearl millet, and cowpeas, improved cultural practices, improved post-harvest seed processing and storage techniques available to farm families throughout Chad, Ghana, Mali, Niger, and Senegal. This innovative partnership in which WVI extends technologies developed by the two CRSPs to end users in several West African Countries is supported by the Africa Bureau of the U.S. Agency for International Development.

# **INTSORMIL**

## **2000 Annual Report**

### **Executive Summary**

**Fighting Hunger with Research . . . A Team Effort**

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

**This publication was made possible through support provided by the U.S. Agency for International Development, under the terms of Grant No. LAG-G-00-96-90009-00. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development**

**INTSORMIL Publication 00-2**

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## Introduction and Program Overview

Presently, worldwide, more than 800 million people are hungry and over 1 billion are desperately poor, and food demand is increasing rapidly. The majority of poor live in rural areas in developing countries and agricultural and food systems development is vital to economic growth; improving environmental quality; strengthening nutrition, health and child survival; improving the status of women; and promoting democratization. It is estimated that by 2000, the number of people living in developing countries will grow from 4.9 billion to 6.8 billion people. More than 1.3 billion people today live on less than one dollar per day. It is estimated that the number of hungry people will exceed one billion by 2020. The global population of underweight children below age five is expected to increase from 193 million in year 2000 to over 200 million in year 2020. 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 of the world. In 1999, 65.8 million metric tons (MT) of sorghum were produced worldwide, of which 19.7 million MT were produced in Africa, mainly for direct consumption by humans, and 14.7 million MT were produced in the United States, mainly for livestock feed to produce meat for human consumption. In the crop year 1997-1998, the United States exported 5.3 million MT 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 United States. 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 utilization as food and feed are vitally important to developing countries and to the United States.

Millet, 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, and pearl millet, like sorghum, is a staple for 300 million people worldwide. Most of these people are in countries where malnourishment is a persistent problem. In 1999, 37.2 million hectares (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 United States. In 1999, the amount of millets harvested worldwide was 29 million MT, of which 12.9 million MT were harvested in Africa and 180 thousand MT were harvested in the United States. Millets are crops used mainly for direct consumption by humans in developing countries, and the millets are used mainly for feeding live-

stock, 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.

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 United States plans to contribute to the global effort to reduce hunger is by the United States' 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 for mobilizing the U.S. Land Grant Universities in the international food and agricultural research mandate of the U.S. Government. The CRSPs are communities of U.S. Land Grant Universities working with USAID and other U.S. Federal Agencies, strengthening and enhancing National Agricultural Research Systems (NARS), collaborating country colleges and universities. The CRSPs also work closely with the International Agricultural Research Centers (IARCs), private agencies, industry, and private voluntary organizations (PVOs) fulfilling their mandate. The Sorghum and Millet Collaborative Research

Support Program is one of nine CRSPs currently in operation.

The Sorghum and Millet Collaborative Research Support Program (INTSORMIL CRSP) conducts collaborative research using partnerships between U.S. university scientists and scientists of the National Agricultural Research Systems (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 United States. The INTSORMIL mission is to use collaborative research as a mechanism to develop human and institutional research capabilities to overcome constraints to sorghum and millet production and utilization for the mutual benefit of agriculture in the USA 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 United States.

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 and USDA currently active in the INTSORMIL CRSP are the University of Illinois, Kansas State University, Mississippi State University, University of Nebraska, Purdue University, Texas A&M University, and the USDA at the University of Georgia. 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 United States and those countries as a result of all that has been accomplished during the past twenty two 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 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. Couscous made from food quality sorghum is being market tested in Niger. 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 USA 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 United States, 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 United States 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 research teams of INTSORMIL and NARS scientists who conduct research on applications of existing technology and development of new technology. This integrated relationship prepares them for leadership roles in 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 sus-

## *Introduction and Program Overview*

tainable 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 conserving millet and sorghum germplasm, conserving natural control of arthropod pests and diseases of sorghum and millet, developing resource-efficient cropping systems, developing integrated pest management programs, developing cultivars with improved nutrient and water use efficiencies, and evaluating impacts of sorghum/millet technologies on natural resources and biodiversity.

- **Developing research systems:** Collaboration in the 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 United States 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 a 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 socio-economic 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 semi-arid 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 four years occurred in the United States and collaborating countries.

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

## *Introduction and Program Overview*

University; Dr. Gebisa Ejeta, Purdue University; Dr. John Axtell, Purdue University; Dr. Stephen Mason, University of Nebraska; Dr. Henry Pitre, Mississippi State University; Dr. Aboubacar Touré, Institut de Economie Rurale, Mali; and Dr. Medson Chisi, Golden Valley Research Station, Zambia.

- INTSORMIL, INRAN, ICRISAT and other sponsors held a Regional Hybrid Sorghum and Pearl Millet Seed Workshop in Niger, September 28-October 1, 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, the 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 review of INTSORMIL activities in West Africa, Southern Africa, the Horn of Africa and Central America.
- 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 developed 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 past four years included:

- \* Publication 97-1: Policy and Operating Procedures
- \* Publication 97-2: Directory of U.S. CRSP PIs
- \* Publication 97-3: "Inside INTSORMIL" Newsletter
- \* Publication 97-4: INTSORMIL Directory
- \* Publication 97-5: Proceedings of the International Conference on Genetic Improvement of Sorghum and Pearl Millet
- \* Publication 98-1: 1997 INTSORMIL Annual Report
- \* Publication 98-2: 1997 Annual Report Executive Summary
- \* Publication 98-3: "Inside INTSORMIL" Newsletter
- \* 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: INTSORMIL CRSP Directory update
- \* Publication 99-5: "Inside INTSORMIL" Newsletter
- \* Publication 99-6: 1999 Annual Report
- \* Publication 99-7: "Inside INTSORMIL" Newsletter
- \* Publication 99-8: 1999 Annual Report Executive Summary

## Introduction and Program Overview

- \* Publication 00-1: 2000 Annual Report
- \* Publication 00-2: 2000 Annual Report Executive Summary

### 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.

### Training

#### *Year 21 Training (June 30, 1999-July 1, 2000)*

During 1999-2000, there were 51 students from 22 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. This is the same number of students we had in the previous year. Approximately 73% of these students came from countries other than the USA. The number of students receiving 100% funding by INTSORMIL in 1999-2000 totaled 18. An additional 14 students received partial funding from INTSORMIL and the remaining 19 students were funded from other sources but are working on INTSORMIL projects.

#### *Years 18-19-20 and 21 Training (June 30, 1996 through July 1, 2000)*

During this four year period, there were 213 students from 33 different countries enrolled in an INTSORMIL advanced degree program and advised by an INTSORMIL principal investigator. Approximately 77% 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 22% of all INTSORMIL graduate students were women.

The number of students receiving 100% funding by INTSORMIL during this period total 79. An additional 62 students received partial funding from INTSORMIL and the remaining 72 were funded from other sources but worked on INTSORMIL projects. These students are enrolled in graduate programs in six disciplinary areas, agron-

omy, 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, and now 18 in 1999-2000. 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.

Graduate degree programs and 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 this four year period. Students enrolled during these years are listed on pages 211 to 216 of this report.

### Networking

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

- Promotes networking with IARCs, NGO/PVOs, Regional networks (ROCAFREMI, ROCARS, ASARECA, SADC/SMINET, SADC/SMIP, and others) private industry, and government extension programs to coordinate research and technology transfer efforts.
- Supports INTSORMIL 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, Mali, Niger, Central America and Zimbabwe; SAFGRAD, WCASRN, WCAMRN, ASARECA, ECARSAM, 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 and WCAMRN 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 ROCAFREMI in West Africa has much potential in allowing INTSORMIL utilization scientists to collaborate regionally. ROCAFREMI is a good mechanism for promoting millet processing at a higher level than has been seen before in West Africa. During the last three years, INTSORMIL, the Bean/Cowpea CRSP, and World Vision International have been working with NARS researchers and farmers in five countries under the West Africa Natural Resource Management Project, 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**

#### *West Africa*

Research momentum has improved significantly the past two years in Mali, as well as morale and enthusiasm among researchers. The new Director General, Dr. Alpha Maiga, has gained a high level of confidence and support among researchers. A number of good trained scientists, have just recently returned to IER including Samba Traore, Minamba Bagayoko, and Moussa Sanogo, thus strengthening the IER research program especially in pearl millet. The millet breeding program is looking much stronger with the new breeder, Moussa Sanogo, and the anticipated strong collaboration with the new INTSORMIL Millet PI, Dr. Wayne Hanna. The multidisciplinary team approach has made excellent progress in Mali.

The Board mandate to regionalize the West African programs has progressed well but somewhat slowly, despite some well intended efforts by Malian scientists. INTSORMIL PIs now have new collaboration in Ghana and Burkina Faso, and a potential collaborator has been identified in Senegal. Efforts are underway to formalize the collaboration in Ghana and Senegal in the fall of 2000. Scientists in Mali and Niger are communicating in regard to research plans and collaborative projects. The regional networking with ROCARS and ROCAFREMI is working quite well. New contacts with SG2000 show excellent promise regarding the interaction of IER breeders in getting their improved new cultivars into the extensive SG2000 field trial system. This should not only be of benefit in Mali but throughout the region where SG2000 operates.

The on-farm trials and collaboration with NGO/PVOs is very good, especially with World Vision. This has helped the evaluation and movement of new-promising varieties on-farm. There is now extensive activities conducted on-farm.

The announcement of the commercialization of Dali-ken, a cookie made from a mixture of 20% flour from the tan-plant N'Tenimissa and 80% wheat flour, is a major step in demonstrating the potential for commercialization of sorghum provided a reliable source of value-added, identity-preserved-grain is available. It was slow coming, but hopefully will serve as a focal point to encourage other commercialization efforts.

The West Africa Hybrid Seed Workshop planned for the past several years was conducted in the fall of 1998. This was the first focused effort to inform West African sorghum and millet scientists about the potential for hybrids in West Africa. All the pros and cons were discussed and the general consensus of the 150 participants was that further research and development should be pursued. The hybrid NAD-1 in Niger is an excellent successful example for others to follow. Experiences in India, Zambia, Sudan and Nigeria provided a road map for other developing countries to follow in the development of a private sector seed industry in West African countries. This was the first focused effort to inform West African sorghum and millet scientists about the potential for hybrids in W. Africa.

One gratifying outcome from this workshop was the formation of a Niger Seed Producer's Association by the hybrid seed producers, independent of INRAN. The association is off and running with the purchase of the government seed farm at Lossa to begin private sector seed production on small holdings as well as larger farms. Secondly, this association recognizes INRAN as an honorary member, but is intent on controlling the seed association outside of the formal structure of the government. INTSORMIL thinks this is an encouraging development which should be nurtured. 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.

The farmer producer seed industry is going well in Niger. The pearl millet research program within INTSORMIL must be strengthened. The addition of Dr. Wayne Hanna at Georgia is a significant resource for future pearl millet research.

#### *Horn of Africa*

A promising regional sorghum and millet collaborative research program has been put in place in the Horn of Africa. A Memorandum of Understanding (MOU) has been signed with each of the five collaborating countries. A two-tier collaborative research initiative has been developed. At one level, we have identified individual collaborative research projects between NARS scientists and their respective collaborators at an INTSORMIL institution on a bilateral basis. At a second level, based on a series of interactions among those concerned, we have developed a re-

gional research agenda with the goal of generating technologies that would have regional application. Research projects under the bilateral initiative have been implemented beginning with the 1997 crop season. Disciplinary projects in breeding, agronomy, entomology, pathology, food science, economics, and extension were undertaken. Examples of research results of collaborative experiments conducted in the region in the last four years are reported in this four year report. Interest in collaboration with INTSORMIL by NARS scientists in the Horn of Africa has been positive and continues to grow.

#### *Southern Africa*

During the 1996-2000 time period, INTSORMIL activity in Southern Africa has evolved into a truly regional, collaborative research program. Research accomplishments are reported in detail in this report.

Regional activity has evolved to now include research projects on breeding, pathology, food quality, insect pests, production and marketing, and ergot. Ergot was separated from other pathology research due to its importance to the U.S. seed industry. Project work plans are developed between host country scientists and U.S. counterparts. The work plans are approved by the SMIP Steering Committee as part of the total regional activity in Southern Africa. Funds are dispersed through ICRISAT/Bulawayo and expenditure receipts provided to INTSORMIL through the same facility. Project organization provides for integration of INTSORMIL activities into existing activities in the region. This insures that INTSORMIL conducts research and supports institutional development in areas of importance to collaborating institutions.

#### *Central America*

During 1996-2000, the Central America program has evolved from a program focused on Honduras to a more regional program with increased activity in El Salvador and Nicaragua. Concurrent with this has been increased collaborative research in plant pathology and agronomy. Memorandums of understanding have been signed with national research programs in El Salvador (CENTA) and Nicaragua (INTA), and with the National Agrarian University (Nicaragua) and the National Autonomous University of Nicaragua. Plant breeding research has emphasized development of improved maicillos criollos, but also has developed grain, forage and broomcorn hybrids. Entomology research has focused on the "langosta" complex of lepidopterous insect pest of maize and sorghum, and on sorghum midge. Grain quality research has focused on use of sorghum to replace maize in tortillas and rosquillos, and to replace wheat flour in cookies and sweet breads. INTSORMIL has had close ties with private industry through operation of the PCCMCA hybrid trials throughout Central America and the Dominican Republic. This activity provides useful information to seed companies, producers, and plant breeders throughout the region. The program changes put in place

during the past year should lead to increased collaborative research productivity, but at the same time will require increased personal support by INTSORMIL principal investigators and increased financial support from INTSORMIL.

#### *Regional Benefits by Technical Thrust*

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

#### *Germplasm Enhancement and Conservation*

Breeding sorghum varieties and hybrids for use in developing countries requires proper recognition of the major constraints limiting production, knowledge of germplasm, and an appropriate physical environment for evaluation and testing. Successful breeding efforts also require knowledge of mode of inheritance and association of traits that contribute to productivity as well as tolerance to biotic and abiotic stresses. Germplasm exchange, movement of seeds in both directions between the USA and collaborating countries, involves populations, cultivars, and breeding lines which carry resistance to insects, diseases, *Striga*, drought, and soil acidity. Research and germplasm development activities in INTSORMIL attempt to address these essential requirements. INTSORMIL/Purdue project (PRF-207) addresses major biotic and abiotic constraints (drought, cold, grain mold, and other diseases) that limit productivity of sorghum in many areas of the world. Over the years, significant progress has been made in some of these areas. Superior raw germplasm have been identified, mode of inheritance established, chemical and morphological traits that contribute to productivity as well as to tolerance to these stresses have been identified. Selected gene sources have been placed in improved germplasm background, some of which have already been widely distributed. In the last four years, research efforts in PRF-207 have focused on a selected core of constraints that limit the productivity and utilization of the sorghum crop. Specific research studies were conducted in an attempt to understand the genetic and physiologic basis of drought tolerance using a mix of both traditional and molecular approaches. They also conducted several studies in elucidating the basis of grain mold resis-

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tance in low and high tannin sorghums. Specific studies were undertaken in determining the role of physical and chemical kernel properties associated with mold resistance, and in assessing the nature of specific phenolic compounds that contribute to grain mold resistance. They also conducted a major study in assessing genetic diversity using molecular markers.

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). 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. Germplasm was identified for advanced testing with resistance to selected insects and diseases, and will contribute to production of 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.

Several U.S. seed companies are now producing seed of brown midrib sorghum sudangrass commercially. The 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 five million acres of sorghum sudangrass in the United States at the present time, compared with nine million acres of hybrid sorghum for grain production. The potential of brown midrib sorghum sudangrass in West Africa is being explored through collaboration with Dr. Issoufou Kapran 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.

INTSORMIL/Purdue University have developed a rapid screening technique for breeders to assess the new high digestibility trait recently discovered in sorghum germplasm. The new rapid screening technique, which measures disappearance of alpha kafirin in sorghum grain has been developed by INTSORMIL P.I., Bruce Hamaker and his Nigerian Post Doctorate Fellow, Dr. Adam Aboubacar. The test is rapid and readily distinguishes between normal sorghum and the highly digestible sorghum cultivars. Mr. Lex Nduulu, Kenya, 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.

Plant biotechnology has become a powerful tool to complement the traditional methods of plant improvement. This report includes the development of a protocol for sorghum transformation via *Agrobacterium tumefaciens*. It demonstrates that *Agrobacterium*-mediated transformation is a feasible technique for the genetic transformation of sorghum. Sorghum transgenic plants were produced via *Agrobacterium tumefaciens*, and the transformation evidenced by Southern blot analysis of T0 and T1 plants, detection of GUS activity, and production of T1 plants resistant to hygromycin. Immature embryos of sorghum were very sensitive to *Agrobacterium*, and embryo death after co-cultivation was considered the limiting step to increase the transformation efficiency. 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 once the protocol is further refined and improved.

The mutable pericarp color gene designated as "candystripe" was first identified by Orrin Webster in Sudan. Research done in collaboration with Surinder Chopra and Tom Peterson at Iowa State University 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 scientists 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 research team (INTSORMIL/Texas A&M Project TAM-222) 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.

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 an 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*

In West Africa, INTSORMIL's main collaborative agronomy research activities have been focused in Mali and Niger. However, a Memorandum of Understanding was signed in 1999 with IN.E.R.A., the NARS of Burkina Faso,

and collaborative research was initiated in Burkina Faso. INTSORMIL also participates in the West and Central African Sorghum and Millet Research Networks. In research conducted during the past four years, 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, such 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 Sabel.

During the four-year time frame, the INTSORMIL/University of Nebraska (UNL-213) project has been extremely productive in graduate education of West African collaborating scientists agronomic research, which has led to publication in scientific journals, the production of extension bulletins, and the transfer of improved practices to pearl millet producers; and strengthening the activities of the West and Central Africa Pearl Millet Research Network. In the USA, the project has documented the potential for pearl millet as a new grain crop in the Great Plains, and developed production practice recommendations for planting date, row spacing, and nitrogen fertilizer application. During this period, collaborative research was expanded from Mali and Niger to Burkina Faso, and in the near future, to Central America.

On-farm trials conducted by the INTSORMIL/University of Nebraska (UNL-214) have successfully demonstrated the value of using new hybrids, inorganic fertilizer and tied ridges to conserve moisture which is now being adopted in certain regions of Niger. Contacts have been made between NARS scientists in Ghana, Mali and Niger and WVI personnel as expedited by the UNL-214 PI. Collaboration between and among these individuals should result in greater efficiency for extending new technology. The underlying physiological mechanism for nitrogen use efficiency (NUE) has been determined to be a key enzyme in the photosynthesis pathway. This discovery will soon be published in a major journal.

A study conducted by INTSORMIL/Purdue University project (PRF-205) in Burkina Faso which focused 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 tech-

nology 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.

Research in Mali by the West and Central African Millet Network (WCAMRN) 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 United States were finalized. The results of the research are now being written for publication by Drs. Pandey and Maranville 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, Dr. Pandey has conducted greenhouse studies at UNL to strengthen the field results from Niger. Dr. Pandey has returned to India and continues to work with Dr. Maranville on publication of the manuscripts. Dr. Samuel Buah 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 Dr. Buah with a new computer and chlorophyll meter, and will also provide operating funds for him to conduct his collaborative research.

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<sup>-1</sup>. Application of Malian rock phosphate also increased sorghum yield about nine percent.

### **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*.

Witchweeds (*Striga* spp.) are obligate parasitic weeds of significant economic importance. Control methods available to date have been costly and beyond the means of farmers in developing countries. While combining several control measures may be necessary for eradication of *Striga*, crop losses to *Striga* can be effectively minimized through host-plant resistance. In the INTSORMIL/Purdue University project (PRF-213), the goal has been to exploit the unique life cycle and parasitic traits of *Striga* towards developing sorghum lines that are resistant to *Striga* because of disrupted interaction between the parasite and the host. In the last four years, significant results were obtained in both the research and development efforts of PRF-213. They established the simple inheritance of low production of the *Striga* germination stimulant in sorghum. New assays were developed for stages in host-parasite interaction beyond *Striga* germination. Using these assays, unique mutants were identified that have the capacity to disrupt normal parasitic association. These include sorghum lines with low production of the haustorial initiation factor, mutants with a hypersensitive response to penetration by *Striga* thereby delaying the growth and development of the parasite, and those with incompatible response to penetration where the host response results in eventual withering and death of the parasitic growth. Genetic and physiologic characterization of these mutants, as well as introgression into elite cultivars of the particular genes involved in each mutant, is currently underway. As a development effort, *Striga* resistant sorghum lines developed in the past have been effectively distributed and adopted. PRF-213 collaborated with World Vision International in distributing large quantities of eight *Striga* resistant sorghum varieties into 12 African countries. Following their introduction, the project worked with national programs in carrying out testing and demonstration of these varieties in farmers' fields. In Ethiopia, a collaborative relationship with the Ethiopian Agricultural Research Organization (EARO) and the Sasakawa Global 2000 program led to the evaluation, demonstration, and the eventual official release of two INTSORMIL varieties for commercial cultivation in the country. Seed supply is likely to be a bottleneck in efforts to promote an expanded cultivation of

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these varieties. INTSORMIL will continue to cooperate with the NARS in efforts to put in place an effective seed production and distribution mechanism to ensure reliable supply of these varieties in the future.

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 United States (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 United States. 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 United States, 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 some accessions of *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 *Claviceps africana* was observed to persist in an active phase predominantly on feral grain sorghum in Mexico and as far north as Corpus Christi 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.

Triazole fungicides continue to be the most effective in controlling sorghum ergot in the field but aerial application proved ineffective due to poor contact and coverage of heads with the fungicide. Conidia of *C. africana* in sphacelia or on honeydew on seed surfaces do not survive well in storage environments. The combination of poor survival of conidia and the good efficacy of contact fungicide seed treatments make seedborne inoculum a negligible factor especially in areas where the pathogen is already endemic.

Sorghum diseases are, and remain important factors reducing the potential 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. The next global conference on sorghum and millet diseases has been set for September 25-30, 2000 at Guanajuato, Mexico.

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 land race Mote, the level of infection increases as the nematode number increases. In the presence

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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 United States and Mali plan to develop IPM strategies for insect pests, especially panicle-feeding bugs and sorghum midge, that attack traditional and improved insect-resistant and susceptible sorghums.

Sorghum and maize are important grain crops for human consumption and animal feed in developing countries in Central America. The crops are damaged each year by soil inhabiting insects, stem borers, caterpillar defoliators, and panicle feeding insects that contribute to reduced yields of both crops on farms in this region. The complex of defoliators and sorghum midge are considered to be the most damaging to these crops in Honduras and Nicaragua, and annually cause extreme damage to the crops. The caterpillar pest complex has been identified by the INTSORMIL/Mississippi State University (MSU-205) project to consist principally of several armyworm species and a grass looper, and the impact that these insects and the sorghum midge have on sorghum production has been elucidated. Aspects of the biology, ecology, behavior and population dynamics of the armyworm species in Honduras and the sorghum midge in Nicaragua have been identified. This information has contributed to the successful conduct of entomological research designed to evaluate ecological relationships of the pest insects with crop and non-crop 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 on subsistence farms in both Honduras and Nicaragua. Recommendations for planting dates, weed control, and insecticide applications to manage the caterpillar defoliators, as well as sorghum midge have been developed.

The information obtained in these MSU-205 studies on sorghum and corn will assist subsistence farmers in Honduras, Nicaragua and surrounding areas with similar insect pest constraints in producing grain crops with increased yield at minimum cost for pest control and with reduced risk to human health. The extension of the project into Nicaragua in 1998 expanded the scope of MSU-205 activities in this ecogeographic zone. Recent studies to determine minimum, effective rates of insecticide for control of whorl feeding lepidopterous insects, stem and stalk feeding insects, and panicle feeding insects in Mississippi will be useful technology for crop production in the United States and for transfer to developing countries.

Locating quality graduate students to train and conduct INTSORMIL research, and active participation of collaborator scientists, administrators, and in-country coordinators are significant to the success of the MSU-205 project. The

project has been successful because each of the above has been realized.

In Southern Africa, collaborative research relationships were reestablished with Dr. Christopher Manthe in Botswana and Dr. Johnnie van den Berg in 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.

A systematic strain collection and strain identification of *Fusarium* species has been progressing (INTSORMIL/Kansas State University project (KSU-210A), but many of the easy identifications have been made and the process is now much slower. Development of the AFLP technique has enabled them to group strains relatively quickly, but the formal descriptions still require significant effort, and additional collections will be needed to identify more members of relatively rare species. Adding global positioning capability to localizing collection sites for repeated sampling should be accomplished before the next major collecting expedition is conducted. The AFLP technique has been successfully transferred to South African colleagues who are now trained in the use of this technique. Training a student from sub-Saharan Africa in the use of these techniques needs to become a priority, if funds permit. Toxicology work now needs a collaborator who can test the effects of toxins in commercial animal feeds, and who can model their effects in laboratory systems using human and animal cell lines as models. Screening of grain for these toxins needs to be made to determine relative levels of these toxins in animal and human food supplies.

Scientific Writing and *Fusarium* Laboratory workshops by KSU-210A have increased the visibility of this program significantly. These workshops need to become a more visible part of the INTSORMIL program, as they serve as interdisciplinary venues for scientists in developed and developing countries that work on various crops to exchange information and to interact with one another in an informal setting. Activities growing out of this project have led to requests to update, along with South African collaborator, Prof. Walter F. O. Marasas, an introductory book on mycotoxicology, and that the KSU-210A PI participate in the development of a laboratory manual for general use in the identification of *Fusarium* species.

INTSORMIL/Texas A&M Project (TAM-225B) has made progress 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 received his Ph.D. degree in 2000. His dissertation was developed from field studies begun in Year 17 on MHM immature stage mortality, adult MHM biology on alternate hosts and fecundity, and MHM biology on alternate host

plants. Results from the Mali and Niger 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. Ultimately, these data will support developing a "Millet Head Miner Warning System" model to forecast the probability of MHM outbreaks in a given area so that appropriate measures can be implemented to control the pest before it damages pearl millet. 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. 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.

INTSORMIL/Purdue University cereal chemists have developed rapid screening techniques for breeders to use which assesses the new high digestibility trait recently discovered in germplasm of sorghum. This rapid screening technique, which measures disappearance of alpha kafirin in sorghum grain has been developed by Bruce Hamaker and Adam Aoubacar of Niger. The test is rapid and readily distinguishes between normal sorghum and the highly digestible sorghum cultivars. Lex Ndumu, INTSORMIL collaborator from Kenya, 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. This research was done with a buy-in to the INTSORMIL project by the Texas Grain Sorghum Board.

The Niger couscous project is advancing quickly. There is an excellent group of technologists/scientists in Niger that are committed to the project. With procurement of the new entrepreneurial-scale decorticator and mill, the INRAN cereal processing group are adding production of high quality flours and grits and other potential products to their research objectives. At this point, processing parameters have been optimized at least to a sufficient extent to produce four high quality products: two couscous' of different particle sizes, *degue* (a large particle agglomerated product used for breakfast), and flour. A market study has begun with participation of the INTSORMIL/UIUC/Nelson project, and about 1 MT of high quality couscous, *degue*, and flour from the sorghum hybrid NAD-1 has been produced. Packaging labels for the study have been made at Purdue. The INRAN Cereal Processing Lab group hopes to begin working with entrepreneurs/NGOs in Niamey and elsewhere to stimulate commercial processing of sorghum and millet products. Ideally, one or more processing units should probably be placed outside of INRAN to facilitate this. There continues to be a good deal of interest both within Niger and in neighboring countries about the potential of commercializing couscous made from sorghum and millet.

A stronger collaboration is being developed with the cereal technologist in Ethiopia. INTSORMIL is in the final stages of purchasing a decorticator and hammer mill for EARO's cereal technology laboratory located at Nazret. With this equipment, there are plans to develop high quality flours from sorghum that can be used commercially in local Ethiopian industries.

At INTSORMIL/Purdue project PRF-212, an active research program has concentrated on improving use of sorghum and millet grains through better understanding of their fundamental chemistry and physical properties. We now have a good understanding of the basis for couscous and porridge stickiness, which is an undesirable characteristic connected to some sorghum (and probably millet) cultivars. It has been shown that sorghum kafirin protein can participate in viscoelastic fibril formation with wheat gluten to strengthen dough and improve loaf volume. While not immediately transferable this knowledge may in the future become useful, perhaps even through genetic modification of sorghum. Studies on grain chemical interactions during food processing or cooking has revealed a three-component interaction/complex that greatly affects cooling paste viscosities, that relates to porridge quality.

The WCAMRN/ROCAFREMI participation has much potential in allowing INTSORMIL utilization scientists to collaborate regionally. So far WCAMRN/ROCAFREMI 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/Texas A&M Project TAM-226 reports that new markets for value-enhanced white food sorghums are being developed by the U.S. Grains Council from re-

## Introduction and Program Overview

search on food sorghum processing and prototype products developed in this project. Value-enhanced white food sorghums sent to Japan made a positive impression. Sorghum is an excellent ingredient in extruded snacks and related food products. Sorghum flour was demonstrated effective in nearly 20 traditional Japanese foods in Tokyo.

A new snack from white sorghum was marketed in the United States. Several mills are producing sorghum flour for niche markets. In Central America, white sorghums are used in cookies and other products as a substitute for wheat or maize. Personnel in Honduras successfully conducted baking trials demonstrating the value of white food sorghums.

Special sorghums with high levels of phenols and antioxidants produce excellent chips and baked products. The antioxidant level in certain bran fractions is higher than that of blue berries.

New commercial sorghum hybrids with tan plant red and white pericarp color are nearing release from commercial hybrid seed companies and TAES. Several parental sorghum lines released from programs are used in commercial hybrids grown in Mexico and the United States. ATx635 hybrids have outstanding milling properties.

Antifungal proteins appear related to grain mold resistance in sorghum. A molecular linkage map for sorghum kernel characteristics, milling properties, and mold resistance is nearing completion.

New markets for value-enhanced white food sorghums are being developed by the US Grains Council from research and information on food sorghum processing and products developed by INTSORMIL/Texas A&M project TAM-226. The first value-enhanced white sorghums were sent to Japan. The Japanese have a positive impression of sorghum for extrusion in snacks and related food products. They believe it is better than rice for extrusion. Sorghum flour was demonstrated effective in traditional Japanese foods in Tokyo by chefs and dieticians.

A new snack from white sorghum has been marketed in the United States. Several mills are producing sorghum flour for niche markets. In Central America, white sorghums are being used in cookies and other products as a substitute for wheat or maize. Personnel in Honduras successfully conducted baking trials demonstrating the value of white food sorghums. Special sorghums have high levels of phenols and antioxidants. They produce excellent chips and baked products with high levels of antioxidants and dietary fiber. White food sorghum flour can be substituted for 50% of the wheat flour in Mexican cookie formul. New commercial sorghum hybrids with tan plant red and white pericarp color are nearing release from commercial hybrid seed companies and TAES. Antifungal proteins may be related to grain mold resistance in sorghum. A molecular link-

age map for sorghum kernel characteristics, milling properties, and mold resistance is nearing completion.

INTSORMIL research on processing of sorghum has yielded significant results over the past four 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.

A workshop organized by Professor Taylor, University of Pretoria, Dr. Janet Dewar, CSIR, and Lloyd Rooney, Texas A&M University, was hosted by University of Pretoria. More than 36 participants from the food industry, university, and research institutes in Southern Africa interacted during the 3.5 day Sorghum Quality Assessment Workshop. It included tours to a Sorghum Brewery and the ARC Summer Grains Institute in Potchefstroom. Students at the University of Pretoria enrolled in the Southern African Regional M.S. Degree program at the University of Pretoria participated.

### Future Directions

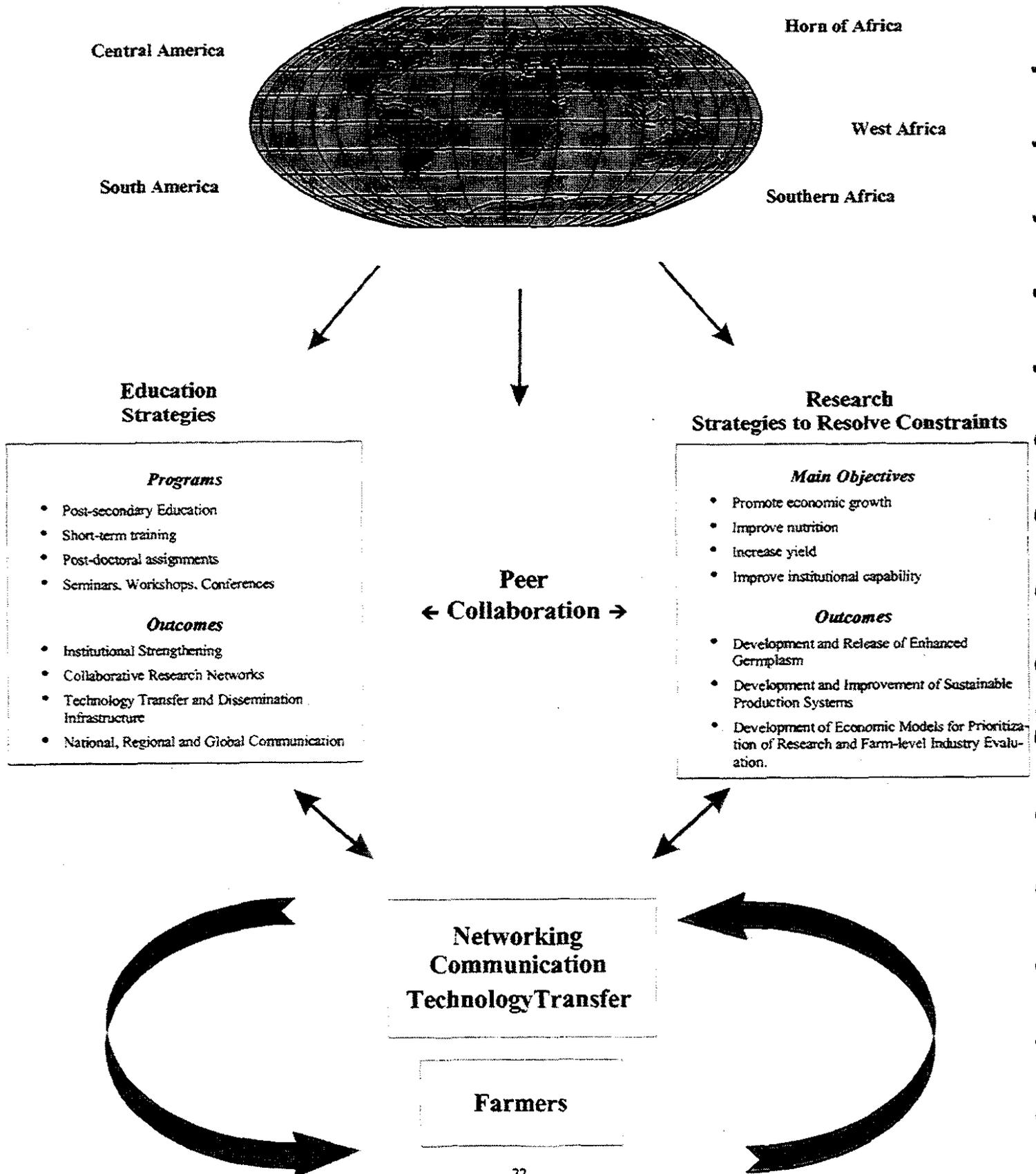
Based on its achievements, the INTSORMIL team is well positioned to contribute even more effectively to ending hunger and raise incomes. With its increasing strength of scientific expertise in developing countries, INTSORMIL is now able to more effectively reduce constraints to production and utilization of sorghum and millet to the mutual benefit of developing countries and the United States. Advances in sorghum and millet research over

## *Introduction and Program Overview*

INTSORMIL's first 21 years, INTSORMIL scientists in the United States, Africa, and Central America are now able to jointly plan and execute collaborative research which will have increased benefits to developing countries and the United States. These collaborative relationships are keys to INTSORMIL's success and will continue as fundamental approaches to meeting the INTSORMIL mission. In the future, INTSORMIL will target NARS collaborative ties that reflect regional needs for sorghum and/or millet production. These ties are 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.

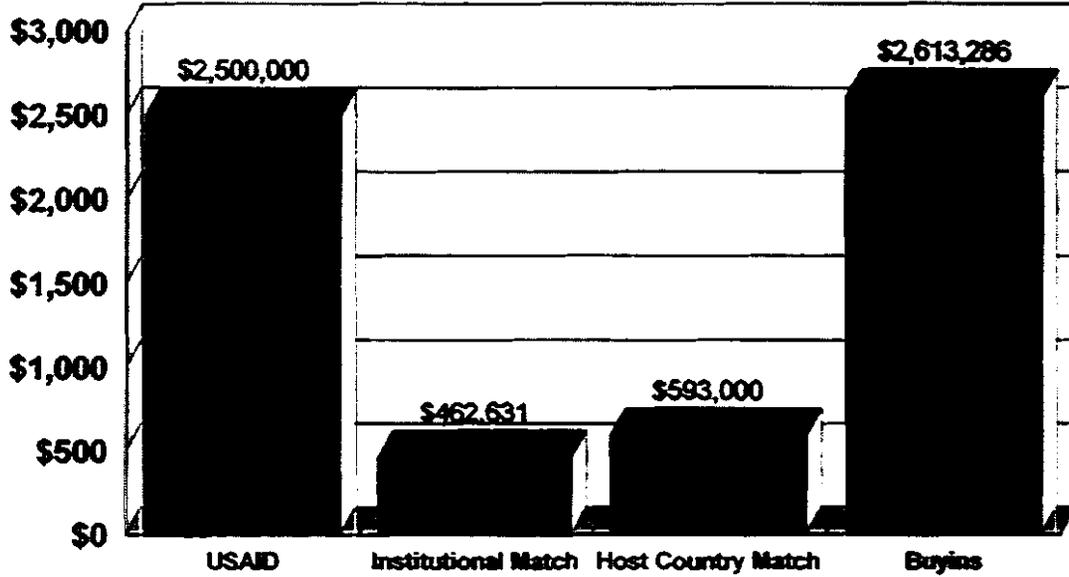
In the past, INTSORMIL focused a major part of its resources on graduate student training and generating research particularly useful within the scientific community. The INTSORMIL agenda for the future continues to include graduate student training and generation of scientific knowledge and information 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



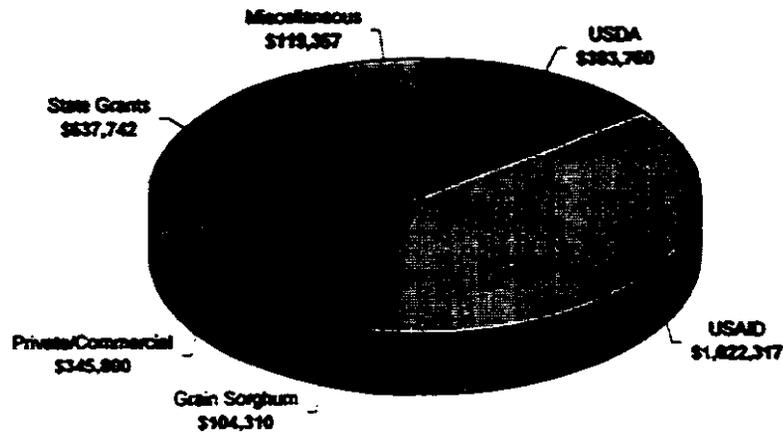
# INTSORMIL FY 2000 Source of Funding

## Total Year 21 - \$ 6,168,917



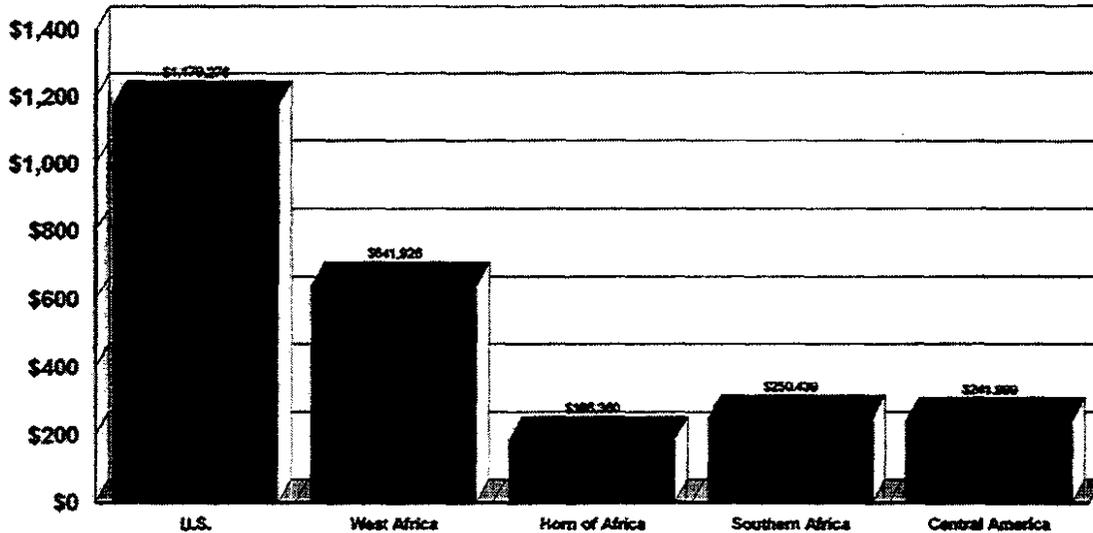
### Breakdown of Buy-Ins

#### \$ 2,613,286

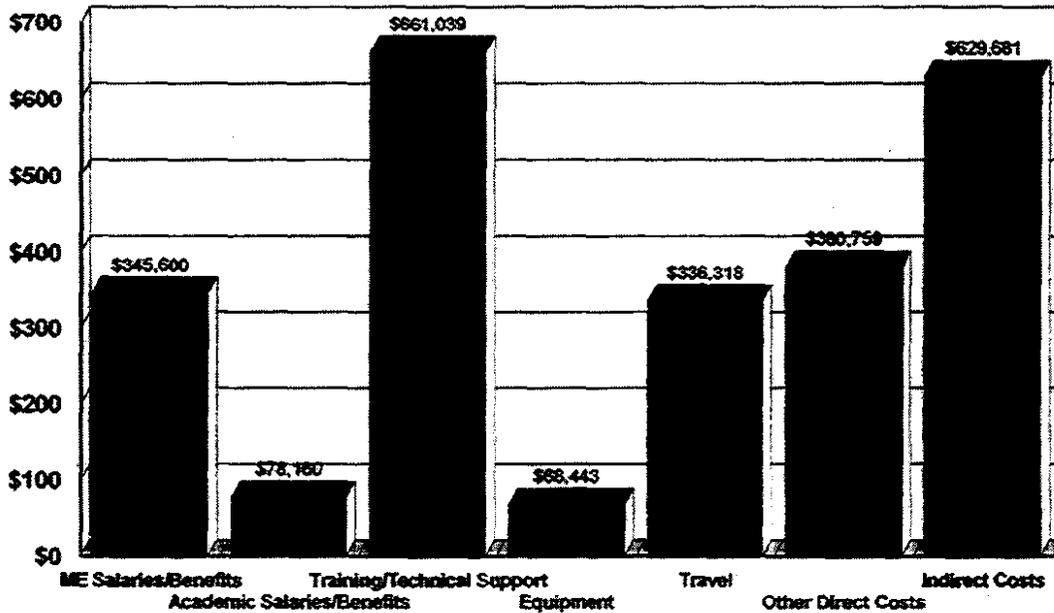


# INTSORMIL Budget Analysis - Year 21 - FY 2000

## Functional - \$ 2,500,000



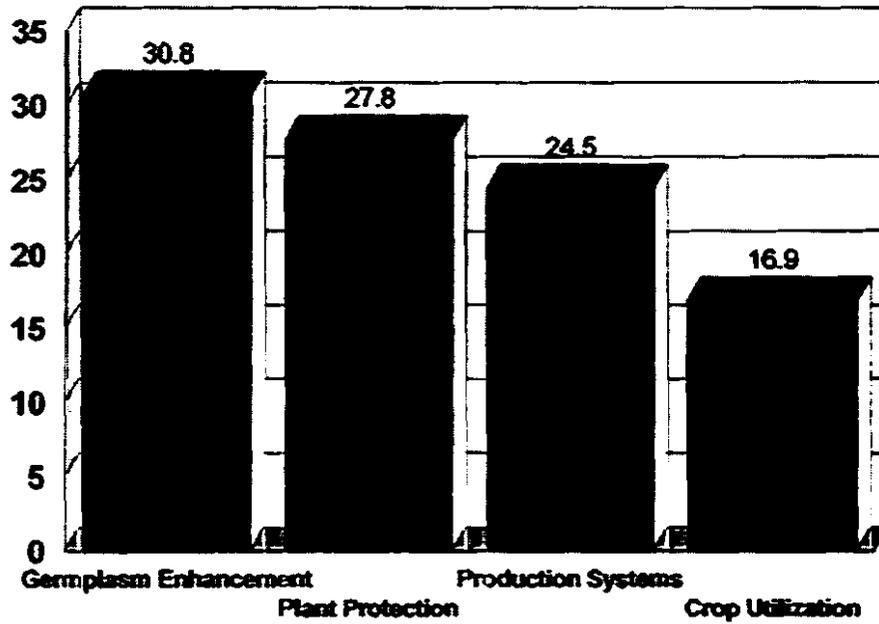
**By Region**



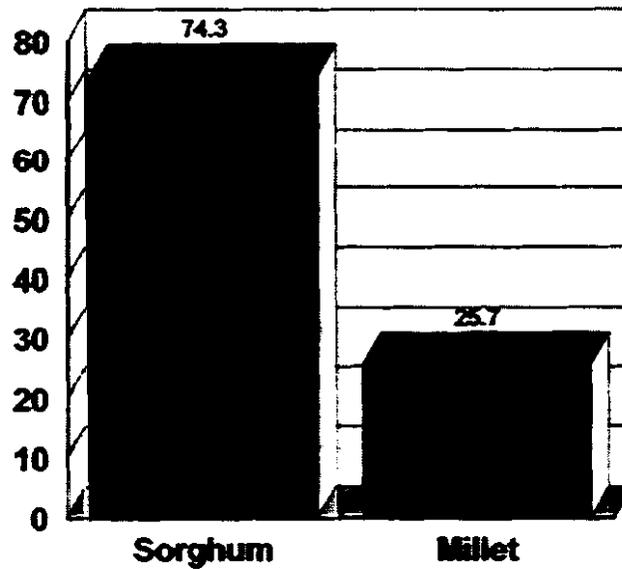
**By Line Item**

# INTSORMIL FY 2000 Technical Budget Analysis

## Year 21 - \$ 1,845,000



Technical Thrusts - By Percentage



Crops - By Percentage

**Table 1. USAID-Grant Contribution to Sorghum/Millet CRSP for Years 1 (FY 80) through 21 (FY 2000) for all Collaborative Research and Management Entity.**

Budget Line Items	Years 1 - 20 FY 80 - 99	Year 21 FY 2000	Totals FY 80 - 2000
Salaries and Benefits	\$ 23,834,704	\$ 1,084,799	\$24,919,503
Equipment and Facilities	2,622,328	68,443	2,690,771
Travel	6,380,620	336,318	6,716,938
Other Direct Costs	6,053,770	380,759	6,434,529
Networking	625,090		625,090
LDC Special Projects	4,357,186		4,357,186
Mission Buyin	100,000		100,000
Indirect Costs	13,227,184	629,681	13,856,865
<b>Total</b>	<b>\$ 57,200,882</b>	<b>\$ 2,500,000</b>	<b>59,700,882</b>

**Table 2. Management Entity Office Budget Details for Years 1 (FY 80) through 21 (FY 2000).**

Budget Line Item	Years 1-20 FY 80 - 99	Year 21 FY2000	Total
Salaries	\$ 3,554,259	\$ 345,600	\$ 3,899,859
Equipment	54,834	1,400	56,234
Travel	933,256	40,000	973,256
Consultants	44,600		44,600
Other Direct Costs	501,971	33,000	534,971
Indirect Costs	2,072,106	180,000	2,252,106
<b>Total</b>	<b>\$ 7,161,026</b>	<b>\$ 600,000</b>	<b>\$ 7,761,026</b>
Workshops	151,000		151,000
EEP	260,000		295,000
Special Projects	377,800	55,000	482,800
<b>ME Total</b>	<b>\$ 7,459,826</b>	<b>\$ 655,000</b>	<b>\$ 8,689,826</b>

**Table 3. Summary of Non-Federal Matching Contributions by U.S. Institutions - Grant Years 1 (FY 80) through 21 (FY 2000).**

U.S. Institution	Years 1-20 FY 80 - 99	Year 21 FY 2000	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	1,867,084	\$ 23,315	1,890,399
Mississippi State University	976,119	17,500	993,619
University of Nebraska	2,379,147	61,800	2,440,947
Purdue University	3,084,116	164,558	3,248,674
Texas A&M University	4,853,311	165,286	5,018,597
University of Illinois - Urbana-Champaign	35,538	24,872	60,410
USDA		5,300	5,300
<b>Total</b>	<b>\$ 13,584,172</b>	<b>\$ 462,631</b>	<b>\$ 14,046,803</b>

**Table 4. USAID-Grant Contribution to Sorghum/Millet CRSP for all Collaborative Research, Year 21 (FY 2000), July 1, 1999 - June 30, 2000 USAID Grant LAG-G-00-96-90009-00.**

	IL	KS	MS	NE	PR	TX	USDA	Inst. Total	ME Spec.Proj.	ME HC	ME	Total
Salary	\$ 30,115	\$ 34,520	\$ 29,302	\$ 96,387	\$ 299,039	\$ 198,193	\$ 26,075	\$ 643,631	\$ 9,800	\$ 85,768	\$ 345,600	\$ 1,084,799
Equipment			3,563	17,248		11,232		32,043		35,000	1,400	68,443
Travel	10,006	19,079	13,000	20,724	53,017	113,992	2,000	231,818	8,500	56,000	40,000	336,318
ODC	5,094	8,046	4,650	29,800	74,127	68,965	3,745	194,427	36,700	116,632	33,000	380,759
Indirect	24,785	28,355	19,485	55,841	155,417	162,618	3,180	449,681			180,000	629,681
<b>Total</b>	<b>\$ 70,000</b>	<b>\$ 90,000</b>	<b>\$ 70,000</b>	<b>\$ 220,000</b>	<b>\$ 511,600</b>	<b>\$558,000</b>	<b>\$ 35,000</b>	<b>\$1,551,600</b>	<b>\$ 55,000</b>	<b>\$ 293,400</b>	<b>\$ 600,000</b>	<b>\$ 2,500,000</b>

## Year 21 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 22 different countries were enrolled in an INTSORMIL advanced degree program. Approximately 73% 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 1999-00, 31% of all INTSORMIL graduate participants were female. Eighteen of the total 51 students received full INTSORMIL scholarships. An additional 14 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 1999-2000 there are 19.

Graduate degree programs and short-term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Five post doctoral scientists and nine visiting host country scientists were provided the opportunity to upgrade their skills in this fashion during 1999-2000.

The following table is a compilation of all INTSORMIL training activities for the period July 1, 1999 through June 30, 2000.

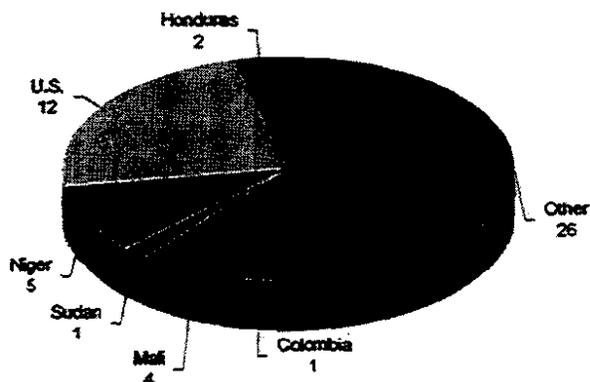


Figure 1. Participants by Country

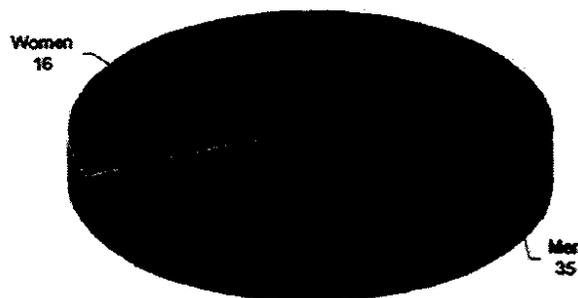


Figure 2. Participants by gender

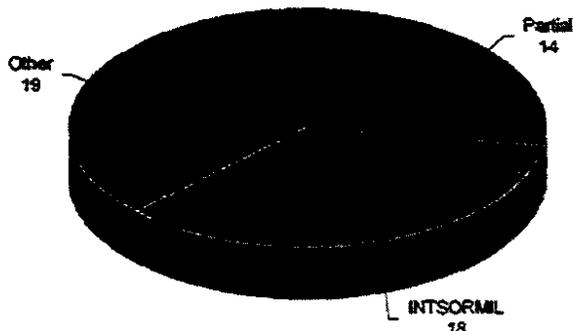


Figure 3. Source of Funding

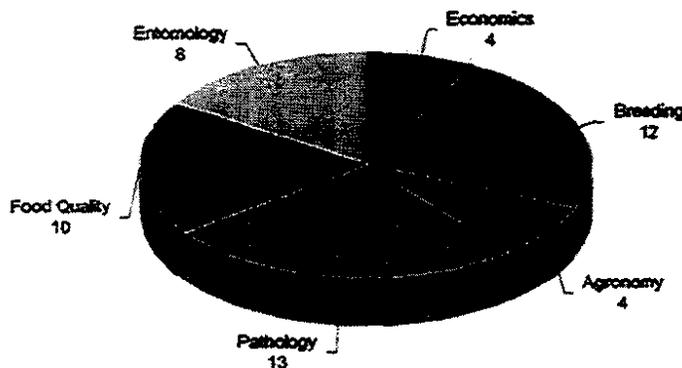


Figure 4. Discipline Breakdown

## Year 21 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Regassa, Teshome	Ethiopia	UNL	Agron/Physiol	Marraville	PHD	M	O
Cimino, Suzanne	U.S.	UNL	Agronomy	Mason	MSC	F	P
Maman, Nouri	Niger	UNL	Agron/Physiol	Mason	PHD	M	P
Seibou, Pale	Burkina Faso	UNL	Agronomy	Mason	MSC	M	I
Carvalho, Carlos H.S.	Brazil	PRF	Genetics/BioTech	Axtell	PHD	M	P
Ndrou, Lexingtons	Kenya	PRF	Breeding	Axtell	PHD	M	I
Grenier Cecile	France	PRF	Striga Physiology	Ejeta	PD <sup>2</sup>	F	O
Genaratna, Nihupa	U.S.	PRF	Breeding	Ejeta	MSC	F	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 <sup>2</sup>	M	I
Coulibaly, Sidi Bekaye	Mali	TTU	Breeding	Rosenow/Peterson	PHD	M	P
Sibene, Dena	Mali	TAM	Breeding	Rosenow	VS <sup>1</sup>	M	I
Teme, Niaba	Mali	TTU	Breeding	Rosenow	MSC	M	I
Mogorosi, Michael	Botswana	UNL	Breeding	Andrews	VS <sup>1</sup>	M	I
Setrucha, Peter	Botswana	UNL	Breeding	Andrews	PHD	M	O
Kazianga, Harouman	Burkina Faso	PRF	Economics	Sanders	PHD	M	O
Tahirou, Abdoulaye	Niger	PRF	Economics	Sanders	PHD	M	O
Vitale, Jeff	U.S.	PRF	Economics	Sanders	PHD	M	I
Wubeach, Nega G.	Ethiopia	PRF	Economics	Sanders	MSC	M	I
Gorena, Roberto Luis	U.S.	TAM	Entomology	Peterson/Teetes	PHD	M	I
Boire, Soualika	Mali	TAM	Entomology	Gilstrap/Teetes	PHD	M	I
Kadi Kadi, Hamc	Niger	TAM	Entomology	Gilstrap/Teetes	MSC	M	I
Lingren, Scott	U.S.	TAM	Entomology	Teetes	PHD	M	O
Jensen, Andrea	U.S.	TAM	Entomology	Teetes	PHD	F	I
Carrillo, Mario	Argentina	MSU	Entomology	Pitre	MSC	M	I
Cordero, Roberto	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Johnson, Zeledon	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Aboubacar, Adam	Niger	PRF	Food Quality/Util	Hanzlker	PD <sup>1</sup>	M	O
Bugusu, Betty	Kenya	PRF	Food Quality/Util	Hanzlker	PHD	F	I
Mahaden, Michelle	India	PRF	Food Quality/Util	Hanzlker	MSC	F	P
Mix, Nadege	France	PRF	Food Quality/Util	Hanzlker	MSC	F	I
Awika, Joseph Mobutu	Kenya	TAM	Food Quality/Util	Rooney/Waniska	MSC	M	P
Bueso, Francisco (Javier)	Honduras	TAM	Food Quality/Util	Rooney/Waniska	PHD	M	P
Gordon, Leigh Ann	U.S.	TAM	Food Quality/Util	Rooney	MSC	F	P
Leon-Chapa, Martha	Mexico	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P
Maurer, Giselle	U.S.	TAM	Food Quality/Util	Rooney	BSC	F	O
Mitre-Dieste, Marcelo	Mexico	TAM	Food Quality/Util	Rooney	MSC	M	P
Zelaya, Nolviz	Honduras	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P
dos Santos, Claudia	Brazil	KSU	Pathology	Clafin	VS <sup>1</sup>	F	P
Narvaez, Dario	Colombia	KSU	Pathology	Clafin	PHD	M	O
Chulze, Sofia	Argentina	KSU	Pathol/Mycology	Leslie	VS <sup>1</sup>	F	O
Jurgenson, Jim	U.S.	KSU	Pathol/Genetics	Leslie	VS <sup>1</sup>	M	O
Hanson, Amy	U.S.	KSU	Pathol/Genetics	Leslie	MSC	F	O
Kerezy, Zoltan	Hungary	KSU	Pathol/Genetics	Leslie	PD <sup>2</sup>	M	P
Lee, Yin-Won	South Korea	KSU	Pathology	Leslie	VS <sup>1</sup>	M	O
Neumann, Melody	Canada	KSU	Pathol/Mycology	Leslie	VS <sup>1</sup>	F	O
Rheeder, John	South Africa	KSU	Pathology	Leslie	VS <sup>1</sup>	M	O
Salah, Amgad	Egypt	KSU	Pathology	Leslie	PHD	M	O
Silva, Gabriella	Uruguay	KSU	Pathol/Genetics	Leslie	VS <sup>1</sup>	F	O
Zeller, Kurt P.	U.S.	KSU	Pathology	Leslie	PD <sup>2</sup>	M	O
Kollo, Issoufou	Niger	TAM	Pathology	Frederiksen	PHD	M	O

\* 1 = Completely funded by INTSORMIL

P = Partially funded by INTSORMIL

O = Other source

<sup>1</sup>VS = Visiting Scientist<sup>2</sup>PD = Post Doctoral

KSU = Kansas State University

MSU = Mississippi State University

PRF = Purdue University

TAM = Texas A&amp;M University

TTU = Texas Tech University

UNL = University of Nebraska - Lincoln

## Years 18-19-20 and 21 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 years covered by this report, 213 students from 33 different countries were enrolled in an INTSORMIL advanced degree program. Approximately 77% 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. During the period of 1997-2000, 22% of all INTSORMIL graduate participants were female. Seventy nine of the total 213 students received full INTSORMIL scholarships. An additional 62 students received partial INTSORMIL funding and the remaining 72 students were funded from other sources as shown in Figure 3.

All 213 students work directly with INTSORMIL principal investigators on INTSORMIL projects. These students are enrolled in graduate programs in six disciplinary areas, agronomy, breeding, pathology, entomology, food quality, and economics (Figure 4).

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 only 19 in 1999-2000.

Graduate degree programs and short-term training programs have been designed and implemented on a case by case basis to suit the needs of host country scientists. Eighteen post doctoral scientists and 22 visiting host country scientists were provided the opportunity to upgrade their skills in this fashion during this four year period.

The following tables are a compilation of all INTSORMIL training activities for the period of July 1, 1996 through June 30, 2000.P

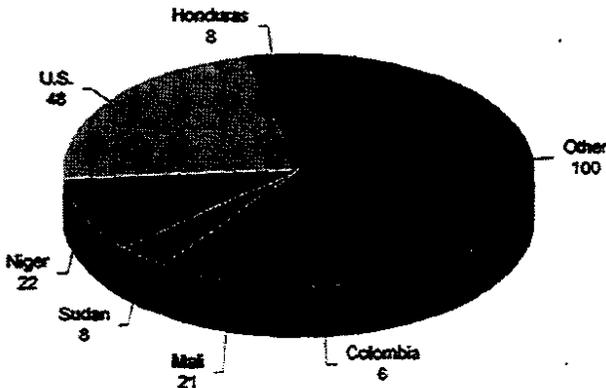


Figure 1. Participants by Country

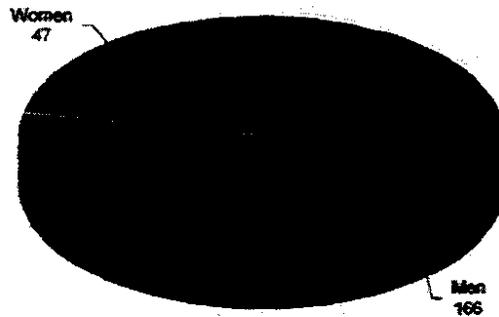


Figure 2. Participants by gender

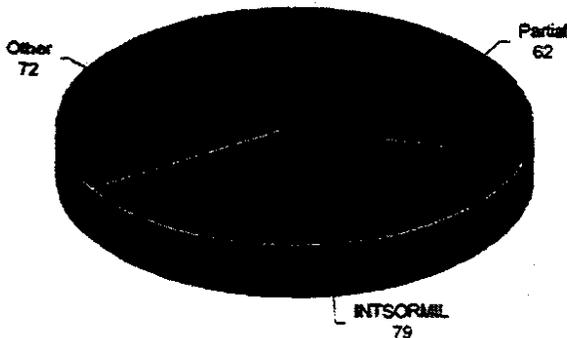


Figure 3. Source of Funding

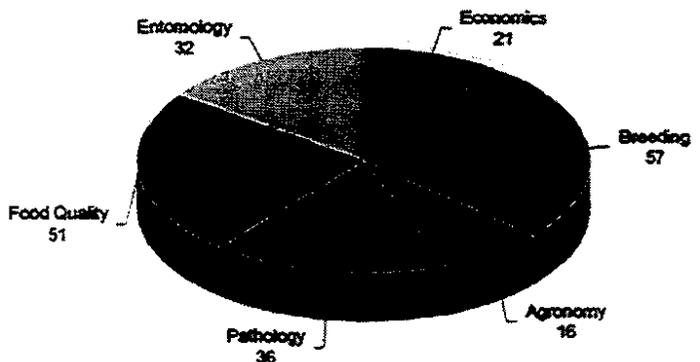


Figure 4. Discipline Breakdown

## Year 20 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Regassa, Teshome	Ethiopia	M	Agron/Physiol	Maraville	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, Lexington	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 <sup>2</sup>	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 <sup>1</sup>	M	I
Rai, K.N.	India	UNL	Breeding	Andrews	VS <sup>1</sup>	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 <sup>2</sup>	M	P
Coulibaly, Bakary	Mali	PRF	Economics	Sanders	MSC	M	O
Kazianga, Harounam	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, Soumilka	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 <sup>1</sup>	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 <sup>1</sup>	M	I
Miranda-Lopez, Rita	Mexico	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Rodriguez-Hererra, 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, Notvia	Honduras	F	Food Quality/Util	Rooney/Waniska	MSC	F	I
Narvaez, Dario	Colombia	KSU	Pathology	Clafin	PHD	M	O

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

## Year 19 INTSORMIL Training Participants

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

<sup>1</sup>VS = Visiting Scientist<sup>2</sup>PD = Post Doctoral

KSU = Kansas State University

MSU = Mississippi State University

PRF = Purdue University

TAM = Texas A&amp;M University

TTU = Texas Tech University

UNL = University of Nebraska - Lincoln

## Year 18 INTSORMIL Training Participants

Name	Country	Univ.	Discipline	Advisor	Degree	Gender	Funding*
Gutierrez, Patricio F.	Ecuador	UNL	Agronomy	Clegg	PHD	M	I
Masi, Cassim	Zambia	UNL	Agronomy	Maranville	PHD	M	O
Traore, Abdoulaye	Mali	UNL	Agronomy	Maranville	PHD	M	I
Maman, Nouri	Niger	UNL	Agronomy	Mason	MSC	M	I
Stockton, Roger	U.S.	UNL	Agronomy	Mason	PHD	M	P
Traore, Samba	Mali	UNL	Agronomy	Mason	PHD	M	O
Carvalho, Carlos H.S.	Brazil	PRF	Breeding	Axtell	PHD	M	P
Kapran, Issoufou	Niger	PRF	Breeding	Axtell	PHD	M	I
Ndulu, Lexington	Kenya	PRF	Breeding	Axtell	PHD	M	I
Ibrahim, Yahia	Sudan	PRF	Breeding	Ejeta	PHD	M	I
Melakebrhan, Admasu	Ethiopia	PRF	Breeding	Ejeta	PD <sup>2</sup>	M	I
Mohammed, Abdalla	Sudan	PRF	Breeding	Ejeta	PHD	M	P
Mulatu, Tadesse	Ethiopia	PRF	Breeding	Ejeta	MSC	M	P
Tuinstra, Mitchell	U.S.	PRF	Breeding	Ejeta	PD <sup>2</sup>	M	I
Katsar, Catherine Susan	U.S.	TAM	Breeding	Peterson/Tectes	PHD	F	P
Rodriguez, Raul	Mexico	TAM	Breeding	Roscnow/Rooney	PHD	M	P
Teme, Niaba	Mali	TTU	Breeding	Roscnow	MSC	M	I
Witse, Curtis	U.S.	TAM	Breeding	Roscnow/Rooney	MSC	M	P
Jeutong, Fabien	Cameroon	UNL	Breeding	Andrews	PHD	M	O
Setimela, Peter	Botswana	UNL	Breeding	Andrews	PHD	M	O
Tiryaki, Iskender	Turkey	UNL	Breeding	Andrews	MSC	M	O
Coulibaly, Bakary	Mali	PRF	Economics	Sanders	MSC	M	O
Sidibe, Mamadou	Senegal	PRF	Economics	Sanders	PHD	M	O
Tahirou, Abdoulaye	Niger	PRF	Economics	Sanders	PHD	M	I
Vitale, Jeff	U.S.	PRF	Economics	Sanders	PHD	M	I
Boire, Soualika	Mali	TAM	Entomology	Gilstrap/Tectes	PHD	M	I
Kadi Kadi, Hame	Niger	TAM	Entomology	Gilstrap/Tectes	MSC	M	I
Calderon, Pedro	Honduras	MSU	Entomology	Pitre	MSC	M	O
Cordero, Roberto	Nicaragua	MSU	Entomology	Pitre	MSC	M	I
Vergara, Oscar	Ecuador	MSU	Entomology	Pitre	MSC	M	I
Diarisso Yaro, Niamoye	Mali	TAM	Entomology	Tectes/Peterson	PHD	F	P
Jensen, Andrea	U.S.	TAM	Entomology	Tectes	PHD	F	I
Lingren, Scott	U.S.	TAM	Entomology	Tectes	PHD	M	O
Aboubacar, Adam	Niger	PRF	Food Quality/Util	Hanaker/Axtell	PHD	M	I
Buckner, Becky	U.S.	PRF	Food Quality/Util	Hanaker	PHD	F	P
Itapu, Suresh	India	PRF	Food Quality/Util	Hanaker	PD <sup>2</sup>	M	O
Mamadou, Lewamy	Niger	PRF	Food Quality/Util	Hanaker	MSC	M	P
Zhang, Genyi	China	PRF	Food Quality/Util	Hanaker	MSC	M	I
Acosta, Harold	Colombia	TAM	Food Quality/Util	Rooney	PHD	M	P
Asante, Sam	Ghana	TAM	Food Quality/Util	Rooney	PHD	M	P
Bueso, Francisco Javier	Honduras	TAM	Food Quality/Util	Rooney/Waniska	MSC	M	I
Floyd, Cherie	U.S.	TAM	Food Quality/Util	Rooney/Waniska	PHD	F	P
Kunetz, Christine	U.S.	TAM	Food Quality/Util	Rooney/Waniska	MSC	F	P
Quintero-Fuentes, Ximena	Mexico	TAM	Food Quality/Util	Rooney	MSC	F	P
Seetharaman, Koushik	India	TAM	Food Quality/Util	Rooney/Waniska	PHD	M	P
Suhendro, Ely	Indonesia	TAM	Food Quality/Util	Rooney	PHD	F	P
Zhao, Haryan	China	TAM	Food Quality/Util	Rooney/Waniska	VS <sup>1</sup>	M	O
Diourte, Mamourou	Mali	KSU	Pathology	Claffin	PHD	M	O
Lu, Ming	China	KSU	Pathology	Claffin	PHD	M	P
Muriithi, Linus M.	Kenya	KSU	Pathology	Claffin	PHD	M	O
Narvaez, Dario	Colombia	KSU	Pathology	Claffin	MSC	M	P
Nzioki, Henry S.	Kenya	KSU	Pathology	Claffin	MSC	M	O
Arjula, Vaishali	India	KSU	Pathology	Leslie	MSC	F	O
Zeller, Kurt P.	U.S.	KSU	Pathology	Leslie	PD <sup>2</sup>	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

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O = Other source

IVS = Visiting Scientist

<sup>2</sup>PD = Post Doctoral

KSU = Kansas State University

MSU = Mississippi State University

PRF = Purdue University

TAM = Texas A&amp;M University

TTU = Texas Tech University

UNL = University of Nebraska - Lincoln

## INTSORMIL BUYINS - FY 2000

<b>KSU-210A</b>	Kansas Agriculture Experiment Station	19,000	
	CONICET/Argentina	55,357	
	IIE/USAID - Egypt	27,606	
	ATUT/USAID - Egypt	75,000	
	Ivy Laboratories	36,800	
	American Society for Microbiology	20,000	
	USDA/NRICGP - Food Safety Panel	60,000	
	USDA/National Scab Research Initiative	35,000	
<b>KSU-210B</b>	Kansas Agriculture Experiment Station	15,000	
	North Central Region	14,000	
	USDA/ARS	<u>19,760</u>	<b>\$377,523</b>
<b>USDA/Georgia</b>	ICRISAT/USAID	7,000	
	Department of Energy	<u>61,000</u>	<b>\$68,000</b>
<b>PRF-203</b>	McKnight Foundation	10,000	
	Winrock/McKnight Foundation	20,000	
	Rockefeller Foundation	20,000	
	Purdue University/ Dean of Agriculture	30,000	
	World Bank	28,000	
	INRAN/Hybrid Seed Development	20,000	
<b>PRF-205</b>	USAID/Africa	176,279	
	IGAD/USAID/Horn of Africa	35,000	
<b>PRF-207</b>	Purdue University/Agronomy Department	1,000	
<b>PRF-209</b>	Purdue University/Dean of Agriculture	30,000	
	Winrock International	15,000	
	McKnight Foundation	10,000	
<b>PRF-212</b>	Texas Grain Sorghum Board	45,000	
	Mahyco Research Foundation	35,000	
<b>PRF-213</b>	ICRISAT/USAID	30,000	
	Rockefeller Foundation	<u>80,000</u>	<b>\$582,279</b>
<b>TAM-222</b>	Sorghum Biotech Partnership	10,000	
	USDA-NR1	15,000	
	Texas Higher Education/ATP	169,500	
	USDA-ARS	6,000	
<b>TAM-223</b>	Texas Higher Education	79,579	
	Rockefeller Foundation	10,000	
	PROFIT Initiative/TAES	60,380	
<b>TAM-224</b>	USDA/FAS	40,000	
	USDA/ARS	15,000	
<b>TAM-225</b>	Texas Grain Gene Initiative	35,027	
	Texas Dept of Agriculture & Pest Management Assoc.	19,659	
	PROFIT Initiative/TAES	8,472	
<b>TAM-226</b>	Hatch	145,000	
	Texas Grain Sorghum Producers	50,000	
	Texas Higher Education/ATP	102,500	
	PROFIT Initiative/TAES	40,625	
<b>TAM-228</b>	USDA-ARS	<u>48,000</u>	<b>\$854,742</b>
<b>UNL-213</b>	Anna Elliot Fund/UNL Foundation	30,000	
<b>UNL-214</b>	Pioneer Seed	20,000	
<b>UNL-218</b>	Nebraska Grain Sorghum Board	<u>9,310</u>	<b>\$59,310</b>
<b>Management</b>	IGAD/Intergovernmental Authority on Development in the Horn of Africa Region	<u>671,432</u>	<b>\$671,432</b>
	<b>Total Buyins - July 1, 1999 to June 30, 2000 - FY 00 - Year 21</b>		<b>\$ 2,613,286</b>

## INTSORMIL Sponsored and Co-Sponsored Workshops 1979 - 2000

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 Nacional 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 Baños, 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

## *Workshops*

	Name	Where	When
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
54.	Central America Regional Planning Workshop	Zamorano, Honduras	10/99

## Publications and Presentations

### Sustainable Plant Protection Systems

#### Journal Articles

- Bailey, C. A., J. J. Fazzino, Jr., M. S. Ziehr, A. U. Haq, G. Odvody, and J. K. Porter, 1999. Evaluation of Sorghum Ergot Toxicity in Broilers. *Poultry Sci.* 78:1391-1397.
- Bandyopadhyay, R., D. E. Frederiksen, N. W. McLaren, G. N. Odvody, and M. J. Ryley. 1998. Ergot: A New Disease Threat to Sorghum in the Americas and Australia. *Plant Disease* 82:356-367.
- Boora, K. S., R. A. Frederiksen, and C.W. Magill. 1998. DNA-based markers for a recessive gene conferring anthracnose resistance in sorghum. *Mol. Gen. Genet.* 261:317-322.
- Bowden, R. L., and J.F. Leslie. 1999. Sexual recombination in *Gibberella zeae* (*Fusarium graminearum*). *Phytopathology* 89:182-188.
- Britz, H., T.A. Coutinho, M.J. Wingfield, W.F.O. Marasas, T. R. Gordon and J. F. Leslie. 1999. *Fusarium subglutinans* f. sp. *pini* represents a distinct mating population in the *Gibberella fujikuroi* species complex. *Applied and Environmental Microbiology* 65:1198-1201.
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