Central America

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Coordinators

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Mr. Rafael Obando Solis, Agronomist, CNIA/INTA, Apdo. 1247, Managua, Nicaragua [Nicaragua Country Coordinator]
Dr. Raúl Espinal, Escuela Agrícola Panamericana (EAP), Apdo. 93, Tegucigalpa, Honduras [Honduras Country Coordinator].
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Collaborating Scientists

Francisco Vargas, Agronomist, Nicaraguan Grain Sorghum Producers Association (ANPROSOR), Managua, Nicaragua
Mr. Sergio Pichardo Guido, Plant Pathologist, UNA, Managua, Nicaragua
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Mario Ernesto Parada Jaco, Entomologist, CENTA, El Salvador
Ing. Hector Deras F., Plant Breeder, CENTA, El Salvador
Ing. José Wilfred Castaneda, Agronomist, CENTA, El Salvador
Ing. Quirino Argueta Portillo, Agronomist, CENTA, El Salvador
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Orlando Tellez Obregon, Soil & Water Scientist, INTA, Nicaragua
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Description of Collaborative Program

Institutions

Active INTSORMIL collaboration in Central America is occuring primarily among the following institutions: Centro Nacional de Technología de Agricopecuaria y Forestal (CENTA), El Salvador; Instituto Nicaragüense de Tecnología Agropecuaria (INTA) ,Nicaragua; Universidad Nacional Agraria (UNA), Nicaragua; Universidad Nacional Autónoma de Nicaragua (UNAN), Nicaragua; Escuela Agrícola Panamericana (EAP), Honduras; Kansas State University, Mississippi State University, Texas A & M University; and the University of Nebraska.

Organization and Management

In 1999, INTSORMIL shifted program emphasis in Central America to El Salvador and Nicaragua. Scientists from collaborating institutions met and developed a research plan for the 2000 -2001 years with collaborative projects in plant breeding, utilization, plant protection (entomology and plant pathology), and agronomy. On February 27-28, 2002 scientists met to present two-year research results and develop priorities for collaborative research for 2002-2006.

Financial Inputs

Primary financial support for the program is from the INTSORMIL Central America Regional Program budget, which was \$105,000 during the past year.The four collaborative research projects (plant breeding, utilization, plant protection, and agronomy) were budgeted \$16,000 each, with the balance maintained at the INTSORMIL Management Entity to cover regional expenses. These regional expenses included short-term training for three scientists in plant breeding, expenses associated with the Central America Sorghum Research Conference, equipment purchases and administrative travel.

Collaboration

INTSORMIL's Central America program has supported informal collaboration with many non-governmental organizations mainly in validation of sorghum varieties, and formal collaboration with national extension services, and it has served as a catalyst for Central American grain sorghum research and technology transfer. In addition, René Clará Valencia coordinated the regional grain sorghum yield trials conducted by the PCCMCA, and grain sorghum germplasm was shared with watershed projects of the Centro Internacional de Agricultura Tropical (CIAT) at Yorito, Honduras and San Dionisio, Nicaragua. During the past year, a collaborative relationship was developed with ANPROSOR, the Nicaraguan grain sorghum producers association, which has assisted in identifying research priorities and is collaborating with a number of research studies in 2002.

Sorghum Production/Utilization Constraints

Grain sorghum is the third most important crop in Central America (El Salvador, Guatemala, Honduras, and Nicaragua) after maize and beans. The area devoted to grain sorghum in 2000 was 252,544 ha^{-1} with an average grain yield of 1.5 Mg ha^{-1} (FAO, 2001). During the last decade sorghum grain yield in Central America increased due to improved technology (including improved cultivars and hybrids, herbicides, insecticides, planting date, minimum tillage, seed treatments and fertilizer) available to producers.

Small-scale Central American farmers are burdened with low productivity and limited land resources. Intercropping provides a means to increase total productivity per unit land area and reduce the risk of dependence on one crop. The dominant cropping system is maize intercropped with maicillos criollos (called millón in Nicaragua). These tropical grain sorghums are three to four meters tall, drought tolerant, and photoperiod sensitive. The grain is used as human food and a feed grain for livestock, and the stover is used for livestock forage. Although maicillo criollos produce low yields, they are planted on approximately 67%, of the grain sorghum area in Central America.

The limited grain yield response of traditional maicillo criollo varieties to management practices is a primary constraint to increased production. Soil and water conservation, improved production practices and soil fertility management, and increased genetic potential of cultivars is essential to obtain economical yield increases. To date, increased grain sorghum production, yield and area are due primarily to utilization of improved cultivars (hybrids and varieties).

Alternative uses for sorghum grain need to be developed to encourage sustainable economic growth in semi-arid areas in Central America. White grain, tan-plant colored grain sorghum cultivars are well adapted to Central American human food and livestock feed systems. Innovative processing systems, like extrusion and flaking, are needed to increase starch digestibility and maximize net energy intake for livestock feed. A lack of milling equipment for production of grain sorghum flour limits adoption of the use of grain sorghum flour for baked products. Human consumption needs to be promoted, especially in tortilla related products, extruded snacks and flour substitution through use of superior grain-quality sorghum cultivars. Use of grain sorghum cultivars for forage, or dual use for both grain and forage are important to small producers.

Research Accomplishments and Planning

Sorghum Research Reporting and Planning Workshop

The workshop was held on February 27 - 28, 2002 and attended by 36 participants sponsored by INTSORMIL, 5 sponsored by INTA, and several administrators from INTA, UNA and ANPROSOR. The first day focused on presentation of experimental results from the past two years, and was brought to a close by presentations by Francisco Vargas (ANPROSOR) on sorghum producer priorities, Pedro Pablo Orosco (CIAT) on verification research and technology adoption by small farmers, and the keynote presentation on the potential future uses of sorghum in Central America by Dr. Sergio Serna Saldivar, Monterrey, Mexico. Efforts are being made to publish certain reports in a special issue of the journal "La Calera."

The second day focus was developing multi-disciplinary team efforts for work plan development, after starting with a presentation about community-based extension programs. The following programmatic changes were developed based on production/ processing themes identified during the conference.

Plant Breeding

(1) **Future direction** should focus on variety development in El Salvador and hybrid development in Nicaragua, although degree training will be required for implementation.

(2) **Lodging**. An increased effort on lodging issues will be implemented recognizing the need for increased collabration with agronomists, plant pathologists and entomologists.

(3) **Grain quality**. Efforts will be continued to produce white kernel, tan plant type grain sorghum cultivars. Increase efforts for tan glumes, thin pericarp, larger round kernel, high density and high test weight will be implemented. Increased collaboration with plant pathologists on grain mold/weathering resistance. Increased educational efforts with private industry and extension services in the value of white sorghum for livestock feed. Increased collaboration with food scientists is needed to develop quick food quality tests for evaluation of advanced breeding materials.

(4) **Forage**. Continue efforts with stay green, and brown midrib/juicy midrib traits. Increased collaboration with plant pathologists for resistance to leaf diseases. Ruminant animal science projects do not exist in INTSORMIL, but increased collaboration with this discipline is needed.

(5) **Insects and Diseases**. Increased collaboration with entomology and plant pathology to identify priorities for research. Workshop presentations suggest an Anthracnose priority in Nicaragua, rust priority in El Salvador, grain mold priority for food and feed uses, and the langosta insect complex is a problem in the entire region.

(6) **On-Farm Testing**. Need to develop collaborative efforts with plant pathologists, entomologists and agronomists.

(7) **Drought Tolerance.** Continue recognizing interactions with management practices.

(8) **Special Needs**. Regional breeding programs need to generate more of their own material and evaluate segregating material, since there are unique adaption reactions in Central America. Institutional development and training of young plant breeding scientists is urgently needed.

Agronomy

(1)**Orientation**. Although some station research is justified, but the emphasis will shift to on-farm research.

(2) **Collaboration**. Efforts need to have broader collaboration with universities, national programs (including extension services), private companies and NGOs.

(3) **Research Focus**. One of the priority research needs is nutrient management, especially for N and P. This should focus on evaluating N rate recommendations on-farm, and collaborating with plant breeders to identify nutrient use efficient cultivars. These efforts should include evaluation for grain physical quality and nutritive value. Weed control was identified as an important problem, but it was felt that adequate resources would not be available to address both fertilizer use efficiency and weed control issues in the near future.

(4) **Soil Degradation**. Interest was expressed to pursue collaboration with CIAT in their watershed project to evaluate the effect of different sorghum-based production systems on soil erosion. This interest is enhanced by a new French led project with CIAT and INTA to focus on upland rice and grain sorghum.

Plant Protection

(1) **Production constraints**. Interdisciplinary efforts to study grain sorghum production on farms with the intent to identify production constraints.

(2) **Economic thresholds**. Producers expressed need to develop scouting procedures and economic thresholds, and train agronomists, producers and chemical salesmen on their use.

(3) **Plant resistance**. Collaborative research should increase for host-plant resistance to anthracnose in Nicaragua, and rust in El Salvador.

Grain Utilization

(1) **Sorghum flour**. Increased research should be conducted on the use of decorticated grain to increase shelf life.

(2) **Grain quality**. Continue to collaborate with plant breeders to improve grain quality of new cultivars and genetic materials, including resistance to grain mold/weathering damage.

(3) **Scientific capacity**. There is a huge need in El Salvador and Nicaragua to improve scientific capacity through graduate education. This is evident given that Fidelia Herrera is the only food scientist working with grain sorghum in El Salvador or Nicaragua. Interest was expressed in trying to develop collaboration with a university in El Salvador.

(4) **Animal use**. Emphasized the importance of effectively incorporating Dr. Joe Hancock into the regional effects, especially in Nicaragua where sorghum is widely used for animal feed.

Plant Breeding

Research Methods

The plant breeding programs in both El Salvador and Nicaragua are striving to identify adapted grain sorghum lines with good agronomic and utilization characteristics for development either as photoperiod-sensitive or insensitive varieties for grain production or dual use as grain and forage. Photoperiod-sensitive lines may also serve as parents for hybrids. Once potentially superior lines are identified, then preliminary yield trials are conducted followed by on-farm verification trials and ultimate release. The breeding programs are constantly evaluating new sources of germplasm identified in the region, from INTSORMIL breeding programs in the United States, and from ICRISAT. Each year, grain sorghum hybrid tests have been conducted in three to seven countries in Central America. In 2001, these studies were conducted in the Dominican Republic, El Salvador, Guatemala, and Nicaragua with 16 hybrids/varieties from the private companies Cristiani Burkard (Guatemala), SEMINACA (Venezuela), Monsanto, and from the El Salvador national program (CENTA) are being evaluated.

Research Results

Regional trials were conducted for photoperiod insensitive varieities, and hybrids in the Domincan Republic, El Salvador and Nicaragua. The combined analysis indicated that the photoperiod insensitive variety ICSV-LM 89503 produced higher yield than the local check. The white grain, tan plant hybrids ATX 629 × 86EO361 and ATX 623 96CA635 were the highest yielding with over 7.4 Mg ha^{-1}. The PCCMCA hybrid trial was conducted at eight locations, with the cultivars CBX-8016-2 and CBX-8016-1 producing the highest average yield of over 6.4 Mg ha^{-1} with the local check cultivar having an average yield of 5.1 Mg ha^{-1} (Table 1).

Research in Nicaragua focused on evaluation of photoperiod-sensitive and insensitive varieties. The photoperiod-sensitive variety EIME 113 appears to be a promising with high yield (4.7 Mg ha^{-1}), desirable plant, panicle and grain properties. Other promising early generation lines were identified for further testing in 2002. An evaluation of 30 hybrids from El Salvador and 160 hybrids from Texas were evaluated, and based upon the performance of the 10 best hybrids identified the inbred lines ATX-623, ARG 34-A, ATX-629, 96CA635, BTX-635 and 98BRON-125 as promising for hybrid production for Nicaragua production conditions. Germplasm from Texas A & M University Drought Line Test (81 Advanced Lines) Midge Line Test (70 Advanced Lines), and Grain Weathering (Mold) Test (40 Advanced Lines) were evaluated for the second year, and useful material will be incorporated into the Nicaraguan breeding program.

In El Salvador, photoperiod-sensitive lines were evaluated in relay intercropping with maize, and photoperiod insensitive varieties and hybrids were evaluated. The photoperiod-sensitive varieties 85-SCP-805, ES-790, EIME-119, 86-EO-226, Pre-EIME-112 and Punta de Lanza were well suited to relay intercrop production with maize producing 4.3 to 5.9 Mg ha^{-1} yield without reducing maize yield, but Punta de Lanza was tall and susceptible to lodging. Three superior white grain, tan plant hybrids [ATX-623*86-EO-361, 8.1 Mg ha^{-1}; 34-A*86-EO-361, 7.2 Mg/ha; and ARG 34-A*96EON-328, 6.7 Mg ha^{-1}] were identified. The red grain hybrids produced lower yields than the white grain hybrids, but ARG 34-A*ICSR-LM 92502 and ATX-623*ACSR LM-92502 were promising with 6.4 Mg ha^{-1} yields. The photoperiod insensitive variety ICSV LM-90538 appeared very promising with a yield of 7.9 Mg

Table 1. Cultivar evaluation in the PCCMCA Regional trial, results averaged over eight locations in four countries.

Entry	Yield (Mg ha)	Height (cm)	Disease Rating (1 = excellent; 5 = poor)
CBX-8016-2	6.7 a	168	2.2
CBX-8016-1	6.6 ab	176	2.2
HIMECA 101	6.5 abc	166	2.7
MTC-1197	6.3 abcd	150	2.4
MTC-7439	6.2 abcd	162	2.6
D-66	6.1 abcd	154	2.5
MTC-7379	6.1 abcd	156	1.9
MTC-1177	6.1 abcd	164	2.3
CB-2006	6.0 abcd	151	2.6
MTC-7389	6.0 abcd	157	2.2
HIMECA 404	5.7 abcd	179	2.2
ESHG-2001	5.4 bcd	136	2.2
ESHB-2	5.2 cde	129	2.7
CB-8966 (TC)	5.2 cde	155	2.7
Local Check	5.1 e	182	2.0
ESHG-1	4.3 e	131	2.7
Mean	5.8	157	2.4
C.V. (%)	14	6	24

ha^{-1} which was 1.6 Mg ha^{-1} higher than the next best variety.

Considerable interest is present for pearl millet as a forage crop in El Salvador and Nicaragua, and as a potential grain crop in the driest production areas of Nicaragua. Twenty-four forage pearl millet cultivars from INTSORMIL Project ARS-204 were evaluated as a green chop forage source, and 10 of these cultivars produced good yields of high quality forage in this system.

Entomology and Plant Pathology Research

Research Methods

Farmer surveys and evaluation of the All Disease and Insect Nursery (ADIN) were used in El Salvador and Nicaragua in 2000 and 2001 to identify the pests more commonly occurring in grain sorghum fields to help guide future research. M.S. thesis research on sorghum midge was conducted in Nicaragua. This studied midge seasonal occurrence *(Stenodipolosis sorghicola)*, oviposition behavior on specific hosts and management strategies including planting date, sorghum variety and insecticide efficacy. In El Salvador, insecticide studies on fall armyworm were conducted.

Research Results

Producer surveys and evaluation of ADIN indicated that the most prevalent sorghum disease in Nicaragua was anthracnose and in El Salvador it was rust *(Puccinia* species), and the most prevalent insect pests were fall armyworm *(Spodoptera frugiperda*) and sorghum midge. INTSORMIL Project MSU-205 has conducted research on fall armyworm for over a decade and on sorghum midge during the past four years. Future research will emphasize collaborative, multidisciplinary, multiinstitutional, on-farm pest management tactics and strategies in collaboration with ANPROSOR, National Grain Sorghum Producers Association. Entomology research will continue to focus on fall armyworm and midge, while the pathology research will shift emphasis to anthracnose and rust.

In El Salvador, insecticide evaluations indicated that the chiten inhibitor insecticides Lufenuron and Teflubenzuron provided the best control of fall armyworm, with intermediate control with Lorsban, and low efficacy for several biological insecticides. Water volume had little effect on efficacy of Lorsban, while repeat applications increased control. Sorghum plants damaged during early growth were capable of compensation for fall armyworm damage, indicating that crop growth stage should be considered in making insecticide recommendations. Additional research is needed to define recommendations for fall armyworm control at different growth stages of sorghum.

Grain Utilization (Quality) Research

Research Methods

The Central America program has historically concentrated on improving the grain yield and processing characteristics of sorghum for use in tortillas and related products with research conducted at the Escuela Agricultura Panamericano (EAP) in Honduras. In recent years the research has broadened to include grain sorghum flour substitution in yeast and sweet breads in El Salvador. This research has included market surveys, and research on specific grain quality/food utilization issues usually with undergraduate students at EAP, or graduate students at Texas A & M University or the Instituto Tecnologico y de Estudios Superiores, Monterrey, Mexico.

Research Results

Research in El Salvador during the past 20 years has developed the technology for incorporating sorghum flour from white, food-grade sorghum cultivars for use in French and sweet bread for urban areas, and use of 100% sorghum flour for sweet bread, cold drinks (horchatas, refrescos), and hot drinks (atoles); and the use of popped sorghum (alboroto). During the past year the focus has been on technology transfer of this technology in urban areas. This included 22 training sessions with 124 members of the Asociacíon Salvadoreña de Panifacadores (ASPAN) in urban areas, who are substituting 5 to 10% sorghum flour in French bread and 25 to 40% sorghum flour in sweet breads. In addition, one private company who produces snack food (golosinas) is interested in using sorghum flour. There is need to develop "identity preserved" strategies to assure consistent flour quality, and to obtain equipment to decorticate sorghum and to mill the quality flour required. Strategies to address these issues and assist with micro-enterprise development will be a priority in the coming year.

Agronomy Research

Research Methods

Agronomic research was conducted in 2000 and 2001 to evaluate nitrogen use efficiency of grain sorghum photoperiod-sensitive and insensitive genotypes and to determine optimal nitrogen fertilizer rate recommendations. Four to six grain sorghum varieties were grown at sites in El Salvador and in Nicaragua with four nitrogen fertilizer rates. Flowering date, plant height, grain and stover yield, and grain and stover nitrogen concentration data were collected. Fertilizer and utilization nitrogen use efficiencies were calculated from these data.

Research Results

Only small differences in fertilizer and utilization nitrogen use efficiency was found among the photoperiod insensitive varieties tests, thus it was concluded that screening of a broad base of germplasm was required to identify high nitrogen use efficient genotypes. (UNL-213, Table 4). This research is being initiated in the coming year. The photoperiod-sensitive variety 85-SCP-805 produced high grain yield and grain nitrogen use efficiency, while ES-790 had very high fertilizer nitrogen use efficiency.

Nitrogen fertilizer application increased grain yield quadratically at each location with the highest nitrogen rate not maximizing grain yield. The impressive yield increases obtained from nitrogen application are being tested on-farm during the coming year.

Mutual Research Benefits

Many production constraints are similar between Central America and the U.S. including drought, diseases, and insects. U.S. based scientists can provide germplasm that could at least partially alleviate the effect of some of these constraints. The maicillo criollos are a unique type of grain sorghum and can potentially contribute useful food quality traits to U.S. germplasm, and several lines are presently in the Texas A&M University /USDA-ARS Sorghum Conversion Program. Germplasm exchange will contribute to development of novel genetic combinations with multiple stress resistance, wide adaptation, and improved food quality. Entomology and plant pathology research includes pests that affect grain sorghum both in Central America and in the U.S., such as sorghum midge and ergot.

Institution Building

Equipment and Other Support

INTSORMIL has provided pass-through funding and supplies for pathology laboratories in El Salvador and Nicaragua, notably repair of a Zeiss microscope at UNA resulting in a potential savings of $10,000. Books, reprints and other written materials were provided in several disciplines. A computer was provided to INTA, along with pollinating bags to plant breeding.

Training and Education

Mr. Javier Bueso (Honduras), Assistant Professor, EAP , is pursuing a Ph.D degree in the Grain Quality Lab at Texas A&M University. Johnson Zeledon (Nicaragua) is pursuing a Ph.D. degree at Mississippi State University with dissertation research on grain sorghum insect pest management in Nicaragua and the United States.

Drs. Claflin (KSU-210B) and Pitre (MSU-205) conducted a five-day sorghum plant protection workshop in Managua, Nicaragua, 10 - 14 June, 2002 for 36 agricultural professionals from Nicaragua and two from El Salvador. Short-term training for grain sorghum plant pathologist Yanet Gutierrez (UNA) was provided at Kansas State University, and for plant breeders René Clará and Hector Deras (CENTA) and Rafael Obando (INTA) at Texas A&M University.

Networking

Institutions/Organizations

Collaboration among CENTA, INTA and UNA have improved greatly during the past three years, and an increased number of countries participated in PCCMCA trials this year. In El Salvador, increased collaboration with the NGOs MAG/AVES, FUNDPROCOOP, PRODAP, and FUNDESYRAM primarily with validation testing of sorghum varieties to be released. In Nicaragua, increased collaboration with the CIAT Hillside Project at San Dionisio has been forged. National programs have strong linkages to private seed companies, and are developing closer ties with feed and food utilization companies. Noteworthy is the close working ties with the Asociacíon Salvadoreña de Panifacadores (ASPAN) in El Salvador. Improved networking with INTSORMIL universities and Instituto Tecnologico y de Estudios Superiores, Monterrey, Mexico is desired through graduate education and collaborative research efforts.

Travel

INTSORMIL sponsored the Central America Sorghum Research and Planning Conference, 27 - 28 February, 2002 with 40 participants.

Dr. Henry Pitre traveled to El Salvador and Nicaragua to direct graduate student research and assist with collaborative research. He was a presenter in the Sorghum Pest Management Work Shop, 10 - 14 June, 2002.

René Clará represented INTSORMIL at the PCCMCA meeting in the Dominican Republic in April, 2002. He represented the Central America Regional Program at the joint Technical Committee/Host Regional Coordinator Meeting in Lincoln, NE in April, 2002. He traveled to Nicaragua in June, 2002 to assist in coordinating research activities in Nicaragua and El Salvador.

Dr. Larry Claflin visited INTSORMIL scientists conducting collaborative research in El Salvador and Nicaragua in Dec., 2001 and February, 2002. He was a presenter in the Sorghum Pest Management Work Shop, 10 - 14 June, 2002.

Drs. Joe Hancock, Gary Peterson, Darrell Rosenow, Lloyd Rooney, Bill Rooney and Thomas Crawford participated in the Central America Sorghum Research and Planning Conference, 27 - 28 February, 2002.

Dr. Stephen Mason, Regional Coordinator, made trips to El Salvador and Nicaragua in Nov. 2001 and Feb. 2002.

Horn of Africa

Gebisa Ejeta
Purdue University

Program Coordinators

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Peter Esele, Uganda country Coordinator, Serere Agricultural and Animal Production Research Institute, Serere, P.O., Soroti, Uganda

Collaborative Program

INTSORMIL/Horn of Africa is an initiative to regionalize our collaborative research efforts in Eastern Africa. Before the start of the current regional effort, INTSORMIL had a productive collaborative program with the Agricultural Research Corporation (ARC) in Sudan. This collaboration has resulted in an array of technical developments that have impacted on sorghum agriculture in Sudan. Sudanese scientists have been trained in INTSORMIL institutions. U.S. scientists have traveled extensively in Sudan and worked alongside their Sudanese counterparts. Joint workshops and conferences were organized and attended. Results of joint research efforts have been published and distributed widely. Extensive raw and improved germplasm have been identified, assembled, and catalogued for the benefit of U.S. and Sudanese agriculture.

Under the Horn of Africa initiative, memoranda of agreements have been signed with NARS in Ethiopia, Eritrea, Kenya, and Uganda. With these MOA, INTSORMIL now has collaborative relationships with five countries in the Horn of Africa region. A two-tier program has been under development in the Horn of Africa. With each national program, we have initiated a traditional collaborative program between a NARS scientist and a U.S. principal investigator(s) on a topic of common concern and interest with at least one disciplinary project identified in each country. A scope of work is jointly developed and submitted for review and approval by the NARS country coordinator, NARS research director and the Horn of Africa program coordinator before becoming the INTSORMIL/Host Country workplan. Each workplan has its own funding. Funds are forwarded directly from Purdue University, and are then disbursed in-country to each collaborating scientist to carry out the research project. With limited funds available to the INTSORMIL/Horn of Africa, it has not been possible to initiate a full range of collaborative projects with each of the NARS in the region. Instead, the intent has been to establish a full complement of collaborative partnerships with the Institute of Agricultural Research in Ethiopia and to use this program as a hub from which to network with the other member countries of the Horn. A line item for networking has been built into the budget of the INTSORMIL/Horn of Africa program to catalyze exchange of information and ideas among member NARS and INTSORMIL scientists. A major initiative that has been under consideration is the identification of major regional constraints upon which considerable research may have been undertaken by one or more of the NARS in the region. There has been great interest among scientists in the region to identify such research projects and undertake regional evaluation and verification with the hope of generating technologies that could have regional application. We continue to have dialogue on the feasibility of implementing such a regional initiative. Once agreed upon, collaborative research projects among NARS in the region will be developed, in consultancy with appropriate INTSORMIL scientists, on a priority research agenda of regional importance. Inputs from concerned scientists in the region will be solicited in developing the research agenda as well as in refining the research protocol on a timely basis. Collaborative scientists will be encouraged to meet regularly (preferably once a year) to exchange ideas and to sharpen the focus of the regional research agenda.

Annual field/laboratory touring workshops will be organized alternately at a site in one of the host countries in the region. Participation in the tour will be based on interest and the topic of the workshop for that year. These tours will provide INTSORMIL PIs opportunities for interaction with many scientists in the region. Scientists from the region will also have an opportunity to pick up useful germplasm, research techniques, or potentially transferable technologies that they may come across during these tours.

Opportunities for collaboration with other organizations such as ASARECA, ICRISAT/East Africa, World Vision International, Sasakawa Global 2000, and the IPM CRSP have been good and there are initiatives under development with each of these organizations. Discussions have also been underway to determine possibilities of buy-ins from USAID Missions in the various countries in the Horn of Africa. A major agreement was developed between INTSORMIL, USAID/REDSO/East, and the Inter-Governmental Agency for Development (IGAD) with funds allocated through the Greater Horn of Africa Program. Through this initiative INTSORMIL spearheaded a study on availability and use of technologies that alleviate problems associated with dryland agriculture. This comprehensive study is expected to provide direction for future agricultural research and transfer of technologies for drought prone environments of the Horn of Africa.

Research Disciplines and Collaborators

Ethiopia

Agronomy – Kidane Georgis, EARO; Jerry Maranville, INTSORMIL.

Striga Management – Gebremedhin Woldewahid, EARO, Wondemu Bayu, MOA; Gebisa Ejeta, INTSORMIL.

Entomology – Tsedeke Abate, EARO; Henry Pitre, INTSORMIL.

Agricultural Economics -Yeshi Chiche, EARO; John Sanders, INTSORMIL.

Sorghum Utilization – Senait Yetneberk, Aberra Debelo, EARO; Lloyd Rooney, Bruce Hamaker and Gebisa Ejeta, INTSORMIL.

Research Extension – Beyene Seboka, Aberra Deressa, EARO; Gebisa Ejeta, INTSORMIL.

Pathology – Girma Tegegne, IAR; Larry Claflin, INTSORMIL.

Kenya

Sorghum Breeding – C. K. Kamau, KARI; Gebisa Ejeta, INTSORMIL.

Food Quality – Betty Bugusu, KARI; Bruce Hamaker, INTSORMIL.

Striga – C. Mburu, Kari; Gebisa Ejeta, INTSORMIL

Uganda

Sorghum and Millet Pathology – Peter Esele, NARO; Gebisa Ejeta, INTSORMIL.

Striga Management – Joseph Oryokot, NARO; Gebisa Ejeta, INTSORMIL.

Eritrea

Sorghum Breeding – Tesfamichael Abraha, DARE; Gebisa Ejeta, INTSORMIL, Eritrea – Neguse Abraha, DARHRD,

Entomology – Asmelash Woldai, DARE; Henry Pitre, INTSORMIL.

Striga Management – Asmelash Woldai, DARE; Gebisa Ejeta, INTSORMIL.

Sorghum/Millet Constraints Researched

Sorghum and millet are important crops in all of the countries in the Horn of Africa, ranking first or second in cultivated area among the major cereal crops of the region (Table 1). Sudan and Ethiopia are the indisputable centers of origin for sorghum and are major centers of genetic diversity for both crops. In addition, a wealth of improved sorghum and millet germplasm has been made available in both of these countries as a result of association with INTSORMIL and ICRISAT. Collaborative research between Sudan and INTSORMIL has also resulted in research and production technologies that can be shared by other members of the Horn of Africa.

According to the sorghum and millet scientists in the Horn of Africa region, "the major sorghum and millet pro-

Table 1. Sorghum and Millet Production.

	Sorghum			Millet		
Countries	Area 1000 ha	Yield Kg ha^{-1}	Production 1000 mts	Area 1000 ha	Yield Kg ha^{-1}	Production 1000 mts
Eritrea	60	842	51	15	546	8
Ethiopia	890	1236	100	280	1000	280
Kenya	120	745	90	85	682	58
Sudan	4684	785	2386	1150	192	221
Uganda	255	1498	382	407	1602	652

Table 2. Production constraints of sorghum and millet across eastern Africa countries.

	Eritrea	Ethiopia	Kenya	Sudan	Uganda
Varietal Development	X	X		X	X
Striga	X	X	X	X	X
Crop Protection					
Pest	X	X	X	X	X
Diseases	X	X	X	X	X
Drought	X	X	X	X	X
Production	X	X	X	X	X
Technology Transfer	X	X	X	X	X
Training – Long-term	X	X	X		X
- Short-term	X	X	X	X	X
Socio-economics				X	
Utilization	X	X	X		X
Information Exchange				X	X
Germplasm Introduction	X	X	X		X
Soil/Water Conservation	X		X		
Seed Production & Marketing	X	X	X	X	X

duction and utilization constraints are generally common to all countries (Table 2).

These constraints include lack of improved germplasm, drought, *Striga*, insects and diseases (anthracnose, leaf blight, grain molds, smuts, ergot in sorghum, blast, downy mildew, and ergot in pearl millet). Other problems in the region include lack of adoption of new production and utilization technologies by farmers, soil/water management techniques, as well as the infrastructure and technology for production and marketing of seeds and other essential inputs.

Agronomic research on soil and water conservation techniques has not been extensively evaluated in any of the countries in the region. Lack of moisture and soil nutrients and poor husbandry are primary constraints of sorghum and millet production. Breeding efforts currently in use to incorporate drought tolerance traits to genotypes with high yield potential are limited by lack of a field screening procedure and lack of knowledge of sources of appropriate germplasm with useful traits. The lack of absolute definition of good food quality parameters and good screening methods for food quality to some extent also limit the utilization of high yielding sorghum and millet varieties. Very little research has also gone in developing germplasm with resistance to the major insect pests and diseases. *Striga*, a major parasitic weed of sorghum and millet, constitutes a major constraint to the production of these crops. There is very little sorghum and millet germplasm with resistance to *Striga* and the mechanisms that render resistance to *Striga* are not well understood. Knowledge about inheritance of many of these traits is also lacking. In many of these areas, the crop/bush fallow system of production has traditionally been used to provide enough nutrients and possibly some moisture for a period of crop years (5-10 years fallow/2-4 years cropping). In some areas, other crops are often grown in an intercropping system with millet and sorghum to maximize production. Over the last 2-3 decades, rainfall in the Horn of Africa region has declined, thus reducing the soil recovery rate during fallow. Fallow periods have also decreased due to higher human and animal pressure on plant cover, resulting in further reduction of sorghum and millet yields in the region. Research on all of these aspects is needed to improve sorghum and millet production and utilization in the Horn of Africa.

Research Progress

Ethiopia

Breeding Sorghum hybrids
(Zenbaba Gutema)

The superior performance of hybrid sorghums under stress environments, demonstrated by several sorghum worker, led to the initiation of a modest sorghum hybrid program in Ethiopia. Over the last 20 years several hundred hybrids have been developed and evaluated for their yield potential across moisture stressed lowland sites. Some of these hybrids were uniquely adapted to many of the lowland, moisture stress environments of the country combining early maturity with very high grain yields. Unfortunately, however, seeds and records of these hybrids and their parental material were lost during the political unrest in the country in 1991.

The fact that these experimental hybrids demonstrated stable performance across environmental extremes as compared to recommended open-pollinated varieties, encouraged us to restart this work in order to increase and stabilize food production in the more hostile environments. Further, experience in other African countries, though limited, offers great promise for continuing hybrid sorghum research in our local environments in Ethiopia. Our sorghum hybrid development activities received a great boost with the establishment of a collaborative research with INTSORMIL. Highlights of these activities are briefly presented below.

Evaluation of A, B and R Lines and
Experimental Hybrids

In collaboration with Purdue University we have been evaluating a number of A, B and R lines. In addition several test crosses and experimental hybrids have been evaluated.

The total numbers of such introductions and selections are indicated in Table 3. Each year a number of crosses are made at our off-season station, Melka-Werer. The hybrids are evaluated at various stages at Melkassa; Miesso and Kobo research stations, which are, located dry lowland areas. Hybrids that showed good agronomic performance over the standard check with higher yields are subjected to yield trials in the areas as much as we can cover. Yield, grain quality, panicle exertion, drought tolerance and lodging resistance are the most important characteristics in selecting the hybrids. Tables 4 and 5 present hybrids developed by the program in collaboration with Purdue University. In these tables we can see that most of these hybrids performed better under dry conditions of Ethiopia as compared to the standard open-pollinated varieties. Experimental hybrids also flowered earlier than the open pollinated cultivars used as checks.

In addition to *Striga* nurseries, A, B and R lines and experimental hybrids several genotypes with important traits such as *Striga* resistance, drought tolerance and lodging resistance also have been introduced and evaluated. Again numbers of introductions and selections are given in Table 3.

Eritrea

Millet Breeding
(Negusse Abraha)

Pearl millet (*Pennistum glaucum*) is grown mainly for grain in the tropical and sub-tropical areas of Africa and in the Indian sub-continent. It is an indispensable food for millions inhabiting the semi-arid and arid tropics and is more important in the diet of the poor. In Africa, 70% of the pearl millet produced is grown in western Africa. In Eritrea, pearl millet is grown on total area of over 45,000 hectares and is second in importance among the cereals following sorghum. It is widely used as a grain crop in western and eastern lowlands of the country whereas its use as forage is limited. Under the situation of subsistence farming that exists in pearl millet producing areas of Africa, including Eritrea, grain yields are limited by the poor inherent soil fertility and water holding capacity of the soil and traditional management practices, including limited use of fertilizers and tillage. Further, limitations are imposed by drought, disease (downy mildew), insect pests and low genetic yield potential of traditional landraces .

Research activities on pearl millet have been carried out in Shambiko Research Station. Primary introduction of germplasm for evaluation in Eritrea has been obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Screening of these introductions in subsequent years has led to the release of two cultivars as best varieties (ICMV 221, ICMV 91450) for wide distribution. In the year 1999, ICMV 221 was multiplied and distributed in Zoba Gash Barka and in the year 2000, it was distributed in Zoba Anseba. However, the climate and soil condition of Shambiko Research Station was not a typical pearl millet growing area. Therefore, it was recommended to start research activities in Zoba Anseba , Sub-Zoba Hagaz in new research site. Hagaz Research Station is located at an altitude of 850m above sea level. with minimum and maximum temperatures of 15 c and 45 c respectively. The average rainfall ranges from 300 – 400 mm/annum. The new site has a typical arid and semi-arid climatic conditions which is conducive for pearl millet research work.

At Hagaz, research activities started in 2000 as an off-season program. Germplasm for this program was mainly from the local gene bank (DARHRD) and from the breeding program at ICRISAT. Crossing was done between five selected landraces and five introduced materials. In addition, selfing was done on the best landraces. The result of this activity was continued in the rainy-season of 2000. This section discusses on the breeding activities done during off-season and rainy-season of year 2000.

Experimental material that included 10 local landraces and one released variety as a check was evaluated using a randomized complete block design with three replications.. They were planted with spacing of 4m x 0.75m x 4 rows. Observations were recorded on the central 2 rows of each plots for the following characters:

Table 3. Germplasm introductions from Purdue University and evaluated in Ethiopia from 1996 to 1999.

Types of introduction	1996		1997		1998		1999		Total	
	Intro. *	Adva**	Intro.	Adva.	Intro.	Adva.	Intro.	Adva.	Intro.	Adva.
A & B lines	40	5	158	11	-	-	9	9	207	25
R-lines	-	-	-	-	-	-	223	20	223	20
Test crosses	164	28	-	-	-	-	-	-	164	28
Experimental hybrids	-	-	-	-	54	30	419	218	473	248
Lines with various genetic merits	-	-	400	42	-	-	-	-	400	42
Lowland drought escape materials	-	-	-	-	79	27	-	-	79	27
High potential lines	-	-	-	-	-	-	25	4	25	4
Total	204	33	558	53	133	57	676	247	1571	390

* Introduced
**Advanced

Table 4. Mean grain yield (Q/ha), days to 50% flowering and plant height (cm) of 12 varieties included in Elite Sorghum Hybrid Trial One (ESHT-1) at Melkassa (MS) and Mieso (MI) in 2000 cropping season.

		Grain yield			Days to flowering			Plant height	
Entry #	Identification mean	MS	MI	Mean	MS	MI	Mean	MS	MI
8	P-9518A × 90MW 534456	43	50	67	66	67	190	185	188
6	P-9513A × MR-747*180	52	42	47	69	68	69	180	179
2	M-90950A × MR-747*187	43	50	47	74	71	73	168	205
9	P-9518A × KCTENT #17 DTN 184	49	42	46	68	67	68	185	183
5	P-9513A × 90MW5344 190	45	45	45	68	68	68	186	193
7	P-9518A × 91MK 7013 176	45	37	41	67	66	67	170	182
4	P-9513A × MR-747 167	45	32	39	70	70	70	160	173
1	M-90950A × 91MK 7013*179	38	36	37	74	75	75	166	192
3	P-9513A × P-89006 166	42	29	36	72	69	71	164	167
10	M-90950A × P-46-1 134	32	33	33	67	67	67	116	151
11	Meko 158	31	32	32	66	64	65	160	156
12	Local check 216	21	35	28	86	90	88	188	244
	Mean	42	38		71	70		169	183
	CV%	17	14		3	3		7	7
	LSD (0.05)	10	7		3	3		16	18

* Non-Purdue female parents

Table 5. Mean grain yield (Q/ha), days to 50% flowering and plant height (cm) of 14 varieties included in Elite Sorghum Hybrid Trial Two (ESHT-2) at Melkassa (MS) and Mieso (MI) in 2000 cropping season.

		Grain yield			Days to flowering			Plant height	
Entry #	Identification mean	MS	MI	Mean	MS	MI	Mean	MS	MI
1	P-9501A × ICSR-14 162	60	46	53	65	68	67	174	147
7	P-9534A × KCTENT #17 DTN 171	61	44	53	71	70	71	181	160
2	P-9501A × ICSR-16 164	63	40	52	69	70	70	174	153
5	P-9534A × ICSR-16 168	65	39	52	68	71	70	173	162
8	ICSA-34 × ICSR-14*159	61	40	51	70	70	70	166	152
10	ICSA-34 × ICSR-10*153	50	38	44	68	70	69	156	149
9	ICSA-34 × ICSR-16*150	51	37	44	68	70	69	155	145
6	P-9534a × 82(PLYT-2#5) × 81ESIP 46 161	55	31	43	69	71	70	173	149
3	P-9501A × PGRC/E #222880 182	69	17	43	67	77	72	196	167
14	Local Check 205	47	29	38	86	90	88	215	194
12	ICSA-10 × SK-82-022*176	51	22	37	69	72	71	189	162
4	P-9534A × ICSV-89106 168	42	26	34	73	73	73	179	156
13	Meko 148	34	33	34	66	67	67	166	129
11	ICSA-34 × MR-747 140	38	28	33	72	68	70	138	142
	Mean	53	34		70	72		174	15
	CV%	16	18		2	4		9	15
	LSD (0.05)	12	9		2	4		23	32

* Non-Purdue female parents

days to 75% flowering, plant height, plant count, head count, panicle count, panicle yield and grain yield. To maintain soil fertility, 100 kg ha^{-2} DAP before planting and 100 kg ha^{-2} urea 3 weeks after planting were applied. Thinning and transplanting were done 2 weeks after planting. During the growing period of the crop, 260 mm was recorded and 6 times was supplemented by irrigation. It was cultivated once and hand weeded twice.

The analysis of variance for plant height showed highly significant difference ($P < 0.001$) for days to 75% flowering indicating that plants did not reach 75% flowering date at the same time. In addition, there was significant difference ($P = 0.047$) for plant height. However, there was no significant difference ($P = 0.291$) for the character grain yield showing that there was no significant difference between the landraces for grain yield.

Mean comparison among the ten land races were made (Table 6). When days to 75% flowering was considered, the earliest variety was ICMV 221 (check) and the latest was Bultug Keren. This landrace got acceptable range of grain yield and high levels of downy mildew susceptibility that will require the introgression of resistance from introduced sources. When the grain yield, agronomic score and downy mildew % is considered, Tosho and Zibedi performed better than others and they attain grain yield of 19% and 4% above the mean grain yield respectively. Though there is significant difference between the land races for plant height, all have acceptable range of plant height except one landrace, Gudamay which is short (152 cm). Tokroray, a bristle landrace got the least grain yield and became the most susceptible to downy mildew disease, probably this requires improvement by crossing with resistance and high yielding exotic variety.

Table 6. Preliminary Result of Landrace Millet Varieties Evaluated in Eritrea.

S.N.	Landraces	Flower Day (75%)	Plant ht	Grain yld T/ha	Downy mildew (%)	Agro.score Rank
1	Bultug mebred	49	179	4.33	31.3	1
2	Bultug keren	57	212	5.42	29.4	2
3	Gudmay	48	152	3.74	24.8	4
aspalpha4	Shileti	49	185	3.97	41.7	5
5	Tokroray	49	189	2.88	47.7	1
6	Tosho	47	169	4.84	21.3	2
7	Zibedi	47	174	4.20	14.0	3
8	Kunama berta	49	182	3.64	14.7	4
9	Bicha kunama	49	164	3.75	35.6	3
10	Bultug barka	53	171	3.90	28.2	5
11	ICMV 221	45	172	3.87	1.9	1+
	Mean	49	177	4.05		
	CV %	2.0	8.2	1.97		
	S.e.	1.11	14.5	0.88		
	LSD	2.6	29.2	1.61		
	F- value	***	*	NS		

In addition to the landraces, 52 exotic varieties with three local checks were also evaluated. The experimental design used was RCBD with three replications. The spacing was 4m x 0.75m x 4 rows. Observation was done on two central rows. Traits were considered were days to 75% flowering, plant height, plant count, head count, head yield, and grain yield. Fertility was maintained by adding 100 kg ha^{-2} DAP at the time of planting and 100 kg ha^{-2} urea after three weeks. Thinning and transplanting were also done three weeks after planting. The field was cultivated once and hand weeded twice. During the growing period of the crop, 161.6 mm of rainfall was recorded and it was supplemented seven times by irrigation.

In the analysis of variance for grain yield, there was highly significant ($P < 0.001$) difference between the varieties showing that there is varietal difference in performance. Moreover, there is highly significant ($P < 0.001$) difference for the traits of days to 75% flowering and plant height. This indicated that there is genotype variation in flowering time and attained different plant heights.

The main objective of this trial was to select some promising varieties for future breeding work. Among the 52 experimental varieties, 15 were selected for advanced yield trail (Table 7). Within these varieties, there is no significant difference (3.60 – 4.56 t) for grain yield when they are compared using LSD (1.19) and all have good resistance to downy mildew disease. The plant height attained is at acceptable range (151 – 215 cm) and days to 75% flowering can also be said early for all the 15 varieties (38 – 46 days).

Kenya

Sorghum Breeding
(C.K. Kamau and C. Mburu)

Sorghum (Sorghum bicolor) is an important crop in the semi-arid areas of Kenya. The Sorghum and Millet Program was initiated to increase food security and reduce poverty. To come up with new varieties of Sorghum, yield testing of elite material is conducted in Preliminary Yield Trial, Advanced Yield Trial (AYT), Sorghum National Performance Trial (SNPT) and Sorghum Malt Quality Yield Trial (MQSYT). The elite material are from diverse sources but mainly the Kenya Agricultural Research Institute's (KARI), sorghum breeding program at National Dryland Farming Research Center (NDFRC), Katumani and International Crops Research Institute for Semi Arid Tropics, (ICRISAT) and International Sorghums and Millets (INTSORMI) group of universities. Program activities are targeted at the semi-arid areas where sorghum has a comparative advantage over other cereals. Other researches aimed at enhancing the position of sorghum in the national economy are also conducted.

During the long 2000 and short rains 2000-2001 several experimental trials were undertaken in the KARI/INTSORMIL Sorghum and Millet Collaborative Program: -

The trials comprised of 31 sorghum selection replicated two times in randomized complete block design. Plot size was 3 rows 4 meters long planted at 75 cm apart. Seeds were drilled in the row and thinned to a spacing of 20 cm between plants. The middle one rows was harvested for analysis and evaluation. Selections were assessed for grain yield, stand count, Days to 50% flower, head exertion and plant height.

Based on yield at Katumani eight of the selections were dropped and the seven top yielders were promoted to Advanced Yield Trial (AYT) the rest of the selections were retained in this stage for further testing.

In this yield trial 21 entries were tested in a Completely Randomized Block Design (CRBD) with three replicates during the short rains 2000. Plot size was 3 rows 4 meters long planted at 75 cm apart. Seeds were drilled in the row and thinned to a spacing of 20 cm between plants. The middle one row was harvested for analysis and evaluation. Entries were assessed for grain yield, days to 50% flower and plant height. The results of the top nine performers are shown.

Table 7. Preliminary Result of Exotic Pearl Millet Varieties Evaluated in Eritrea.

S.N.	Variety	Days to flowering (75%)	Plant ht	Grain yield (t/ha)
1	ICMP 89410	42	177	3.92
2	ICMP 93508	45	179	4.17
3	ICMP 95490	41	175	4.56
4	ICMP 97774	41	175	3.75
5	ICMP 98107	42	163	4.11
6	EERC CO	38	160	3.16
7	ICMR 312	42	156	3.99
8	IAC ISC YCP1	43	190	4.22
9	IAC ISC TCP3	40	157	3.84
10	IAC ISC TCP4	44	176	3.85
11	IAC ISC TCP6	46	182	3.72
12	IPC MBJ TCP CO	44	151	3.60
13	POLCOL TCP1	44	164	4.11
14	AfPop 88	46	215	4.13
15	SenPop 88	42	183	3.98
Zibedi (check)		43	165	2.69
B/Keren (check)		47	165	2.69
ICMV 221 (check)		38	149	3.47
Mean		42	162	3.30
CV%		1.1	0.8	0.72
S.e.		0.45	1.23	0.24
LSD		1.62	19.90	1.19
F-value		***	***	***

In the 2000 long and short rain seasons, sorghum yield trials were conducted at Katumani. The trials comprised of 16 varieties replicated four times in randomized complete block design. Plot size was 4 rows 4 meters long planted at 75 cm apart. Seeds were drilled in the row and thinned to a spacing of 20 cm between plants. Only the middle two rows were harvested for analysis and evaluation. Entries were assessed for grain yield, stand count, days to 50% flower head exertion and plant height. The effects of the seasons were also assessed. Data was analyzed by analysis of variance (ANOVA) using General Linear Models (GLM) procedure of SAS (SAS Institute, 1994) and means were separated using Least Significant Differences (LSD).

The two seasons (2000 LR and 200SR) were significantly different in respect of stand (stand establishment) days to flower (maturity), Exertion, plant height, and Grain yield ($p<0.01$). The short rain season was much better than the long rain season.

The varieties were different in stand count, exertion, plant height ($P<0.01$) but not in days to flower and grain yield. The C.V. were generally high, this could be explained by the fact that the seasons were extremes, one very wet and the other very dry. Of the sixteen varieties tested 8 entries performed better than the check variety. There was significant site by entry interaction for stand, exertion, plant height but grain yield and day to flower. The results are shown below.

In another trial 9 varieties introduced for high malting quality were tested for yield beside traits like stand establishment, day to flower (earliness) head exertion and plant height. There were significant differences between season in stand establishment, day to flower exertion plant height and grain yield ($p<0.001$). The short rain season was much better than the long rains season. The results are shown in table 4.

The varieties were different in stand establishment; exertion, plant height and grain yield but not in days to flower. There was significant season by variety interaction stand, head exertion plant height and grain yield but not for day to flower.

Elite lines/Breeders Seed Increase

In this activity Breeders Seed was produced for KARI-Mtama-I, ICSV III, IS76, Serena and Seredo.

In the same activity seed was increased for elite lines in NPT, AYT, PYT and malt quality sorghum trial to back up on-farm research and other activities of the breeding program.

The aim of this activity is to sensitize visitor on the progress of the Sorghum and Millet Program. Varieties about to enter on-farm testing were demonstrated.

In this activity a chief baraza was convene to talk about dryland crops farming in Kimutwa Machakos prior to on-set of rains 2000 short rains season. At the end farmers interested in growing sorghum were asked to volunteer. 31 farmers who volunteer were each given 2kg of KARI-Mtama-1, ICSV 111 or Seredo sorghum varieties. They were trained on necessary management to achieve the highest yields possible.

The season has been very successful. The farmers' response has been that they will certainly grow sorghum in coming seasons. Harvest of threshed grain on farmers' field range from 107 to 430 kg. Land planted on the variety is variable depending farmer efficiency in use of the seed and management.

A *Striga* resistance sorghum nursery trial comprising of twenty-five introductions from Purdue University (U.S.)

were tested in Alupe sub-center, of the Regional Research Center Kakamega in the Lake Victoria region of Kenya. The *Striga* resistance nursery was planted, during the 1999 short rains and 2000 long rains season. Farmers' local variety was included as a check. The trial was planted in RCBD with 4 replications. Each entry was planted in 3 row plots, each row being 5 m long. Plant and row spacing were 15 cm and 75 cm respectively. The recommended fertilizer rate in the region (20 kg N and 20 kg P2 05 per hectare) was applied. Weeding was done twice before the emergence of *Striga* weed. Thereafter, other weeds were hand-pulled leaving only *Striga*.

Data collected include days to flowering, plant height, yield, and *Striga* count among others. Harvesting was done at physiological maturity, and seed kept for planting during the succeeding seasons. The seasons were significantly different in *Striga* count, day to flower, plant height, midge damage and yield P<0.01 but not for stand count. The results are shown in Table 8.

Entries had significant differences in stand per plot, days to flower (DFLW), midge damage (score), *Striga* count (*Striga*), plant height (plant ht (cm), and grain yield (t/ha) (P <0.01). There was significant entry (variety) by season interaction for grain yield only. The results are tabulated in Table 9.

Institution Building

Field supplies, laboratory materials and two computers were purchased for the Eritrea program. This past year, sor-

Table 8. Mean Seasonal Performance of 26 Sorghum Varieties in the *Striga* Resistance Sorghum Nursery During Short Rains 1999 and Long Rains 2000 Seasons.

	Trait					
Seasons	Stand	DFLW	Midge	Striga	Plant ht (cm)	Yield (t/ha)
Short Rains 1999	72.7	63.5	3.4	24.5	126.1	2.3
Long Rains 2000	69.5	70.3	5.9	49.4	115.8	1.1
Mean	71.1	66.9	4.6	36.9	120.9	1.7
LSD (0.05)	3.6	2.4	0.3	12.8	4.1	0.2
SD	14.8	10.5	1.9	59.7	18.3	1.4

Table 9. Mean Performance of 26 Sorghum Varieties in the *Striga* Resistance Sorghum During Short Rains 1999 and Long Rains 2000 Seasons.

	Trait					
Entry	Stand	Dflw	Midge	Striga	Plant ht(cm)	Yield(t/ha
8551	62.4	71.4	4.8	18.6	106.1	1.3
8552	72.8	64.1	4.8	23.5	108.2	0.8
8553	69.8	72.5	5.3	18.9	119.8	0.9
8554	62.3	73.6	4.9	20.8	128.8	1.7
8555	72.4	74.0	4.3	8.5	117.4	1.3
8556	77.7	72.9	4.5	36.5	122.0	2.1
8557	71.8	60.8	4.3	16.9	131.0	2.1
8558	60.4	63.1	5.4	29.6	98.8	1.3
8559	70.8	61.9	5.4	11.0	121.5	1.4
8560	72.9	62.6	4.3	44.0	129.6	2.2
8563	65.8	71.8	4.8	47.0	125.0	1.7
8564	78.3	67.1	4.1	15.4	119.0	2.1
8565	73.3	61.8	5.1	23.2	119.6	1.5
8566	65.4	65.6	5.1	17.1	124.0	1.3
8568	75.1	61.9	5.4	3.6	123.3	1.3
8571	73.0	59.4	4.8	19.1	123.0	1.8
8572	79.5	69.4	3.9	129.0	108.4	1.5
8573	43.1	77.1	5.3	133.4	111.8	1.1
8574	72.3	69.5	4.5	18.6	128.1	1.8
8575	76.8	67.8	4.1	87.3	135.3	4.2
8576	78.9	70.6	5.1	35.6	112.8	1.2
8577	71.8	66.9	5.8	43.0	133.5	1.0
8578	79.0	58.3	2.8	59.5	131.8	4.2
8579	64.5	71.1	4.8	9.3	105.8	1.1
8580	76.6	57.8	5.0	15.0	114.0	0.8
8581	82.1	66.5	2.6	77.3	145.5	3.4
Mean	71.1	66.9	4.6	37.7	120.9	1.7
LSD (0.05)	12.9	8.6	1.2	46.3	14.7	0.7
SD	14.9	10.5	1.9	59.7	18.3	1.4

ghum pollinating bags and an Almaco low-profile thresher (Model LPR-UMB-D) were shipped to Ethiopia.

15 – 19 July 2001 – Dr. Aberra Deressa, EARO/Nazret Research Director, and Dr. Hamis Saadan, Senior Agricultural Research Officer, Ministry of Agriculture/Tanzania, visited Purdue University to discuss current research in Ethiopia and discuss the feasibility of a new collaborative research program in Tanzania.

This travel was supported by the HOA program in conjunction with their participation in the Global Consortium of Higher Education and Research for Agriculture (GCHERA) held in San Francisco from 12 to 14 July 2001.

9 - 22 December 2001 – Dr. Ejeta traveled to Ethiopia to initiate a new sorghum project with EARO as well as work with the research group involved in INTSORMIL activities. He also worked with the EARO Committee which is assisting the Management Entity in organizing the All-PI meetings.

10 – 31 May 2002 - Dr. Gebisa Ejeta traveled to Ethiopia to help set up and facilitate organization of the research to be conducted by Luke Snyder, graduate student, in the implementation of a pilot project on integrated *Striga* management that includes water conservation, Nitrogen fertilization, and *Striga* resistant varieties.

During that time, he also traveled to Tanzania to meet with Dr. Saadan and Ministry of Agriculture staff regarding collaborative research. Negotiations are pending until the MOU is signed by the Ministry.

Southern Africa (Botswana, Namibia, South Africa, Zambia, Zimbabwe)

Gary C. Peterson
Texas A&M University

Coordinators

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Collaborative Program

Organization, Management, Implementation and Financial Inputs

The INTSORMIL Southern Africa regional program involves six projects:

Pearl Millet Breeding: Development of pearl millet cultivars for dryland production, commercialization and industrial development in Southern Africa

Pathology: Disease management research, identification and use of resistance

Food quality: Food Quality

Pests: Genetic resistance to sugarcane aphid and integrated pest management in Botswana and South Africa

Production and Marketing: Identification of factors necessary to promote commercial sorghum production and processing in Botswana

Sorghum Breeding: Development of improved sorghum varieties and hybrids for Southern Africa

Through a Memoradum of Agreement with SADC/ICRISAT/SMIP the regional program is fully integrated with regionally planned sorghum and pearl millet research. This allows INTSORMIL funds to be disbursed to 15 collaborating NARS scientists in 5 countries. The scientists represent 9 research agencies. The SMINET regional coordinator at the ICRISAT SMIP Center at Matopos, Zimbabwe is also involved. Due to INTSORMIL's previous management of a major post graduate training program for the Southern Africa region (25 Ph.Ds and 50 MS's from 9 countries completed their degrees), many of the collaborating scientists in Southern Africa are INTSORMIL trained and had INTSORMIL PI's as their major advisors. Activities in each project are planned annually in conjunction with NARS collaborators and the Work Plans are reviewed at the SMIP Technololgy Transfer Program (SMINET) Steering Committee Meeting to ensure they continue to fit in the profile of work needed for development of sorghum and pearl millet production in the region.

Collaboration with Other Organizations

Research on pearl millet and sorghum breeding is organized with NARS scientists in collaboration with SMINET at Matopos, Zimbabwe to ensure complementarity with existing regional sorghum and pearl millet programs. Pearl millet breeding is conducted with the Ministry of Agriculture, Water and Rural Development, Tsumeb, Namibia; the Ministry of Agriculture, Botswana; and the Ministry of Agriculture, Kaoma Research Station, Kaoma, Zambia. Sorghum breeding is conducted with the Botswana College of Agriculture and the Ministry of Agriculture, Golden Valley Research Trust, Zambia. Grain quality research is with the University of Pretoria, CSIR (South Africa (SA)), and the Agriculture Research Corporation (ARC), SA. The CSIR has strong interactions with the private sector in the region which will assist in transfer of information to help private entrepreneurs. Entomology research is with the ARC Summer Grains Crop Institute, Potchefstroom, SA and the Dep. of Agricultural Research, Gaborone, Botswana. Plant pathology and ergot research is with the ARC Summer Grain Crops Institute, Potchefstroom, SA; Crops and Soil Research, Mt. Makulu Research Station, Chilanga, Zambia; Department of Agricultural Research, Gaborone, Botswana; the Plant Protection Research Institute, Harare, Zimbabwe; and the Medical Research Council, Tygerberg, SA. Marketing research is with the Botswana College of Agriculture.

The Planning Process

Research projects in breeding, pathology, entomology, and food quality are based on on-going linkages. Production and marketing research was based on availability of regional expertise. The future program will be shaped by priorities decided by SADC/NARS (SADC = Southern Africa Development Community) and the availability of matching INTSORMIL scientists and funds. INTSORMIL activity will continue to be developed as part of SMINET to ensure full integration with other regional sorghum and pearl millet research and development projects. Phase IV (initiated October, 1999) of the SMIP program to ICRISAT/Matopos focuses entirely on technology transfer. Since ICRISAT has no core funded scientists in the SADC region, INTSORMIL's participation in regional crops research is regarded as essential by SMINET and collaborating countries.

Sorghum and Pearl Millet Constraints Researched

Production and Utilization Constraints

Sorghum and pearl millet are major food crops in the SADC region, and sorghum is used to make opaque beer. Sorghum is the major cereal in Botswana and parts of Zambia, Mozambique, Malawi, and Tanzania, while pearl millet is the major cereal in Namibia and parts of Tanzania, Mozambique, Zambia, and Zimbabwe. Many constraints associated with low resource agriculture are present including low grain yield potential, infertile soils, variable moisture availability, numerous insect pests and diseases, and poor market structures. Genetic improvement and better disease or insect management can economically address some constraints by increasing grain yield potential and stress resistance, and by improving grain quality to meet end-use requirements. However, market channels need to be improved since sorghum varieties with the required quality to meet commercial consumer requirements frequently have inconsistent production. Availability of a consistent supply of improved quality sorghum and pearl millet for processing into value added urban products is a major problem limiting utilization. Food companies will use but cannot consistently acquire sufficient quantities of high quality sorghums for processing. A strong need exists for developing a system of identity preservation for production, marketing, and processing.

New varieties and hybrids with increased grain yield potential, drought tolerance, and other desirable traits are in development by national programs. Exotic sorghums and pearl millets are continually introduced into the SADC region. It is imperative that improved cultivars have resistance to major endemic disease pathogens and pests, excellent environmental adaptation, and improved end-use traits. Identification of regionally adapted sorghum or pearl millet cultivars or hybrids with stable grain yield and multiple stress resistance will assist the NARS teams in developing lines, varieties, and hybrids for the diverse environments and production systems in each country and in similar SADC environments.

Constraints Addressed by Project Objectives

Pearl Millet Breeding: Develop top cross grain and forage hybrids adapted to low rainfall regimes in Southern Africa suitable for commercialization and stimulating industrial development, test prototype cultivars in commercial and industrial ventures, develop appropriate populations for sustaining the program.

Pathology: Identify adapted, agronomically desirable sources of resistance to major foliar pathogens and charcoal rot, including drought tolerance and resistance to sugarcane aphid where feasible. Identify viruses occurring on sorghum in Botswana and Zambia, determine vulnerability in recently released sorghums and the need for better sources of resistance. Integrate resistant cultivars from various nurseries into a SADC regional nursery. Determine mycotoxin production capabilities of new *Fusarium* species, and the presence of *Fusarium* mycotoxins in grain-molded grain.

Food Quality: Determine the physical, chemical and processing properties of local and improved sorghum and millets. Improve the quality of food products by modification of processes to reduce or eliminate anti-nutritional components. Summarize existing information on quality and utilization and transfer the information on utilization quality to potential users.

Insects: Reduce yield losses by identifying, evaluating, and incorporating sugarcane aphid resistance into sorghum varieties and hybrids adapted to Southern African agricultural systems. Develop integrated pest management strategies for sorghum insect pests in Southern Africa.

Production and Marketing: Through structural village surveys and country-wide equilibrium analysis, identify alternative feasible sources of supply for sustainable sorghum processing in Botswana and their distributional economic welfare impacts.

Sorghum Breeding: Develop high grain yield sorghum varieties and hybrids with improved quality traits for food, forage and feed and adaptation to drought prone areas in Botswana, Zambia and Zimbabwe. Enhance disease and pest resistance with improved germplasm or elite lines. Assist with seed production and distribution systems at a community level

Research Progress

Pearl Millet Breeding

Zambia

Research centered on three major areas 1)Male-parent heterosis, 2)Female (Donor-parent) Effect, and Germplasm exchange. For male-parent heterosis, - the on-going backcrossing program (currently testing the second backcross and developing the third backcross) continued. The were 45 BC_2's evaluated and generally there was: 1)declining male-parent heterosis for grain yield (only 8 BCs show heterosis); 2)uniformity in flowering (61-66 days) for backcrosses regardless on donor or recurrent parent influence; 3)variability for traits such as tillering (1.90-3.90 tillers/plant), head length (28-45cm), and threshing percentage (56-85%).

For female (donor-parent) effect, trait expression varied with the parent. Generally, backcrosses derived from 863 B-P_3, IP 18293 and Tift 23DB-P_1 were better for grain yield. Backcrosses derived from on Tift DB-P_1, 841B-P3 and IP 18293 expressed excellent tillering. Good head-length was obtained in backcrosses derived from 841B-P3, PT732 B-P_1 and ICMP 85410-P_7. Specific backcrosses excellent for certain traits were identified: Tift DB-P_1 x NEC for grain yield; 841B-P3 x NEC for tillering; IP 18293 × ZPMBC for early flowering; 97C 77229 x ZPMV 92008 and ICMP 85410-p7 x NLC for head length; and 863B-P_3 x NLoC for threshing percentage.

Collaboration was established with ARS-204 to test genotypes in Zambia. A 30-entry trial that included genotypes from ARS-204, University of Nebraska, West Africa, SADC-SMIP, and Zambia was assembled and planted at Longe (medium rainfall), and Lusitu (low and erratic rainfall). The test at Lusitu failed due to drought. At Longe, the experimental hybrids, WA-26 and WA-23, were significantly superior to all checks except Kuomboka. Seed stocks of lines obtained from ARS-204 and the University of Nebraska were increased.

Botswana

The current drought showed the superiority of pearl millet over other crops. Twenty-five new hybrids were evaluated in a 5x5 lattice design. Nine hybrids with good agronomic traits and grain yield were identified for continued testing. Most of the hybrids were in the early (based on days to 50% anthesis) maturity class. The hybrids are also medium height 1.7m and less susceptible to lodging. Taller, later maturing hybrids were discarded.

Sorghum breeding

Zambia

The overall goal of the breeding program is to develop alternative cereal crops for drought prone areas deficit in food. Increased sorghum production and use is expected to provide household food security and increased income for the subsistence farming sector. Specific objectives are: 1)Develop high yielding varieties and hybrids suitable for food, feed, brewing for the different agro-ecological regions with good general resistance to all economically important diseases and pests; 2)Develop appropriate agronomic management practices for each agro-ecological region and farming system, and to work as a catalyst in the transfer of technology. In order to meet this objective the team is closely working with developmental teams within the research branch and various provincial units and other extension agencies including NGO's; 3)Maintain pre-basic and basic seeds of all released and pre-released varieties, hybrids and their parents; 4)Identify various biotic and abiotic production constraints of sorghum and millet and develop control measures.

In 2001-2002 season the following INTSORMIL trials that were received late the previous growing season were planted: ARGN (Anthracnose Resistant Germplasm Nursery), ISVN (International Sorghum Virus Nursery), SABN (Southern Africa Breeding Nursery), SAT (Sugarcane Aphid Test), DLT (Drought Line Test), and DHT (Drought Hybrid Test).

One of the main program objectives is to generate genetic diversity through collections, introductions and hybridization. Program emphasis has now shifted to target not only small-scale farmers but also commercial end-users. The development of sorghum varieties suitable for food, brewing, feed and forage is now a major emphasis. It is important to evaluate promising lines for grain yield and other agronomic traits, and to maintain and increase seed of released varieties. A total of eight trials were evaluated at Golden Valley Agricultural Research Trust and Lusitu.

The 2001/2002 season was hindered by erratic rainfall significantly below normal. Trials at most of the testing sites failed. However trials for forage, brewing, feed and food were evaluated at Golden Valley Agricultural Research Trust. Excellent conditions existed to select for diseases and other pests. In the Sorghum Advanced Variety trial the mean grain yield was 3180 kg ha^{-1}. A new variety [Framida x SDS 3845] F6-5 (brewing type) had a mean grain yield of 4325kg ha^{-1}. Other new promising varieties with high mean yields were SDS 4882-1, ZSV-13 and [WSV 387 x ICSV 108] F4-4. The checks ZSV-15, Kuyuma and Sima all had low mean yield. Visual selections were made in test crosses, introductions, F2 populations, segregating generations. Selected materials will be evaluated further next season.

Seed of released varieties was maintained and increased. The germplasm evaluated included 49 pairs of A & B lines; 134 lines for seed increase; 155 experimental crosses and 70 test crosses. Seed of ZSV-15, SDS 4340 A & B, SDS 4283 A & B, A 155 & B, Sima and Kuyuma were increased in isolation fields.

Availability of improved seed to producers and end-users continues to be a major hindrance and challenge to the program. Seed of the released varieties cannot be produced by seed companies citing low demand. The research program and NGO's such as PAM-SHAPES (Program Against Malnutrition - Small Holder Access to Processing, Extension and Seeds Project), have embarked on seed multiplication activities at the village level. The approach is to identify one or two prominent village farmers that will produce seed for sale in the village itself. Extension officers monitor the seed growers. Seed of released varieties such as Kuyuma, Sima and parental lines were produced in isolation. Because of the drought experienced in most parts of the country, very little seed will be available for farmers in the next growing season. This situation could continue for the next two seasons and calls for some intervention to alleviate the shortage of improved seed.

Education on the benefits of new technology (varieties) continued through field days at Golden Valley Agricultural Research Trust and Mt. Makulu Research Station. Small scale farmers and industry representatives participated and were offered the opportunity to see several promising improved varieties and products. Significant interest was generated with the kind of products that can be made from improved sorghum and millet.

Botswana

There were two major research thrusts in 2001/2002 - 1)Evaluation of a sorghum advanced hybrid and variety trial for grain yield and milling quality; and 2)development of new hybrid parental lines. In the hybrid and variety trial, 25 sorghum hybrids and 36 varieties were evaluated at the Notwane farm. The main objective was to identify new genotypes with good adaptation to local conditions and good grain. Based on performance (compared to Phofu and Segaolane) 9 new hybrids and 10 varieties were identified. The best hybrids produced 2 to 3 tons per hectare while the best variety produced 1.5 tons per hectare with little rainfall (less than 350 mm). Most genotypes were medium-maturity (70-80 days to 50% flowering) and semi-dwarf (1.45m to 1.90 m in height) with tan plants and white hard grain which is preferred by millers and consumers. Entries selected for further milling quality tests include SDSH98009, SDSH 94004, SDSH 328, ICSH 93107. For parental line development the fifth backcross for new A-lines was completed. Twenty backcross plants were selected. Selections were based on uniformity, good maturity nick between recurrent and non-recurrent paired rows, good seed set, early maturity, drought tolerance and excellent grain quality. A-lines were testcrossed to Larsyvat 46-85, a well adapted restorer line ready for release. The test crosses will be evaluated in the 2002-03 season for yield potential and fertility.

Regional Activities

Additional breeding activity is directed at the release of high grain yield cultivars that can be used for food and/or brewing. To disseminate improved varieties, seed is increased to supply to farmers, extension, non-governmental organization (NGOs), seed producers, etc., for small-scale seed multiplication and on-farm demonstrations. Nurseries such as the ADIN, Drought Lint Test, Southern Africa Observation, International Sorghum Virus, and Sugarcane Aphid resistance are distributed regionally. Drought during the 2001/2002 growing season severely hindered research and caused several locations to be abandoned.

Plant Pathology

South Africa

Nurseries were planted at Bethlehem, Cedara and Potchefstroom and included local commercial hybrids, the All Disease and Insect Nursery (ADIN), Southern African Breeding Nursery (SABN) and 68 experimental hybrids. Principal diseases targeted for study include damping-off and seedling blight, root rot, leaf blight, ergot and grain mold.

Leaf blight was particularly severe at Cedara and only four commercial hybrids had mean ratings less than 1 on a 0-5 rating scale. These included NK283, which currently makes up approximately 50% of local production. Within the ADIN and SABN nurseries, 6 and 2 entries respectively, remained free from leaf blight while 21 and 18 respectively, had ratings less than 1. Mean leaf blight severities were 1.5 and 1.7 in the ADIN and SABN, respectively. Ergot susceptibility within these nurseries varied and 19 entries in the ADIN had mean ergot severities of less than 10% while 20 entries had ergot severities exceeding 30%. In the SABN 18 entries remained ergot free indicating good pollen viability and self-pollination efficiency in a significant number of entries. Local commercial germplasm was resistant to ergot indicating that selection for cold tolerance and pollination efficacy over a number of seasons has contributed significantly to ergot resistance. Grain mold severity was high and only 5 entries in the ADIN had mean grain mold ratings less than 1 while 52 entries had ratings exceeding 2. In the SABN no ratings less than 1 were recorded and only 11 entries had ratings less than 2, indicating relatively high susceptibility to the disease complex. Within local experimental hybrids, the line SA2063 derived from (IS12612c) appeared to be a good source of heritable leaf blight resistance. Fourteen selections from the ADIN and 22 from the SABN were incorporated into local nurseries and their adaptability to small farmer conditions will be determined during 2002/03.

Increased awareness of grain molds has led to this disease complex receiving greater local attention. Primary isolates from grains were *Fusarium* spp. (mainly *Fusarium graminearum* and *F. subglutinans*), *Alternaria alternata*, *Curvularia clavata* and *Phoma sorghina*. Initial evaluation for aflotoxins and fumonisins in grain from five hybrids, planted at three localities over three planting dates, indicated that these toxins were not present at detectable levels. Additional analyses, including moniliformin, DON and zearalenone are still being conducted. *C. clavata* and *F. proliferatum* were primary isolates from excised embryos. There was a significant correlation between the isolation of pathogens from embryos, reduced seed germination and seedling vigor. Grains were particularly susceptible to infection during milk and soft dough stages of grain development. Under greenhouse conditions, germination was reduced by an excess of 50% when heads were inoculated with primary grain mold pathogens at the susceptible stage. Risk analysis based on weather x grain mold interactions in field trials, suggested that the most critical period for infection is 9-13 days after anthesis. Humidity proved a critical factor and RH >86% is essential for infection. Grain mold severity, rated on a visual 0-5 scale, was highly negatively correlated (R^2=0.94) with hardness and subsequent milling quality. Similarly, reduced germination significantly reduced malt quality (diastatic power).

Under local conditions, ergot severities in unsprayed seed production plots are estimated to average 10-20% with some plots showing 40% or more. Protection of the ovary during the critical period reduces losses due to the disease and increases grain quality. Ergot research to develop a multivariate, risk analysis model continued although dry, hot conditions at Potchefstroom and Bethlehem did not favor ergot development. Attempts to finalize this component and verify model accuracy was suspended until 2002/2003. Fungicides were evaluated for ergot control at Cedara were propiconizole, tebuconazole, tridimenol, tridimefon, and a strobilurin. Significant interactions were recorded between fungicide and application time. Applications prior to anthesis tended to be least effective while applications after anthesis gave best control. This suggested that translocation to the infection site is via the floret and that floret gaping promotes chemical uptake. Triadimenol and triadimefon were the most effective fungicides while propaconizole and tebuconizole were less effective.

Mean root rot severity in commercial sorghum hybrids evaluated at Bethlehem and Potchefstroom ranged from 30.30% to 41.26%, indicating that most local commercial germplasm is susceptible to the disease complex. Variance components based on sums of squares indicate that the effects of genotype, environment and GxE interaction are respectively 15.13 %, 70.51 % and 9.09 % for root discolouration and 4.08 %, 80.85 % and 10.59 % for root volume. Environment was clearly the primary influence on both root rot and root volume of sorghum with genetic components having a relatively small effect on recorded variation. This would indicate that control of the disease, at least in the short to medium term, will have to be achieved through manipulation of the environment using production practices. Additive main effects and multiplicative interaction analyses (AMMI) was successful in identifying those hybrids in which root rot and root volume were more stable over changing environments.

At the Medical Research Council, seven sorghum and seven pearl millet samples were obtained from village granaries in Mali. Grain from these samples was analyzed for fumonisins by using high-pressure liquid chromatography (HPLC) and liquid chromatography-mass spectrometry (LC/MS). The seven pearl millet samples contained between 5 and 70 ppb (mean, 24 ppb) total fumonisins, with only one sample containing fumonisins (FB_2 and FB_3) other than FB_1. Six of the seven sorghum samples contained between 10 and 40 ppb (mean, 20 ppb), with only one of these samples containing a fumonisin (FB_2) other than fumonisin B_1. The seventh sorghum sample contained over 1000 ppb of total fumonisins, and higher levels of all three fumonisins (FB_1 – 360, FB_2 – 345 and FB_3 – 320 ppb). In a diet based primarily on sorghum, the amount of total fumonisins consumed in food from this sample probably would exceed the Joint FAO/WHO Expert Committee on Food Additives provisional Maximum Tolerable Daily Intake level for this toxin of 2 µg/kg of body weight for humans, e.g., a 70-kg person would need to eat 140 g of sorghum from this sample to exceed this level of fumonisins in the diet. This report is the first of the natural occurrence of fumonisins in pearl millet and the first LC/MS confirmed report of fumonisins in pearl millet. Four identifiable *Fusarium* species and at least three other *Fusarium* spp., the putative source of these toxins, were recovered from these sorghum and pearl millet grain samples. Techniques beyond observation in the light microscope are required to accurately identify the bulk of the fungal cultures as a significant proportion appear to belong to previously undescribed species. Further characterization and identification of these strains with molecular techniques will be made by Dr. Leslie at Kansas State University.

Botswana

Trials planted to evaluate for disease severity were the International Sorghum Virus Nursery (ISVN), the Southern Africa breeding nursery (SABN), and the ADIN (data not reported due to lack of disease symptoms). The ISVN was evaluated at Sebele and Pandamatenga for reaction to sugarcane mosaic virus (SCMV). Disease incidence was recorded as the total number of plant displaying virus symptoms in each plant, and disease severity was recorded using standard visual ratings for scoring the approximate percentage of leaf area affected by the virus. Susceptible entries were Mahube, New Mexico 31, BTx378, and Tx7000. Tolerant cultivars were Atlas, Bugoff, SC175-14E, SA384 (Combine Shallu), P135038, Tx3048, Hegari, and Tx398. Resistant cultivars were Tx2786, BTx430, Tx09, QL11, QL3 (India), Tx623, and Tx2858.

The SABN was evaluated for reaction to grain mold, sorghum downy mildew, rust, leaf blight, sooty stripe, red leaf strip, and sugarcane mosaic virus at Pandamatenga. Lines with no symptoms for any disease scored include: (B1*Town)-HL?-HL1, (BTx635*B4)-HF4, CE151, Sureno, 86EO361, Kuyuma, Sima, Tegemeo, WM#177, ZSV15, 90EO328, (CE151*BDM499)-LD17-BE1, (SRN39*90EO328)-HF4-CA1, (Sureo *SRN39)-BE15-CWBK-BE1, (Sureno*SRN39)-BE!-CW5-BE2, several derivatives of (86EO366*WSV387), (86EO361*Macia)-HF25, (M84-7*WSV387)-HD7, (Macia*Dorado)-LL7, and (CE151*MP531)-DL47.

Food Quality

Dr. Leda Hugo (Mozambique) completed her Ph.D. program at the University of Pretoria. Her research demonstrated that malting and fermentation improved the baking properties of sorghum flour in composite breads like those made in Southern Africa. The fermentation procedure was the most promising and practical method and made good bread containing 30% sorghum. The soured or fermented sorghum paste could be added directly to the wheat flour and with slight modifications to the current procedure could be utilized to effectively incorporate sorghum flour into bread baking. It also improved the in vitro digestibility of the protein of the sorghum. Dissertation citation: Hugo, L.F. 2002 Malted and Fermented Sorghum as Ingredient in Composite Breads. Ph.D Dissertation. U of Pretoria, Pretoria, S. Africa 171pp

Cooperative research underway with the Dep. of Food Science, Univ. of Pretoria is providing insights into improved sorghum and pearl millet processing and utilization. Through this collaboration INTSORMIL is able to reach the next generation of African food industry leaders. The following research projects are underway to support improved end-use of sorghum and pearl millet:

Optimization of pearl millet milling - In Namibia, pearl millet milling is a rapidly growing entrepreneurial business and improving food security by encouraging increased cultivation of the grain. The milling process being used is highly complex and inefficient. It involves: dehulling of the grain, steeping/fermentation, partial solar drying, wet milling with a hammer mill, and solar drying of the flour. A Namibian masters student under the supervision of Drs. Taylor (Univ. of Pretoria) and Rooney (TAMU), will study the role of pearl millet grain quality and the effect of various processing parameters on the efficiency of the milling process and the nutritional quality of the resulting flour.

Optimization of sorghum roller milling - Small double-roller mills can be used to mill sorghum and revolutionize the production of quality sorghum meal meal throughout Africa. However, the optimum processing parameters, such as conditioning levels and times, for the various types of sorghum, (e.g., white tan, red pericarp, tannin) are not known. This places sorghum at a competitive disadvantage with respect to other grains, particularly maize, since low extraction levels and poor quality flour/meal are obtained. A South African masters student, under the supervision of Drs. Taylor and Rooney and in collaboration with a leading South African small company roller mill manufacturer, will study the role of sorghum grain quality and the effects of various processing parameters, including conditioning and roller settings, on the efficiency of the roller milling process in terms of extraction rate and flour/meal quality.

Research is on-going to develop sorghum grain end-use standards for breeding with respect to injera making quality. The research is a doctoral research project conducted by Mrs. S. Yetneberk of the Nazret Institute of Agricultural Research, Ethiopia, under the joint supervision of Drs. Taylor and Rooney.

Research is on-going to study the natural shelf-life extension of food. This research is sponsored primarily by the National Research Foundation of South Africa and the European Union. There are three major objectives to the research: 1)Study the antioxidant potential of sorghum milling by-products for food shelf-life extension; 2)Develop of sorghum protein biofilms to extend the shelf-life of Southern African fruit and nut exports; 3)Through competitive microbes suppress fungal contamination and pathogens in sorghum malting.

Insect Pest Management

Four experiments (two sugarcane aphid screening trials, one greenhouse screening trial for sugarcane aphid and a midge line test) were conducted during the 2001/2002 cropping season.

Sugarcane Aphid Screening Trials

Two field trials (100 entries x 3 replications) were planted, one at the mid-altitude research station of the ARC-Grain Crops Institute at Potchefstroom and one at the sub-tropical low-altitude station at Burgershall. Sorghum was planted late in the growing season (late December) to increase the likelihood of high levels of aphid infestation. Aphid damage was evaluated when the majority of the hybrids were flowering. The severity of infestation was evaluated using a 1 to 5 scale where, 1 = no aphids present on plants, 2 = light infestation with aphids present on a few leaves (no dead leaves), 3 = moderate infestation with many aphids present on two to three leaves (one or two dead leaves may be present), 4 = high infestation with many aphids on nearly all leaves (many dead leaves) and 5 = majority of plants in plot dying. Plants with a rating of 1 or 2 were considered to be resistant to damage while a rating of 3 indicated intermediate levels of resistance. Plants with a rating of 4 and 5 were considered to be susceptible.

Sugarcane aphid infestation levels at the Burgershall field station were significantly lower than at Potchefstroom. Only 3 % of the entries rated a 3 (medium infestation levels). No conclusive results could therefore be made from this field trial. The grain yield expression experimental entries was superior to that at Potchefstroom. Leaf diseases were also common. In the future this station will be used for disease evaluation as well. Infestation levels at the Potchefstroom site were high. Results indicated that 29 % of the entries rated below a 2 (indicating none to light damage). Three entries (6BRON161, TAM 428, and (Macia* TAM428)) had no aphids on any of the plants in any replication.

In a greenhouse trial resistance to sugarcane aphid was evaluated during the seedling stage with artificial infestation. Results indicated that 30 % of the entries exhibited no damage symptoms 22 days after inoculation while the whole plot row of 37 % of the entries were dead. Results from this trial will be used to develop the 2003 Sugarcane Aphid Trial.

Midge Line Test

One field trial (85 entries x 3 replications) was planted at the ARC-Grain Crops Institute, Potchefstroom. No midge infestation occurred at this locality. However, sugarcane aphid infestation levels were high and aphid damage was evaluated on the 1 to 5 scale when the majority of the entries were flowering. Six entries had no aphid infestation and were considered highly resistant. These entries (TAM2566, MLT180, MLT181, Tx2882*SRN39, BVar*MB102-3 (source 00LI1338), BVar*MB102-3 (source 00LI1339)) will be included in the 2003 Sugarcane aphid test.

Mutuality of Benefits

Productivity and utilization of both sorghum and pearl millet will ultimately be improved both in SADC countries and the USA through joint research. Reciprocal germplasm flow is mutually beneficial. Basic research from the USA can often be adapted for use in developing countries where grain yield potential, adaptation, stress resistance, and grain quality need to be increased. U. S. pathologists and entomologists can become familiar with diseases and insects not yet present in the USA, or find new resistance sources to existing pests. For example, research in South Africa on sources of ergot resistance, understanding environmental conditions conducive to disease spread, and methods of research are of vital interest to U.S. scientists. Nutritional components of food quality researched in collaborative projects have relevance to grain values for livestock feed.

Institution Building

Equipment and Supplies

One computer and printer was delivered to the Zambia pearl millet breeding program.

One computer and printer was delivered to the Zimbabwe sorghum breeding program

Training of Host Country Researchers

Through a previous regional USAID program INTSORMIL provided long-term training to a large number of SADC sorghum and pearl millet scientists. Currently one regional scientist is selected each year for a short-term training assignment with a U.S. principal investigator. Mr. F. Muuka, pearl millet breeder, participated in a short-term training assignment in August 2001 with Dr. Wayne Hanna (USDA-ARS/INTSORMIL). Mr. Leo Mpofu, sorghum breeder, was selected for a short-term training assignment in July-August 2002 with Dr. Bill Rooney (TAM-220) and Dr. Gary Peterson (TAM-223).

Plans were initiated for Rachel Ngulube-Msikita (Zambia) to travel to the University of Nebraska to complete her M.S. Degree with Dr. Jerry Eastin.

Ms Leda Hugo completed her Ph.D in food science and technology at the U of Pretoria. She has returned to Mozambique where she is a professor at U of Eduarado Mondolane. Professor Taylor, University of Pretoria was her major professor.

Under the supervision of Dr. J.R.N. Taylor the University of Pretoria Food Quality Laboratory has participated in graduate training as advisor or co-advisor of 4 Ph.D. students (Ghana -1, Zimbabwe-2, South Africa-1) and 10 M.S. students (Botswana-1, Ghana -1, Kenya-1, Mozambique-1, Nigeria-1, South Africa-2, Uganda-1, Zimbabwe 2). Dr. Taylor advises 4 M.S. and 6 Ph.D. students from 8 African countries in sorghum and millet food science and technology.

Additional short- or long-term training will occur as individuals and funds are identified, and a regional strategy will be developed at the INTSORMIL Principal Investigators in November, 2002.

Mr. Hoffman (Namibia) conferred with INTSORMIL scientists regarding pearl millet research and training opportunities.

Host Country and U.S. Scientist Visits

John Leslie discussed INTSORMIL research with collaborators in South Africa in November, 2002.

Gary Peterson, Bonnie Pendleton, and Darrell Rosenow visited Botswana, Zambia and South Africa 1-13 April 2002. In Botswana met with Department of Agricultural Research scientists to plan future research activity. Met with Botswana College of Agriculture administrators and scientists to discuss initiating additional collaborative research in plant breeding and entomology, and potential in other disciplines. In Zambia met with Ministry of Agriculture, Department of Agricultural Research scientists to discuss sorghum and pearl millet research. Evaluated sorghum research plots at Golden Valley and Siavonga region. Discussed INTSORMIL Southern Africa activity with USAID/Zambia representatives. In South Africa, met with collaborators at the ARC, Potchefstroom, to evaluate collaborative activity and plan future research. Evaluated sorghum research plots at the Cedera Research Station near Hilton, the ARC at Potchefstroom, and the Lowveld Station near Hazyview. Also met with Dr. John Taylor at the University of Pretoria to discuss sorghum and pearl millet grain quality research.

Medson Chisi participated in the INTSORMIL Regional Coordinators and Technical Committee meetings at the University of Nebraska 30 April - 3 May 2002.

Germplasm Exchange

Several hundred sorghum lines and cultivars were provided to evaluate for reaction to various diseases, adaptation, drought response, and sugarcane aphid resistance in the SADC region in the 2001-2002 growing season (collaborative with TAM - 222, TAM - 223, and Dr. B. Rooney (now TAMU - 220)). Millet germplasm to Zambia was provided by ARS-204.

Networking

An efficient sorghum and millet research and technology transfer network exists in the SADC region conducted by the SMIP program and INTSORMIL's SADC collaborative research program is completely integrated on a regional basis. The Zimbabwe unrest and political situation has imposed significant restrictions and a reduction of activity in Zimbabwe. Interaction with the Univ. of Pretoria, Council for Science & Industrial Research, South Africa in sorghum and pearl millet utilization research efficiently utilizes scarce resources and personnel. Graduate students in the Food Science Department at the University of Pretoria are from many other African countries. Many of them are participating in the Regional Master of Science program which consists of joint programs between CSIR and University of Pretoria. The regional program has the goal of providing education for African scientists on African crops that are of importance in the region. Sorghum and millets are a key components of these food systems. Thus, interactions with this program informs many future African food industry leaders on the potential role of sorghum and millets as food and industrial ingredients. INTSORMIL can provide assistance to the region by involvement in these programs where possible. Through allocation of resources INTSORMIL has started encouraging regional scientists to collaborate across countries.

Program Accomplishments

INTSORMIL is fully integrated into the SADC and SMIP sorghum and pearl millet regional research and technology transfer activities. INTSORMIL regional work plans are annually reviewed by the SMINET Steering Committee.

Factors influencing the incidence and control of sorghum ergot are now better understood, leading to better control of the disease, especially in hybrid production fields.

New sorghum and pearl millet varieties and hybrids are ready for release or in final testing prior to release. A large number of sorghum germplasm has been characterized for resistance to major diseases and sugarcane aphid. Multi-location testing of sets of such lines provides strategic ecogeographic information on distribution and severity of diseases.

Collaboators at the Department.of Food Science, University of Pretoria presented the following short-courses to improve the food technology skills of professionals in the sorghum and millet food industry in Southern Africa. 1)Course in sorghum malting technology has been presented to six groups of 12 people over the past 8 years. 2)Short course in opaque (sorghum) beer brewing has been presented annually to a total of some 150 people from throughout southern Africa over the past 6 years. 3)Under the sponsorship of the FAO and the Namibian government a pearl millet processing technology training facility has been designed and is the process of being constructed in northern Namibia.

Research into improving sorghum processing technologies is being carried out for the sorghum food industry in South Africa through its industry body, the Sorghum Forum. With the support of the USAID RAPID Program, (Regional Activity to Promote Integration through Dialogue and Policy Implementation) sorghum grain end-use quality standards and methods have been developed to facilitate grain trade in southern Africa. Technical assistance has been rendered to the Botswana Bureau of Standards to implement sorghum grain standards incorporating these concepts and methods, and to Tanzanian businesses in the setting up of a sorghum industry forum.

The Department of Food Science, University of Pretoria and CSIR Bio/Chemtek in South Africa are the official SADC (Southern African Development Community) center for post-graduate training in Food Science and Technology. Because of the economic importance of sorghum and millets to the Region, a high percentage of post-graduate training involves research into these grains. Currently 4 masters and 6 doctoral students from 8 African countries are being trained sorghum and millet food science and technology. INTSORMIL collaboration with the Dep. of Food Science provides additional mutually beneficial training and research opportunities.

Factors influencing incidence and control or sorghum ergot have been identified leading to better understanding of the disease mechanisms. Fungicides for control of ergot have been evaluated and significant interactions between fungicide and application time identified.

West Africa – Eastern Region

Bruce Hamaker
Purdue University

Coordinators

Issoufou Kapran, INRAN/INTSORMIL Coordinator, B.P. 429, Niamey, Niger
Bruce Hamaker, Regional Coordinator, Food Science Department, Purdue University, West Lafayette, IN 47907
Katy Ibrahim, Administrative Assistant, International Programs in Agriculture, Purdue University, West Lafayette, IN 47907

Collaborative Program

The recently regionalized INTSORMIL program in the eastern region of West Africa includes a long-standing collaborative research effort in Niger, and newer and smaller programs in Burkina Faso and Nigeria. All are multidisciplinary efforts that focus on sorghum and millet improvement in the region, however Niger has the only full range of research activities spanning production agriculture-related projects, utilization, and economics. ICRISAT has been an institutional collaborator in the region, as well as the regional millet and sorghum networks of ROCEFREMI and ROCARS. Research plans are developed between host country PI's and U.S. INTSORMIL collaborators. A first regional meeting was held in Niamey in March 2000 with the aim of sharing research results and strategizing to meet the needs of the region. In this last year, a meeting was not held in lieu of the All-PI Conference in Addis Ababa in November 2002. However, in future years there will be a resumption of regional PI meetings.

List of Disciplines and PI Collaborators

Genetic Enhancement – Sorghum and Millet

Sorghum: INRAN, Niger - I. Kapran; KSU - M. Tuinstra, Purdue – G. Ejeta, and L. House (ret.)

Nigeria - P. Marley; TAM – D. Rosenow

Burkina Faso – A. Neya; TAM – D. Rosenow

Millet: INRAN, Niger – J. Gonda; ARS – W. Hanna

Lake Chad Research Institute, Nigeria – I. Angarawai

Sustainable Plant Protection Systems

Entomology: INRAN, Niger - H. Kadi Kadi; TAM – B. Pendleton, F. Gilstrap

Plant Pathology: INRAN, Niger – A. Kollo (on leave to Texas A&M University/ARS)

Sustainable Crop Production Systems

Agronomy: INRAN, Niger – S. Sirifi; UNL – S. Mason

INERA, Burkina Faso - J.B. Taonda; UNL – S. Mason

Economics: INRAN, Niger – T. Abdoulaye; PU – J. Sanders

Utilization and Marketing

Utilization: INRAN, Niger – K. Saley, M. Moussa; PU – B. Hamaker

University of Maiduguri, Nigeria – I. Nkama; PU – B. Hamaker

Marketing: UI – C. Nelson

Sorghum/Millet Constraints Researched

Sorghum and pearl millet are staple food crops of Niger, Burkina Faso, and northern Nigeria. In Niger, sorghum acreage increased from less than half a million hectares in 1961 to more than two million hectares in 2000. Grain yield declined from 0.6 t/ha to 0.2 t/ha during the same period. Sorghum and millet production in the eastern Sahelian region of West Africa is severely limited by biotic and abiotic stresses including drought, poor soils, insect pests (especially midge and headbugs), and diseases including long smut and *Striga*. In the 1998 strategic plan for sorghum and millet prepared by the Institut National de Recherches Agronomiques du Niger (INRAN), emphasis was placed on technology transfer, development of varieties with better yield stability, and plant protection. Improved utilization of these cereals, such as through commercial processing to products or animal feed use, is also key to expanding demand and markets, as well as generating income at the entrepreneurial level.

INTSORMIL's support for sorghum and millet improvement has been significant in terms of human resource enhancement and vision for technologies that can be transferred and adopted by farmers and other end-users. For example, sorghum and millet breeders and food technologists work together to demonstrate feasibility of the use of improved seeds to increase food production, diversify uses for local consumers, and stimulate entrepreneurial businesses.

Institution Building

Office supplies including a typewriter, binding machine and shredder, as well as research expandable supplies (pollinating bags) were purchased for field work in Niger. In addition, a laptop and software were purchased for the same program.

Tahirou Abdoulaye completed his Ph.D. studies at Purdue under the supervision of John Sanders. He will be remaining at Purdue University until December 2002 to work with Dr. Sanders on a biotechnology potential and constraints study in West Africa, and developing a millet and sorghum marketing project in collaboration with ROCAFREMI. These two activities will involve traveling to Niger, Burkina Faso, Senegal, and Mali.

Dr. Abdourahmane Kollo continues his position as visiting scientist in the USDA/ARS plant pathology laboratory at Texas A&M.

Dr. Issoufou Kapran, INRAN/INTSORMIL host country coordinator made two trips to the U.S. during FY2001/2202. He spent approximately 3 weeks on campus in October to evaluate the Purdue sorghum nursery and make selections for use by INRAN in Niger. He also traveled to Nebraska to participate in the Technical Committee meetings and the All-PI organizational meeting in late April early May 2002.

Research Progress

Niger

Sorghum Breeding and Seed Production
I. Kapran, G. Ejeta, and L. R. House (consultant)

Major constraints facing sorghum production in Niger include drought, poor soils, insect pests, diseases, and *Striga*. INRAN has a strategic plan that recognizes the need to focus on yield improvement as a means to achieve higher sorghum production. Priority areas include (1) collaborative on-farm evaluation of existing improved varieties and hybrids; (2) development of new varieties possessing high and stable yields; and (3) pest management.

In Year 2001, activities focused on breeding nurseries and trials, and hybrid seed production. Field trials and nurseries were organized to identify the best materials to go for release as cultivars, or as breeding lines for further improvement. INTSORMIL PIs at Purdue University (Ejeta) and Texas A&M University (Rosenow) supplied germplasm; other partners were the regional sorghum network (ROCARS), and NARS in the West Africa region (Mali, Nigeria, Burkina Faso). It should be stressed that the INRAN/INTSORMIL joint breeding program has a strong orientation for collaboration with the INRAN Seed Unit (U.S.) and the INRAN Food Technology Laboratory (LTA).

The objective is to identify highly productive and well adapted hybrids that will be released for commercial production. New hybrids and lines were evaluated for early maturity, grain quality, grain yield and overall adaptation at the following INRAN locations: Konni, Tahoua, Bengou, Kollo Lossa, and Tillabery. Planting was done between June 15 (Lossa) and July 23 (Konni). Common problems were high damages by midge and some long smut infestation.

The following nurseries were installed:

A1. Identification of A-lines with good adaptation and stability in seed production to replace TX623A. TX623A, the female parent of NAD-1 hybrid, while being an excellent combiner, has many problems of adaptation (susceptibility to long smut disease, *Striga*, midge) and has poor seed quality (often translating into poor germination), all of which complicate seed production; TX623A is also of a different maturity than MR732, the male parent of NAD-1, thus staggered planting is required for seed production, which is not the easiest way for on-farm production. Based on the above, a nursery was planted with two planting dates at the Lossa station (June 15 with irrigation; and july 15 rainfed) to collect data on flowering, and susceptibility to long smut and grain mold. As for the previous year, the following female parents were selected as the most adapted, and cover a wide range of maturities: P9504, P9511, P9512, P9521, P9526, AHF8, 223A.

A2. Field testing of experimental hybrids. More than 1300 hybrids were tested (Table 1). This wide array of combinations is designed to provide new hybrids that not only have agronomic performance equal to or better than NAD-1 check, but also better grain quality and wider adaptation (especially early hybrids), in the framework of parents with the same maturity. Yields were generally low, but there were strong indications of entries that merit further testing. Results of selected trials are shown in Table 2.

Hybrids with female 223A are highly productive and possess good evident grain quality, although not earlier maturing than NAD-1. A subset of hybrids in the observation nursery was sent to the INRAN Food Technology Lab for analyses (see report below).

Earliness was clearly expressed in IS10360A hybrids, however their yield was not as good as that of the check (MM) and their grain quality was poor.

Table 1. Experimental hybrids tested, Niger 2001

Hybrid observation nursery	767	Intercrosses between 60 A-lnes (PU, TAMU, UNL) and 74 R lines (INRAN, ICRISAT, ROCARS, PU, TAMU)	Lossa, Kollo	Only hybrids between parents of same maturity group
Preliminary hybrid trial	97	Intercrosses between selected A&R lines	Kollo, Lossa, Bengou, Maradi	
Advanced hybrid trial	8	Intercrosses between most elite A&R lines	Kollo, Lossa, Bengou, Konni, Maradi	
idctlparPU Hybrid observation nursery	400	Crosses of dryland adapted lines	Maradi	
PU early maturing hybrids	33	Single female parent=IS10360A	Maradi	
PU advanced hybrid trial	26	Selected female and male parents	Kollo, Lossa, Maradi	

Table 2. Yield averages in selected hybrid trials

Trial	Trial mean (kg ha^{-1})	Best yield (kg ha^{-1})	Check mean (kg ha^{-1})
Preliminary (Maradi)	476	2250 (223AxR1/ST9007)	666 (MM)
Advanced (Kollo)	1097	1550 (223AxMR732)	1122 (MM)
Early maturing (Maradi)	714	1667 (MM)	1667 (MM)

Hybrid seed production: This activity has received higher priority than variety trials, in the context of the existence of a seed unit at INRAN. As noted before, the seed unit is modeled after NAD-1 seed activities designed and implemented thus far under INRAN/INTSORMIL collaboration. Other partners include the IFAD/INRAN technology transfer project, the IFAD/Tillabery project, and the WINROCK-ONFARM project.

The objectives of the seed unit are:

- Management of breeder and foundation seed of cultivars in high demand (millet, sorghum, cowpea, groundnuts, onions);
- Contribution to the initiation of a modern seed industry in Niger.

The following activities were successfully conducted:

Parental seed production (on-station): Female parents TX623A and 223A were each increased at Lossa station (Table 3). This location has been selected over the years for parental seed production because of isolation, availability of irrigation, dry air, no *Striga*, midge, or grain mold (or negligible levels).

Hybrid seed production: NAD-1 and F1-223 hybrids were produced at the Tillabery station (Table 3). The quantities of hybrid seed were still low, due to limited funding and land availability with INRAN. This activity will need major financial input to take off. All seeds produced were cleaned and stored at the Lossa national seed farm for optimum storage quality. In addition to INTSORMIL, INRAN through its seed unit, and the regional sorghum network (ROCARS) supported this activity.

Table 3. Elite sorghum varieties and hybrids increased, INRAN/INTSORMIL 2001

Identification	Seed produced (kg)
NAD-1 hybrid (released)	1437
F1-223 hybrid (advanced)	677
TX623A (female)	292
223A (female)	273
SEPON82 OPV (released)	180
MM landrace (released)	1652
Total	4511

On farm hybrid seed production and farmer training: Farmer cooperatives at Tiaguirire (WINROCK) and Gidan Iddar (IFAD/INRAN) also undertook hybrid seed production. At both locations there was continuous monitoring of procedures to help farmers produce good quality seeds. Gidan Iddar farmers and technicians also received formal training using the manual for hybrid seed production in Niger (House/Kapran) that was translated into local languages with support from Winrock International. In addition regular on-hands training sessions will be organized for farmers during seed production period.

In addition to the above, a trial was initiated in collaboration with INRAN and INTSORMIL agronomists Dr. S. Sirifi and Dr. S. Mason. This is in response to our search for the best management options to optimize hybrid seed production. Initial observations indicate that high density planting (80 cm x 20 cm) and high fertilizer rate (200 kg ha^{-1} of urea) may be conducive to excellent nick and hybrid seed production.

Sorghum/Millet Quality and Utilization

K. Saley, M. Moussa, M. Oumarou, I. Kapran, A. Aboubacar, and B. Hamaker

Primary Objective

- The overall objective of this project is to initiate processing and commercialization of value added sorghum and millet products with particular emphasis on utilization of locally and regionally fabricated food processing equipments.

Specific Objectives

- Optimize sorghum couscous and associated products.
- Complete the 1st and 2nd phase of the marketing study in order to learn about the acceptability and the market potential of the processed NAD1 couscous.
- Optimize the processing equipment
- Transfer of the technology to beneficiaries.

In the past year, the second phase of a marketing survey was conducted by introducing the processed NAD1 sorghum couscous into selected market segments. About 600 kg of couscous was distributed in nine selected stores. A short questionnaire was given by sales agents to consumers who purchased the couscous in those sales stores, and information related to price, rate of sales and packaging quality was collected from buyers.

Table (4) indicates the production capacity of the pilot unit. The current capacity may be sufficient for processors who want to start processing and commercialization of sorghum / millets products.

Regarding the 2nd phase (market potential) of the sorghum couscous, impressive results were obtained this year.

Dissemination of Technologies

The national forum on sorghum/millet organized by INRAN, Sept., 2001

The world food day celebration, Oct 15, 2001, Niamey

The annual workshop organized by Africare-USAID, Niger Oct, 2001

The annual meeting of ROCARS, Nov. 2001, Burkina Faso

The annual meeting of FIDA-ARSAS, Feb. 4, 2002, Maradi, Niger

The workers day celebration, may 1, 2002, Niamey

A team of private processors was trained to process sorghum/ millet products at the pilot unit/ cereal lab/INRAN. From April, 2, 2002 to May, 2, 2002.

Recently, 1 metric ton of NAD1 grain was processed to flour and couscous with financial support from the sorghum network, ROCARS. Information related to consumer acceptability and responsiveness to price of sorghum NAD1 couscous and flour will be collected.

Entomology

H. Kadi Kadi and I. Kapran

In Niger, insects feeding at the different developmental stages cause low yield and grain quality. The most important insect pest of sorghum is the sorghum midge, *Stenodiplosis sorghicola* (Coquillet) causing damage to flowering panicles. Midge is most damaging to late maturing varieties with a long vegetative phase. Such varieties sometimes suffer a non-formation of more than half their seeds.

Table 4. Equipment and throughput involved in couscous processing.

Equipments	Processes	Throughput
Electrical decorticator (abrasif type) 1400 r.P.m; 4 kw = power (URPATA, Senegal)	Dry decortication	150-250 (kg/h)
Electrical Hammer mill 3000 r.P.m ; 5,5-7,5 kw = power (URPATA, Senegal)	Dry milling fine, medium and coarse flour (0,5; 0,7; 1 mm)	200-300 (kg/h)
Sieving (manual type)	0,2-0,5 mm) particle size	100 (kg/h)
Food mixer 650 watt (Kendwood)	Hydration : flour + water	30 (kg/h)
Agglomerator-rouleur 16;22; and 36 r.P.m., 0,25 kw = power (Montpellier –France)	1-2 mm particle size couscous and associated products	40 (kg/h)
Couscoussier (Nigeral, Niger)	Steaming with butane gas cooker	10-20 (kg/h)
Solar dryer 32 m² / aluminum / natural convection / insulation : Solar Radiation	The couscous is spread in thin layer form in the drying chamber	40 kg/24 h
Packaging (Birnberg machinery) 210 watt		30-50 packets/h
Grain destoner (electrical) URPATA Sahel, Senegal		200-300 (kg/h)

Research studies on biology and population dynamics of sorghum midge and the application of the integrated pest management principles (planting dates, cultural techniques, host plant resistance and chemical control) have helped to determine some promising resistant varieties that can sustain sorghum midge damage. In Niger, the adults of *Stenodiplosi* spp. began to appear in the field in two generations between mid-September and early-October (Maïga 1980 and Samir 1984).

- The major objective of the entomology project has been to determine the sorghum lines resistant to sorghum midge. After two years of screening some sorghum materials introduced from Texas by the INRAN breeder, the varieties, TAM 2566, TX 2782, TX 2755, and TX 2890 were identified as resistant to sorghum midge (Kadi Kadi 1994). New resistant sorghum lines must also have, through crossing with high performing varieties, agronomically acceptable characters.

In the 2001 cropping season, the results obtained from single seed descent sorghum lines with midge resistance showed no significant differences between the lines for damaged spikelets ($F = 0.89$, $P < 0.001$) at the 1st planting date. Four sorghum lines (99 SSD F9-3, 99 SSD F9-24, 99 SSD F-32 and IRAT 204 had highest damaged spikelets (50-60%). The percentages of grain loss recorded on these lines were 20-50%. At the 2nd planting date, most of the sorghum lines tested have <10% damaged spikelets. Highest midge damages were recorded at the 1nd planting date because the midge outbreaks were favored by the coincidence with the sorghum flowering stage. Sorghum lines 99 SSD F9-18, 99 SSD F9-21, 99 SSD F9-29, 99 SSD F9-33, 99 SSD F9-35, ICSV 745 were found to be resistant to midge. These lines had the lowest (12-28%) grain loss even though some had highly damaged spikelets. The results confirmed that, after three years of screening, lines ICSV745, 99 SSD F9-21, 99 SSD F-33 and 99 SSD F9-35 are resistant to sorghum midge.

A new process of developing sorghum lines resistant to midge by the single seed descent procedure started in 2000: two midge resistant varieties (ICSV 745 and ICSV 88032) were crossed with 4 varieties (MM, IRAT 204, MR 732, ATX 623). F_1 populations of these differents crosses were obtained. The most promising F_1 populations of ATX 623 x ICSV 745 and ATX 623 x ICSV 88032 were advanced to F_2 during the 2001 cropping season. These populations are being advanced to F_3 generation during the 2002 cropping season. This will help to develop new sorghum lines resistant to midge that will produce high yield even under high midge infestation level. These lines will have higher performance, commercially acceptability, and could be used to develop new sorghum lines.

Perspective. During the past year, progress was made to start some collaborative research activities with Dr. Bonnie Pendleton who was awarded an INTSORMIL CRSP project "Sustainable management of insect pests in West Africa and the United States". Collaborative research activites on sorghum will be oriented to: 1) identify sorghum lines with stable resistance against sorghum midge, 2) determine if variation in the flowering of sorghum lines affect sorghum midge incidence and day-to-day variation in midge population abundance, 3) develop new sorghum lines resistant to sorghum midge through Single Seed Descent procedure, 4) exchange promising materials with other scientists within the region or the USA and 5) deliver and adopt the new lines or varieties at the farmers level.

On millet, collaborative research activities will focus on assessing the abundance and causes of mortality of millet head miner under field conditions to better understand natural enemy-host interactions. Specific objectives of the research activities will be to: 1) verify methodology for sampling and manipulation of millet head miner populations and its natural enemies and 2) conduct field cage exclusion studies on natural enemies attacking millet head miner on millet.

Millet Breeding
J. Gonda and W. Hanna

Millet hybrids introduced from Tifton, Georgia were compared to local checks CIVT and CT6. In general, hybrids were earlier maturing have higher tillering capacity and yield compared to CIVT and CT6. Hybrid WA28 was the earliest maturing with a 50% heading cycle of 61 dap and 50% blooming cycle of 70 to 71 dap, but was significantly different only from the checks CIVT and CT6 and hybrid Wa23. Hybrids Wa27 and 28 had significantly higher tillering capacity (panicle #/ha) with 47,481 heads per ha., but were only significantly different from the local checks CIVT and CT6 , with 29,988 heads per hectare and from hybrids Wa11 with 29,155 heads per hectare. Hybrid Wa11 had the lowest tillering capacity with 29,155 heads per hectare.

One of the potential problems of these hybrids was head length. There were highly significant differences between hybrids and in between hybrids and local checks for panicle length. Local checks had the longest panicles at 61 and 51 cm, and they differed significantly from all the tested hybrids which had panicle lengths of 21 to 37 cm. All the hybrids were short panicle length genotypes.

There was a significant difference between hybrids, and between hybrids and local checks for yield. Hybrid Wa25 yielded significantly better with 1,104 kg per hectare, though differed significantly only from hybrids Wa15 (666 kg ha^{-1}), Wa19(636 kg ha^{-1}) ,Wa29 (583 kg ha^{-1}) and Wa30 (437 kg ha^{-1}). Good yielding hybrids such as Wa25, 24 and Wa16 (yielding from 1104 to 1020 kg ha^{-1}) show promise for future breeding activities.

Socioeconomics
T. Abdoulaye and J. Sanders

T. Abdoulaye of INRAN/DECOR completed his Ph.D. in agricultural economics at Purdue University. His Dissertation, "Farm Level Analysis of Agricultural Technological change: Inorganic Fertilizer Use on Dryland in Western Niger" was funded through INTSORMIL with field work partially funded by the Natural Resource Management Program of ICRISAT and INRAN.

Despite the harsh economic and physical environment, survey results indicate that farmers from the Fakara region are investing in micro and moderate doses of inorganic fertilizer in order to increase their agricultural production and to respond to soil nutrient depletion. This change in their farming practices has been facilitated by their exposure to the effects of inorganic fertilizer through trials and demonstrations according to the econometric results. There is apparently a path of fertilizer use by farmers with different factors becoming critical along the way. Once the traditional soil fertility maintenance system breaks down, due to population pressure, per capita crop production declines, which forces farmers to look for alternatives. They generally start by using manure. When manure potential is exhausted and conditions are favorable, they start using micro-doses of inorganic fertilizer along with the manure. Micro-doses consist of using small doses of inorganic fertilizer applied directly into the hole where the seeds are planted. This method makes efficient use of small quantities of inorganic fertilizer. Moreover because the quantities applied are small, liquidity for input purchase is not a major issue. Farmers gradually increase doses of inorganic fertilizer to eventually move to moderate doses.

Results indicate that in regions where there have been demonstration trials, farmers are using various kinds and techniques of fertilization. There is some statistical support for our hypothesis that the principal factor determining the use of micro-doses of inorganic fertilizer are profitability (millet relative price) and the need for farmers to see it used in the field. Farmer's ability to finance input purchase becomes a factor for moderate dosage level. To get the fertilization process started, the main factors appear to be profitability and farmers being comfortable with the technologies through demonstrations and trials. Wealthier farmers were more likely to use fertilizer but the separate liquidity variable for availability of capital had little effect on its use. The wealth of the household becomes an issue when the farmer wants to shift to moderate doses of inorganic fertilizer. Because the moderate dosage technologies require a higher investment, the farmer needs to be wealthy enough to afford the cost of the investment. With this highly divisible input farmers could and did begin utilization on very small levels and then shifted to moderate fertilization if they were wealthy enough to wait for the post harvest price recovery.

Introduction of new technologies (including higher and better quality inorganic fertilization and new cultivars) will lead to 30% increase in household expected income as well as an increase in farmers' coping ability because of increased crop production. The fertilization process can be accelerated if policy makers recognize the importance of farmer profitability for the intensification of agricultural production. This increase in fertilization leads to higher production and expected farm income is increased by an additional 16% compared to the solution with new technologies alone. Changing the current policy aimed at low food prices by maintaining low prices paid to farmers, would be a significant step toward reducing soil degradation in Niger. Food prices need to give signals to farmers to increase current capital expenditures because intensification will be profitable for them. In the long term technological change enables falling per unit output costs so prices can fall moderately with both farmers and consumers still benefiting.

Agronomic Studies for Producing
Hybrid Sorghum Seed
S. Sirifi, I. Kapran, S. Mason

During the 2001 cropping season, agronomic studies on pearl millet and sorghum were undertaken in Niger. On pearl millet, two experiments were conducted: one on microdose application and the other on population hybrid . The microdose experiment was conducted on-station and on-farm at Kalapaté station and region located at about 120 km from Niamey. The population hybrid study was done in N'Dounga and Kallapaté stations. Work on sorghum concerns trials on density x fertilization (nitrogen or phosphorus) in hybrid production. Trials were installed in Kollo, Maradi and Lossa stations. Due to poor growing conditions, sorghum data is not included.

Pearl Millet Microdose Study. This is a regional INTSORMIL-funded study including Niger, Burkina Fasso and Mali. The objective of the study was to find out the best combination of microdose, nitrogen (N) and phosphorus (P) rates for millet production in the region. The microdose study consisted of on-station and on-farm trials. The on-station trial was installed on sandy sol in a fallow area with an average annual rain of 400 to 500 mm. It had eight treatments which were: a check (T1), microdose (T2), microdose + 20 units / ha of P (T3), microdose + 40 units / ha of P (T4), microdose + 30 units / ha of N (T5), microdose + 60 units /ha of N (T6), microdose + 20 units / ha of P + 30 units / ha of N (T7), and microdose + 40 units / ha of P + 60 units / ha of N (T8). The on-farm trial had three treatments only (T1, T2, T3) and was conducted in seven villages surrounding Kalapaté station on a distance of about 10 km apart. The microdose was the content of a coca cola bottle cup of an NPK fertilizer that was placed with seeds in hills at planting. The source of fertilizer used for the microdose was 15 15 15. For both experiments, an improved millet genotype called Zatib was used. A randomized complete block design was used with four replications. Before planting, soil samples had been taken in each plot for analysis.

In the on-station trial, grain yields varied between 455.7 kg ha^{-1} for the microdose + 40 P units/ha treatment (T 4), and 976.6 kg $ha^{-1}$for the microdose + 60 N units/ha treatment (T6) and microdose + 40 P units/ ha + 60 N units/ha (T8). The same tendency was observed for the other variables such as the biomass yield, the number of heads per meter square and the harvest index. In the on-farm trials grain and biomass production was much lower than in the on-station's. Grain yields of T1, T2 and T3 were 307.84, 326.33, and 460.78 kg ha^{-1}, respectively in on-farm trials, while they were 520.8, 642.9 and 765.0kg ha^{-1}, respectively, in on-station trial. In conclusion, two observations could be made from the microdose study on pearl millet. First, the use of microdose alone tended to improve seed germination and plant growth at early stage. Second, application of N up to 60 units tended to increase grain and biomass yield, but phosphorus application seemed not to have any effect on grain and biomass production.

*Pearl Millet Population Hybrid Study***.** A factorial experiment combining genotypes and environment was conducted at two INRAN research stations : N'Dounga and Kalapaté located at around 20 and 120 km from Niamey, respectively. Two factors was studied in this experiment – 1) genotypes which were composed of an improved local variety called Zatib, and a population hybrid named WA 13 (Georgia) from the U.S., and 2) environment which consisted of a poor cropping condition and a rich one. In the poor environment, both genotypes were cultivated with no fertilizer and planted at 0.80 m x 0.80 m. In the rich environment, the two genotypes were grown with fertilization (30 kg ha^{-1} of N + 20 kg ha^{-1} of P) and planted at 0.80 m x 0.40 m. The main objective of the study was to determine the performance of the population hybrid of pearl millet compared to the locally improved millet genotypes and see if pearl millet hybrids can be adopted by farmers from Niger.

Results did not show any interaction between genotype and environment for all variables in the two study sites. Nevertheless, main effect of genotype and environment indicated some significative differences among the two varieties and the two environments. On the main effect basis, yields from the local millet genotype (Zatib) were twice the amount as those from the population hybrid WA 13 (Georgia) in both localities. At Kalapaté station for example, grain yield of the local variety was 502.93 kg ha^{-1}, while that of the population hybrid was 201.17 kg ha^{-1} (table 6). Grain and biomass yields were greater in the rich environment than in the poor one (table 7). They were 485.35 against 218.75 kg ha^{-1} at Kalapaté and 367.19 against 283.20 kg ha^{-1} at N'Dounga for the rich and poor environments, respectivily. Production of the improved variety and the population hybrid was low eventhough the local millet perfomed much better than the population hybrid. Reasons for the poor performance of millet in this study were diverse, although insects, diseases, striga, soil poverty and drought were the main cause of this failure. For the population hybrid, seed quality might be another reason of its bad performance compared to Zatib, as its germination and stands were very poor.

Nigeria

Pearl Millet Hybrid Evaluations
I. Angarawai, W.B. Ndahi, I. Ezeaku

Multilocational Pearl Millet Hybrid Evaluation. Previous evaluation by Lake Chad Research Institute (LCRI) and ICRISAT have indicated that millet hybrids, based on male-sterile lines, are high yielding, disease resistant and tolerant to environmental stress. The present trials were carried out to evaluate these hybrid lines for yield and early maturing attributes across the millet growing zones of Nigeria. The trial was made up of 12 entries consisting of 10 hybrids, selected from Advance I and II hybrid trial of 2000 season, improved and local checks. The trial was planted in six locations; Maiduguri, Gashua, Kano, Katsina, Gosau and B/Kudu in Northern Nigeria. In each location, the experimental design was RCBD. Each treatment was replicated three times in plot size of 4.5 x 5 metre square. Data were recorded from 4 middle rows for days to 50% flower, grain yield, plant height, panicle length, downy mildew incidence and *Striga* score.

There were significant differences among the hybrid lines for days to 50% flowering and grain yield. Grain yield ranged from 2110 – 2346 kg ha^{-1}, with LCIC MH99=10 given the highest yield of 2346kg/ha. Days to 50% flowering ranged from 53-62 days in which hybrid LCIC MH99-25 was the earliest to flower. Downy mildew incidence was generally very low. In general, there is great potential in the hybrids for higher yields and earliness as indicated at Gosau with average yield of 3552 kg ha^{-1}.

Evaluation of Top cross Pearl Millet Hybrids. Some millet top cross hybrids obtained from the Tifton Experiment Station, U.S.A. under the collaborative arrangement between LCRI and INTSORMIL were evaluated in Maiduguri, during the 2001 cropping season. The main objective was to evaluate the performance of these hybrids their adaptability, stability, resistance to Downy Mildew, *Striga* resistance and grain yield. The trial was planted at the LCRI Experimental Station at Maiduguri. A total of 27 entries consisting of 23 top cross hybrids, 2 open pollinated and 2 checks were planted out in a RCBD experimental design with 3 replications. Planting was done on 29/06/2001 into plots made up of four rows, 75cm apart at an inter-row spacing of 50cm. Fertilizer was applied at the recommended rate of NPK 60:30:30kg/ha. The plots were hoe-weeded at 4 and 8 WAS.

There were significant differences among the hybrids for days to bloom, plant height, panicle length, downy mildew incidence and severity, and grain yield. It was generally observed that all hybrids line with SOSAT-C88 as female parent gave high grain yields, ranging from 1978-2155kg/ha. This shows that SOSAT-C88 can be exploited as a female parent, being a good general combiner for yield, medium maturing, average height, medium panicle length and lower downy mildew and *Striga* incidences.

Millet Utilization
I. Nkama

The major sorghum and millet production and utilization constraints include lack of improved millet varieties and lack of adoption of new production and utilization technologies by farmers and processors. An important use of sorghum and millet food in Nigeria is in the preparation of tuwo, kunu, fura, ogi, adaiey, masa, sinasiri, and dakuwa. Grain and flour properties that may contribute to the production of acceptable food products need to be defined. Also, improvement of traditional food products and revolutionary change of sorghum and millet to new shelf stable foods and industrial products is needed to encourage increased production of grain. Sorghum has faired better than millet in Nigeria because additional industrial uses are now available in areas of bear brewing, malt drinks, biscuits, and animal feeds.

Research Approach and Project Output

Millet grain samples grown by Lake Chad Research Institute (LCRI), Maiduguri, and local cultivars were analyzed for physical, chemical, rheological, and sensory properties. Various food products (weaning foods, tuwo, ogi (akamu), ndaley, fura, kunu, and dakuwa) were prepared to test the quality of the different grain samples.

Grain and Food Quality

Eleven multilocational pearl millet hybrid lines and one farmers' local grown by LCRI were evaluated for their physical, chemical, and sensory attributes. There were variations in the 1000 kernel weight (8.9 – 10.96 g), 1000 kernel volume (5.5 – 6.85 mg), density (1.05 – 1.63 g/ml), and germination percentage (85.7 – 97%). Also, the proximate composition varied considerably with the exception of crude fiber. Protein ranged from 10.6 – 13.8%, fat 4.1 – 6.8%, ash 1.3 – 1.8%, and crude fiber 2.0 – 2.4%. Protein fat, and ash content of all the hybrids ranged within the normal values for pearl millet and also in comparison with farmers' local. Preliminary studies on the acceptability of these hybrids for the preparation of kunu, zaki, and ogi showed that all the hybrid lines can be used to produce acceptable products. These hybrids can be considered as good materials for food processing.

Studies on Tuwon Tsari Flours

Tuwo is a thick porridge which is prepared from rice, maize, sorghum, or millet depending on taste, cost of grain, geographical location, and availability of grain. Tuwo is a common staple food item for about 57 million people living in the northern part of Nigeria. Tuwon tsari is a variation of normal tuwo prepared specifically from pearl millet. During its preparation, the grain is dehulled, steeped in acid water prepared from lime juice or tamarind pulp extract or kadel (steep liquor from previous fermentation for 2 to 3 days, sun-dried and ground into flour). The process of fermentation removes the colored pigment. The flour is cooked into a thick gruel before serving.

During the production of the tsari flour from 4 different pearl millet cultivars (Ex-Borno, GB8735, SOSAT-C88, and Zango), we observed that protein content decreased on an average of 24.5%, fat by 24.8%, and ash by 70.6%. There were no significant differences in the amount of protein recovered among the 4 cultivars, but recovery of fat and ash were significantly different among cultivars. *In vitro* carbohydrate digestibility of the native grain was low (20.4%). On processing, this increased to 71.5%. The *in vitro* protein digestibility also increased from 47.9% in the native grain to 54.8% in the tsari flour. Phytic acid content of the pearl millet samples decreased by 72% in the tsari flours and this resulted in the increase in mineral availability in all samples by 20% for calcium, 13% for copper, and 30% for phosphorous.

All tsari flour samples (6% w/w) had similar hot past viscosities (mean 35,840 centipoise). The peak viscosities were also similar, although tsari flour from Zango millet gave slightly lower peak viscosity. Tsari flour samples had a fairly high set back value which indicates that the cultivars would give good stiff porridges that are normally consumed with fingers. Sensory evaluation studies revealed significant differences in color, flavor, taste, texture, and overall acceptability of the tsari flour samples from the 4 cultivars. Tuwon tsari from Zango (a popular local millet grown in northwestern Nigeria) and SOSAT-C88 (improved cultivar released in 1999 by LCRI) received the highest scores. No sample was rated below average in all the attributes considered. The lowest average score was 6.6 on a 9 point hedonic scale. Studies in the Department of Science and Technology Laboratory at University of Maiduguri indicate that the tsari flour can also be used in the preparation of weaning foods, biscuits, couscous, dakuwa (snack food from millet-groundnut blend), and fura.

Sorghum Trials
P. Marley, D.A. Aba, J.A.Y. Shebayan,
L. Bamaiyi, D. Rosenow

Sorghum production in Nigeria is affected by several constraints which include lack of improved varieties especially those that are medium to late maturing (most suitable for cultivation) in the Sudano-Guinean ecological zones. Other constraints include biotic constraints amongst others. Biotic constraints are mainly pest and diseases of which sorghum midge, stem borers and headbugs remain the major pest problems while anthracnose, grainmould, and smuts are the major disease problems. Although the IAR/INTSORMIL Collaborative Research Programme started late in 2001, seven trials were conducted in the 2001 cropping season. These were in the areas of Pathology and Breeding.

In the International Sorghum Anthracnose Virulence Nursery trial, nine lines including B.TX 398, IS 854, SC 283, IS 12467 R.TX 434, SC 326-6 (IS 3758), IS 18760, SC 414-12E (IS 2508) and IS 6959 were resistant (average disease score of 1-3). Two of these lines SC 326-6 (IS 3758) and SC 414-12E (IS 2508) have currently been selected alongside our materials (SK5912, KSV 8, NRL 3 and Yar'ruruka) for genetic mapping. Of 28 lines that could be evaluated, 9 lines were resistant to foliar anthracnose. All 28 lines were resistant to covered, loose, long, head smut and grain mould. Other foliar diseases especially grey leaf spot and leaf blight were not observed. Insect infestation could not be assessed due to low insect pressure. Nineteen of the lines were resistant to foliar anthracnose while three lines were susceptible.

Results of the *Striga* control nursery showed that lines 97-SB-F5-DT-63, 97- SB-F5-DT-64, MALISOR 92-1, SRN 39 and SAMSORG 41 (ICSV 111) supported low *Striga* infestation and also showed low number of stands infested with *Striga*. This indicates the lines are resistant to *S. hermonthica*. Lines CMDT 45 and SAMSORG 14 (KSV 8) had high *Striga* infestation, but SAMSORG 14 gave the highest grain yield. This clearly either indicates resistance or a high level of tolerance.

In the Advanced Medium Maturing trial, days to flowering ranged from 72.5 for entry 8(97-SB-F5DT-38) to 85 for entry 26 (SURENO 99L-1048). This shows low variation for that character (CV 5.55%). Plant height ranged from 95cm for entry 3 (97-SB-F5DT-149) to 272.5cm for entry 13 (97-SB-F5DT-97). There seems to be a wider variation in this trait (CV 42.41%) than in the previous one. Grain weight ranged from 266.7kg/ha for most of the entries to 1866.7 kg ha^{-1} for entries 21 and 25 (Samsorg 14 and ICSV 905). These are local varieties. Only entries 22, 23 and 24 (KL-2, makaho Da Wayo and Farar Dawa) gave yields above 1000 kg ha^{-1}. All the exotic materials performed below 700 kg ha^{-1}. There are still some promising materials if tested for another year to confirm their performance.

In the Advanced Late Maturing trial, days to 50% flowering ranged from 51 for entry 1(97-FA-FST-71-2) to 85 for entry 16 (Samsorg 17). There is low variation within these traits (CV 29.62%). Plant height ranged from 122.5cm for entry 5(97-SB-FST-154). The entries seemed to differ much in height (CV. 36-46%). For grain yield, it ranged from 333.3kg/ha for entries 5 and 7 (97-SB-F5DT-154 and 98-FA-FST-41) to 1133 kg ha^{-1} for entry 16 (Samsorg 17). Entry 16 is later than all other entries and gave the best yield. Entries 1, 8, 9, 10, 11 and 12 hold some promise in terms of yields.

It is expected that most of these trials will be established in the 2002 cropping season. Further, this collaborative program has started research and extension activities in the area of sorghum utilization. This involves the development of sorghum based food products and an improved charcoal – based oven for use in baking sorghum based products. This improved oven was developed in 2001 under the program and is currently under testing. This will be extended to rural women for enhancement of their income.

Burkina Faso

Mechanized Zaï Research
J.B. Taonda and Steve Mason

The traditional zaï system composed of planting pearl millet seed in a small hole with a small amount of manure increases water infiltration on some soils and results in increased yield, but requires considerable land labor. Scientists at INERA have developed a mechanized zaï using animal traction. The objective of this study was to determine the effectiveness of the mechanized zaï to the traditional zaï and a flat-planted control across six different soil types in Burkina Faso. The study was conducted on 12 farms in three villages with each farm considered a replication. The soil types present on the farms was sandy, sandy loam, sandy clay, clay, gravelly clay and gravel.

Pearl millet grain yields were over 1.0 Mg ha^{-1} on the sandy and clay soil, approximately 0.7 Mg ha^{-1} on the sandy clay, gravelly clay and gravelly soil, and 0.4 Mg ha^{-1} on the sandy loam soil, but no interaction between soil type and planting method was found. The traditional and mechanical zaï produced similar grain and stover yields, which were more than 0.4 Mg ha^{-1} more grain than the control and more than 1.4 Mg ha^{-1} more stover. The mechanized zaï has potential to produce the yield advantage associated with the traditional zaï system through use of animal traction, but with greatly reduced labor and economic cost. The manual zaï system requires approximately 300-man hours of labor/ha while the mechanized zaï requires approximately 22 man hours/ha.

Networking

INTSORMIL supported joint activities with the regional millet and sorghum networks, ROCEFREMI and ROCARS, respectively. Contacts have been made with **AFRICARE** and **World Vision International** in Niger. Africare heads a consortium of four NGO's receiving funding from USAID for a food security development project in Niger. World Vision supports seed activities in the Maradi region of Niger.

Partners in the Niger sorghum hybrid seed production effort include the IFAD/INRAN technology transfer project, the IFAD/Tillabery project, and the WINROCK-ONFARM project.

West Africa/Western Region (Mali, Ghana, Senegal)

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Collaborative Program

Program Structure

The INTSORMIL collaborative program in Mali is a large multidisciplinary research program. The program centers around Malian scientists and each Malian scientist develops research plans cooperatively with a U.S. counterpart which provides for effective research planning, communication, and coordination. Each year INTSORMIL collaborators travel to Mali as appropriate to observe field trials, consult, review progress and plan future activities with Malian scientists. Occasionally, IER scientists also travel to the U.S. for research review, planning, and coordination. The planned project activities then become part of the annual Amendment to the MOA between INTSORMIL and IER.

The program includes all aspects of sorghum/millet improvement with major emphasis on breeding or germplasm enhancement, utilization and quality, nutrient use efficiency, soil management, insect pests, disease control strategies, and *Striga* control.

A new thrust to the program previously centered in Mali began in 2000-2001 with the initiation of collaborative INTSORMIL research in Ghana and Senegal. A MOU between INTSORMIL and ISRA (Institute of Agricultural Research) in Senegal was signed in early 2001. An existing MOU with SARI (Savanna Agricultural Research Institute) in Ghana which involved agronomic research between Dr. S.S. Buah and Dr. J.W. Maranville was utilized to include the new collaborative efforts in Ghana.

Collaborative research was initiated in the 2001 crop season in both countries in breeding, pathology, entomology, and *Striga*, and also in agronomy in Ghana, continuing some of the research initiated in collaboration with Dr. J. Maranville. Breeding, disease, insect, drought, and *Striga* trials were developed collaboratively with Malian and U.S. INTSORMIL scientists and grown in Ghana and Senegal as well as in Mali. Some of these were also offered to scientists in Niger, Burkina Faso, and Nigeria, and scientists there requested seed of specific nurseries according to their interests and needs. Also, an elite sorghum germplasm nursery from worldwide sources was sent to Ghana and Senegal to broaden the genetic base of their breeding program. The mechanism for developing collaborative research plans is evolving as new INTSORMIL PIs initiate their programs, and PIs are able to travel to these new countries. The PI Conference in Ethiopia in November, 2002 will serve as the initial broad based planning conference for collaborative research efforts among Mali and the new countries as well as with the Eastern Region (Niger, Nigeria, and Burkina Faso) scientists.

Other Collaboration

Collaboration involving germplasm exchange, workshops, monitoring tours, and specific research projects continued with the regional networks ROCARS (WACSRN), and ROCAFREMI as well as with ICRISAT at Samanko outside Bamako, Mali. There also was cooperation with NGOs such as World Vision, Winrock, and CMDT in evaluation of potential new cultivars as well as with the Soil Management CRSP and the SYNGENTA Foundation.

Financial Input

The USAID Mission has in the past provided significant financial support to IER research program through the SPARC Project which ended in June 1997. In addition to the Malian Government, the Ciba Giegy Foundation (Syngenta) and World Bank support the IER research program.

Sorghum/Millet Constraints Researched

Plant Production Constraints

The yield level and stability in sorghum and millet production is of major importance in all the countries. Drought is a serious constraint to production over much of the area. Diseases, insect infestations and *Striga* significantly affect both sorghum and millet production. Head bugs and associated grain molds adversely affect sorghum yield and grain quality of sorghum. Anthracnose is a very severe sorghum disease in the more humid areas and long smut is severe in the drier regions. Sooty stripe can be a severe leaf disease problem. *Striga* is a major constraint for both sorghum and millet. Downey mildew is a serious problem on pearl millet.

Land Production Constraints

Low soil fertility combined with the low yield and unstable yields of local cultivars affect sorghum and millet production. Major soil related constraints to production are phosphorus and nitrogen deficiency, and water stress.

Technological and Socioeconomic Constraints

There is a lack of farm credit policy which would encourage adoption of improved sorghum and millet new cultivars. In addition, the prices of these two cereals are low and unstable. New shelf-stable foods, industrial sorghum and millet based products, and enhanced use for animal feed are needed to encourage production.

Research Methods

The collaborative program in the Western Region of West Africa emphasizes research in breeding (germplasm enhancement), entomology, pathology, agronomy (soil, water, fertility relationships), weed science (*Striga*), cereal technology (quality and utilization), marketing, and technology transfer. An effort to develop new food products from sorghum and millet is emphasized in Mali along with new cultivars with improved food quality traits. Major breeding activities involve the use of new genetic materials to develop cultivars to increase or stabilize yields of grain with enhanced food quality traits. Research methods appropriate for each of these are used in this research program.

Research Results

Details of some of the research related to Mali are presented in individual PI project reports in this publication. This Host Country Annual Report will emphasize research done by IER in Mali, SARI in Ghana, and ISRA in Senegal.

Sorghum Breeding

The sorghum breeding program in IER in Mali is a large and diverse program. The IER sorghum breeding program does extensive crossing and intercrossing among elite introductions, improved non-guinea and guinea derived breeding lines, and elite local cultivars. It utilizes genetically diverse germplasm from around the world resulting in much genetic diversity in the breeding program. Extensive use is made of ICRISAT developed lines and elite lines from the U.S. Emphasis in the program centers on developing tan-plant true guinea cultivars, and on improving the head bug/grain mold resistance of high yielding tan-plant non-guinea breeding lines and guinea by non-guinea intergrades. Essentially 100% of the breeding effort is directed to white-seeded, tan-plant genotypes. Breeding for the dry northern areas also involves crosses with local Durras from the area and early Caudatum derivatives from Senegal.

A standard system of moving progenies along at the different locations is in place and understood by the technicians. After the F_2, progenies are separated into early, medium, and late maturing groups and then selected and advanced at appropriate sites. Early materials are selected at the lower rainfall, more northern sites of Bema and Cinzana, while medium maturity materials are grown at Sotuba, Kolombada, and Cinzana. Late maturing progenies are evaluated mainly in the southern, high rainfall sites of Farako (Sikasso), Finkolo, and Kita. Yield trials of advanced breeding lines also are divided into these three general maturity groups and corresponding sites.

New breeding crosses are made annually to assure the gradual improvement of new breeding materials through recombination of the best materials. In the 2001 rainy season, 62 new crosses were made at Sotuba, and the F_1's grown during the 2001-02 off-season nursery to get F_2 seeds along with selected breeding lines for making new crosses.

From the multilocation evaluation of the 119 F2 families in 2001 520 single-plant selections were made to be advanced by the pedigree method. F_3 progenies (860 entries) were grown at Samanko, Cinzana and Béma with 346 panicles selected. The F_4 and F_5 generations were evaluated according to maturity group. The early and medium F_4 progenies were evaluated together this year at Sotuba, Kolombada, Béma and Cinzana with 308 panicles selected among 50 families. The late F_4 progenies were evaluated at Finkolo and Kita with 52 panicles selected. From 843 F_5 generation progeny rows a total of 40 early (Bema and Cinzana), 82 medium (Sotuba and Kolombada), and 44 late (Longorola and Kita) panicles were selected. The F_5 selections move to the off season for seed increase for entry into yield trials the following year.

Yield trials of improved varieties in 2001 were divided into three maturity groups, Early, Medium, and Late with three groups (GI, GII, GIII) within each maturity corresponding to the years in tests (I - first year, II - second year, III - third year). Evaluation was for maturity, yield, agronomic desirability, and food quality.

Advanced Early Variety Trials

In GI at Cinzana there was a significant difference among entries with the highest yielding varieties being 00-BE-F5P-33 (3333 kg ha^{-1}), 00-BE-F5P-135 (3056 kg ha^{-1}) 00-BE-F5P-29 (3000 kg/ha) and 00-BE-F5P-15 (3000 kg ha^{-1}). The first three are derived from (Malisor 84-7*nagawhite)*CEM326/11-5-1-1 while the last one is derived from a cross (Malisor 84-7*nagawhite)*Malisor 84-7. The mean test yield at Cinzana was 2230 kg ha^{-1}, with the local check producing 1222 kg ha^{-1}. At Bema the highest yielding varieties were 00-BE-F5P-71 (2695 kg ha^{-1}) which is derived from (Malisor 84-7*nagawhite)*CEM326/11-5-1-1 and Malisor 92-1 (2489 kg ha^{-1}).

In GII (two year evaluation) at Cinzana with significant differences among lines the variety 99-BE-F5P-122 derived from the cross (Sureno*85-F4-204)*N'Tenimissa ranked first with 2833 kg/ha against 2222 kg ha^{-1} for the local check and a test mean of 2127 kg ha^{-1}. At Béma there was no significant difference among entries for grain yield due to drought damage.

After three years of evaluation in the two locations (GIII), four lines 98-CZ-F5P-31-1, 98-CZ-F5P-18, 98-BE-F5P-24, and 98-CZ-F5P-83 will be in on-farm test this growing season (Table 1).

Advanced Medium Variety Trials

In GI at Sotuba, the variety 00-SB-F5DT-5 ((Malisor 84-7*nagawhite)*CEM326/11-5-1-1) ranked first with 3666 kg ha^{-1} followed by 00-SB-F5DT-18 (3250 kg ha^{-1}) with the same pedigree. The grain yield was 1583 kg ha^{-1} for the local check with a test mean of 1739 kg ha^{-1}. At Kolombada the average yield was lower (1088 kg ha^{-1}) with the highest yielding variety 00-SB-F5DT-18 ((Malisor 84-7*nagawhite)*CEM326/11-5-1-1) with 1846 kg ha^{-1}. In GII at Sotuba and Kolombada, there was no significant difference among entries for grain yield.

After three years of evaluation in the two locations (GIII), the three highest yielding varieties are 98-SB-F5DT-4 (Bimbiri soumale* N'Tenimissa) with 2286 kg ha^{-1}, 98-SB-F5DT-23 (CSM 388*(Bimbiri soumale*ICSV-1034)) with 2470 kg ha^{-1} and 98-SB-F5DT-14 (Bimbiri soumale* N'Tenimissa) with 2209 kg ha^{-1} (Table 1), and were selected for on-farm-testing next year.

Advanced Late Variety Trials

In GI at Finkolo, with an average yield of 1875 kg ha^{-1}, the highest yielding varieties were 00-KI-F5T-47 derived from the cross (N'Tenimissa * Local Tamala) with 3933 kg ha^{-1}, Foulatiéba (3900 kg ha^{-1}) and 00-KI-F5T-32-1 (2933 kg ha^{-1}). At Kita there was no significant differences among entries with an average yield of 1600 kg ha^{-1}. In GII at Finkolo the variety 97-SB-F5DT-150 ranked first with 2142

Table 1. Mean performance data from selected improved varieties from sorghum yield trials, Mali, 1999-2001.

Designation	Pedigree	Days to 50% flowering	Plant height (m)	Grain yield (kg/ha)
Early - GIII (3 years - 2 locations)				
98-CZ-F5P-18*	((Bimbiri S.*S34,)*Malisor 92-1)	76	2.4	2654
98-CZ-F5P-31-1*	((A Var *98-SB-F6-GII-2073)*Bimbiri S.)	73	3.2	2558
98-BE-F5P-24*	((Bimbiri S.*S34)*CSM388)	72	2.6	2347
98-CZ-F5P-83*	((Bimbiri S.*S34)*CSM219)	74	2.1	2307
CSM 63E	Check	66	2.9	1675
Local check		74	3.4	1702
(Test Mean)		74	2.5	2041
Medium - GIII (3 years - 2 locations)				
98-SB-F5DT-23*	(CSM388*(Bimbiri S.*ICSV1034))	84	3.2	2470
98-SB-F5DT-4*	(Bimbiri S.*N'Tenimissa)	85	3.6	2286
98-SB-F5DT-14*	(Bimbiri S.*N'Tenimissa)	83	2.9	2209
98-SB-F4DT-44		90	1.9	2088
CSM 388	Check	88	3.7	2157
Local check		86	3.6	2111
(Test Mean)		87	3.3	1914
Late - GIII (3 years - 2 locations)				
97-SB-F5DT-74-1	(N'Tenimissa*Tiemarfing)	86	3.4	1622
97-SB-F5DT-74-2	(N'Tenimissa*Tiemarfing)	87	3.4	1583
98-FA-F5T-41		86	3.6	1600
Foulatieba	Check	90	3.4	1911
Local check		91	3.5	1483
(Test Mean)		88	3.4	1614

* = Entries to be advanced to on-farm trials in 2002.

kg ha^{-1} against 633 kg ha^{-1} for the local check and a test mean of 1140 kg ha^{-1}. At Kita there was no significant difference among entries for with an average grain yield of 3218 kg ha^{-1}. After three years of evaluation in the two locations, there was no significant difference among entries for grain yield (Table 1).

On-Farm Trials

Three early maturing varieties were compared to the local check by 6 farmers at three locations, Cinzana, Sirakorola, and Didiena. For varieties in their second year of evaluation, there was no significant yield difference, but at Cinzana 98-BE-F5-84 and 96-CZ-F4P-12 produced excellent tô quality. At Sirakorola and Didiena 98-BE-F5P-84 and 97-SB-F5DT-65 was appreciated for earliness, grain quality and plant height, while 96-CZ-F5P-12 was appreciated for stalk quality for animal feed.

Two early varieties, 97-SB-F5DT-63 and 97-SB-F5DT-64 (N'Tenimissa*Tiemarfing) were evaluated for their third year by 6 farmers at three locations. Although there was no significant difference for grain yield, 97-SB-F5DT-63 was particularly promising and was appreciated by farmers enough that they named it "Uassa" (means 'satisfaction' in Bambara). It's main advantage over N'Tenimissa is whiter, higher quality grain.

For medium maturity varieties, 6 farmers at Ouelessebougou and Banocoumana evaluated three varieties for the second year. There was no significant difference in grain yield, but at Ouelessebougou farmers appreciated 97-SB-F5DT-76-2 for its drought resistance and suitable maturity. At Bancoumana, 97-SB-F5DT-76-2 was appreciated for its maturity while 97-SB-F5DT-150 was appreciated for its grain and stalk qualities.

Six farmers evaluated 98-SB-F2-78 for the third year. While not significantly different in yield, it was desired by farmers for its tô quality, drought tolerance and fast grain filling.

For late-maturing on-farm trials, 6 farmers at Kita and Finkolo evaluated seven new varieties with their local check. At Finkolo, all 7 varieties produced significantly higher grain yield than the local check (Table 2). At Kita the top three varieties were not significantly different from the local check.

Table 2. Mean of late maturity varieties for grain yield on on-farm test at Finkolo, Mali, 2001.

Designation	Grain yield kg ha^{-1}
97-FA-F5T-51	1954 a
97-FA-F5T-53	1807 a
97-SB-F5DT-74-1	1807 a
97-SB-F5DT-74-2	1856 a
97-CZ-F4P-98	1801 a
96-CZ-F4P-99	1874 a
97-SB-F5DT-154	1783 a
Local Check	1293 a
Mean	1772 b
CV%	7.7
Significance	**

Hybrid Sorghum - Mali

The cooperative hybrid research of IER and ICRISAT funded by the Rockefeller Foundation continued with the evaluation of breeding lines and local cultivars for restorer (B/R) reaction, and the presence of B_1. Sterilization of B-lines through backcrossing continued. Most U.S. and ICRISAT A-lines are dominant B_2, so recessive B_1 is needed when using these females in order for the grain of the hybrid to not have a testa. Some new Malian breeding lines were evaluated for their fertility reaction and B gene status.

West Africa Sorghum Breeding Observation Nursery (WASBON)

This nursery was divided into three maturity groups, early, medium, and late. Seed was assembled, tests packaged and distributed by Dr. Aboubacar Toure in Mali. The early test contained 16 entries from Mali, 21 from Niger, and 11 from Nigeria, and was sent to Mali, Niger, Senegal, Ghana, Burkina Faso, and Nigeria, as per requests from local scientists. In the 48 entry Early Trial at Cinzana in Mali, the top performers were 90SN-5, 90SN-3 and 90SN-1from Niger, and KSV11 and Samsorg 41 from Nigeria with yields ranging from 2250 to 2563 kg ha^{-1} compared to the test mean of 1521 kg ha^{-1}. At Nyankpala, Ghana, the top six performers were KSV12, KSV111, KSV400, and Samsorg 41 from Nigeria, 90SN-7 from Niger, and 98-SB-F4DT-52 from Mali. Their yields ranged from 1252 to 1501 kg ha^{-1} compared to the test mean of 990 kg ha^{-1}. In Senegal, the 48 entry WASBON was evaluated at Bambey, with yields ranging from 900 to 4700 kg ha^{-1} with a test mean of 2707 kg ha^{-1}. Based on vigor, cycle length, height, grain mold, and grain quality, 8 lines were selected for further testing and 6 others selected for use in crosses.

The Medium maturity nursery contained 29 genotypes, with 20 from Mali, 5 from Nigeria, and 4 from INTSORMIL (Texas A&M). In Mali at Sotuba, the top 7 genotypes were KL-2 (4567 kg ha^{-1}) and Farar Dawa (3133 kg ha^{-1}) from Niger, 97-SB-F5DT-56 (2467 kg ha^{-1}) and 97-SB-F2-78 (2210 kg ha^{-1}) from Mali, and Sureno (2933 kg ha^{-1}) and 90EON328 (2167 kg ha^{-1}) from Texas A&M. The test mean was 1780 kg ha^{-1}. In Ghana at Nyankpala there was tremendous variation in height and maturity. Grain yields were greatly reduced by drought and midge. The very late lines were severely damaged by midge. Grain yields ranged up to 2516 kg ha^{-1} with a test mean of 1577 kg ha^{-1}. Lines ICSV905 and Farar Dawa from Nigeria produced outstanding yields, but the performance by entry was non-readable on the e-mail. Another year of testing will be required before meaningful selection can be done.

In the Late maturity test, there were 9 entries from Mali and 7 from Nigeria. In Senegal, yields were low due to poor stands, short rainy period, birds, and the very late maturity of most entries. Five lines, 97-FA-F5T-53, 97-SB-F5DT-154, 98-KI-F5T-45, 98-FA-F5T-37, and 98-FA-F5T-41, all from Mali were retained for further testing. In Ghana, the late test entries yielded less than the medium maturity entries, with 96-CZ-F4P-99 (1127 kg ha^{-1}), 96-CZ-F4P-98 (1088 kg ha^{-1}), and 98-KI-F5T-45 (1075 kg ha^{-1}) all from Mali produced the highest yields with a test mean of 746 kg ha^{-1}.

Other Sorghum Breeding Activities

Senegal

Other breeding research involved evaluation of 74 F_4-F_6 Guinea derivative families from ICRISAT with 17 selected for further evaluation. Two regional ICRISAT trials of guinea lines were also evaluated but not selected due to their excessive height and average yields. From the INTSORMIL West Africa Drought Test, 3 entries were found to be superior, TX7000, Macia, and the hybrid Hageen Dura 1. From the 50 entry Elite Germplasm Nursery assembled by TAM-222 in Texas, 9 lines were selected for further use; MP531, S-34, ICSV401, Sureno, (ICSV401*S34), ZSV15, KAT 83369, 82-F4-164, and (E36-1*M84-7)-5-1.

Ghana

Due to late and erratic rainfall coupled with the early cessation of the rains, general performance of sorghum trials was poor. The West Africa Drought Test was lost due to poor stands. The INTSORMIL trial, ADIN (All Disease and Insect Nursery), was also evaluated and some data on disease reaction obtained for grey leaf spot and leaf blight. One ADIN entry, SC326-6, was found to be severely attacked by bacterial leaf stripe (*Burkholderia andropogonis*), a quarantine pathogen of sorghum in Ghana. The performance and disease reaction of the WASDON (West Africa Sorghum Disease Observation Nursery) is presented in Table 3.

Millet Breeding

Mali

Trials were conducted to evaluate the performance of population hybrids among West Africa landraces and to determine if cycle of recombination had an effect on performance. Twenty-five population hybrids were evaluated and compared with three local check cultivars. The hybrids were all earlier in flowering, shorter in height, and were severely damaged by birds compared to the check cultivars Boboni, Toroniou C1, and SoSat. The resulting grain yield of the hybrids was much lower, generally about 1,000 to 1,100 kg ha^{-1} compared to 2620, 2305, and 1575 kg ha^{-1} for the locals. From 30 to 50% of the panicles were emptied by bird attack in the hybrids. WA16 showed potential due to its head length and high number of tillers. Delayed sowing by 7 to 10 days may allow the new varieties to avoid bird damage.

In the recombination cycle study among two pedigrees, ExBorno*Ugandi, and ExBorno*Mansori, there was no dif-

Table 3. Performance data and field reactions[1] of sorghum genotypes (WASDON) to different diseases at Nyankpala, Ghana, 2001.

Entries	Origin	Days to 50% flowering	Plant height (cm)	Grain yield (kg ha^{-1})	Grey leaf spot	Leaf blight	Grey leaf spot on panicle	Bacterial leaf stripe
SAMSORG 14	IAR, Nigeria	93	365	373	4.0	1.0	3.0	1.0
SAMSORG 40	“	93	202	973	1.0	2.0	1.0	1.0
SARIASO-01	INERA, Burkina	91	378	2040	4.0	1.0	4.0	1.0
SARIASO-02	“	88	341	813	5.0	1.0	6.0	1.0
OUEDZOURE	“	95	447	1987	4.0	1.0	4.0	1.0
SC326-6	Texas, USA	99	135	520	1.0	1.0	1.0	8.0
VG 153	“	87	192	1667	1.0	4.0	1.0	1.0
SURENO	“	95	176	320	1.0	3.0	1.0	1.0
9GW092	“	87	124	400	1.0	5.0	1.0	1.0
90L19178	“	86	197	1400	1.0	3.0	1.0	1.0
98-FA-EART-101	IER, Mali	99	154	440	1.0	3.0	1.0	1.0
98-SB-F5-DT-25	“	92	342	493	2.0	1.0	2.0	1.0
98-SB-F5-DT-59	“	87	365	1640	1.0	3.0	1.0	1.0
98-SB-F5-DT-4	”	86	355	2000	1.0	4.0	1.0	1.0
98-KO-F5-DT-39-2	“	87	366	1960	1.0	3.0	1.0	1.0
98-KI-F5-T-45	”	90	351	813	1.0	4.0	1.0	1.0
98-F2-82	“	92	177	1160	1.0	2.0	1.0	1.0
97-SB-F5-DT-154	”	93	139	1280	1.0	4.0	1.0	1.0
97-SB-F5-DT-160	“	93	145	267	1.0	4.0	1.0	1.0
F2-78	”	91	129	1133	1.0	3.0	1.0	1.0
97-SB-F5-DT-150	“	95	127	427	1.0	5.0	1.0	1.0
97-SB-F5-DT-151	”	99	152	293	1.0	1.0	1.0	1.0
FOULATIEBA	“	92	421	2200	4.0	1.0	2.0	1.0
IS 18442	ICRISAT, Mali	86	287	920	6.0	1.0	6.0	1.0
A2267-2	“	91	225	867	1.0	3.0	1.0	1.0
Mean[2] (25 entries)		91.5	251.6	1055.5	1.9	2.6	1.8	1.3
CV (%)		2.6	5.7	50.3				

1 Based on rating scale 1-9: 1 = no disease; 2 = 1-5%; 3 = 6-10%; 4 = 11-20%; 5 = 21-30%; 6 = 31-40%; 7 = 41-50%; 8 = 51-75% and 9 = > 75% of leaf area of the plant or panicle parts damaged by the disease.

2 Mean of two replications.

ference in grain yield with up to three recombination cycles compared to the open pollinated.

Senegal

Two advanced yield trials with 10 and 6 lines respectively were conducted in Bambey. Two new synthetics of the Senegal program ISMI9507 (3009 kg ha^{-1}) and ISMI 9503 (2821 kg ha^{-1}) significantly out-yielded the check IB 8004 (1875 kg ha^{-1}) in the first trial with mean 2302 kg ha^{-1}. The 3-year (95, 96, 01) mean yield of ISMI 9507, 9506, 9503 was respectively 37.4%, 35.4%, and 32.7% higher than the checks.

In the second trial, the highest yielder was the check IBMV 8402 (2858 kg ha^{-1}) and is followed by a new synthetic ISMI 9305 (2656 kg ha^{-1}) and IBV 8004 (2595 kg ha^{-1}). Yield of these varieties was not significantly different. However, the 5-year (93, 94, 95, 96, 01) mean yields show that ISMI 9301, 9303, 9305 are superior to the variety IBV 8004 with up to 16% higher yields. Seeds of the new synthetics will be multiplied and introduced in on farm test.

Striga

A West Africa *Striga* Nursery was developed for 2001 with entries solicited from all INTSORMIL collaborating countries. Seventeen entries were received from Mali, Nigeria, Burkina Faso, and USA. Seed was assembled in Mali and distributed to interested countries. Results from the replicated trials were received from Mali, Nigeria, Senegal, and Ghana. Data from Cinzana and Sotuba, Mali, and Samaru, Nigeria are presented in Table 4.

In Ghana two trials were planted with one lost to drought. Data on the 16 varieties is shown in Table 5 with generally a high level of resistance. CE151-262-A1 had no infestation throughout the season but the grain was destroyed by midge. 097-SB-F5DT-64 combined high yield with low *Striga* infestation. N'Tenimissa, Samsorg 14, and IS7777 appeared to be most susceptible.

In Senegal, under field evaluation where pearl millet had been grown continuously, *Striga* emergence was the highest on CE151 with 10 pl/m^2, while all other lines had less than one. CMDT38, Malisor 92-1, Malisor 84-1 and Samsorg 41 were free of *Striga* throughout their cycle. In a screen house with artificial inoculation of *Striga* seed harvested from a sorghum field, *Striga* plants first appeared on CMDT-39 at 43 days and CMDT-38 at 45 days. These two plus CMDT-45 had the highest number of *Striga* plants with 9, 11, and 12, respectively. *Striga* appeared the latest on Seguetana (80 days) and was the attacked along with Malisor 92-1 with only two emerged on each. These results suggest that millet and sorghum are attacked by different biotypes.

Overall, results seem variable with some rather major switches in reaction over location such as with CE151 and Samsorg 41. The Mali improved local Seguetana appeared quite resistant across locations. The trials will be repeated in 2002.

Agronomy

Mali-Sorghum

On-farm research to assess the nutrient availability in Malian soils was conducted in 2001 in three villages each in the Bougouni and Kita areas. Sorghum yield response to various fertilizer treatments was evaluated, using NPKS compared to (-P), (-N), (-S), (-K), and check (no fertilizer).

Table 4. Performance data from the 2001 West African *Striga* Nursery, Mali and Nigeria.

		Cinzana				Sotuba			Samaru, Nigeria						
Variety Designation	Country of origin	Days to 50% flower	Plant height (m)	*Striga* incidence	Grain yield (kg ha^{-1})	60 days	75 days	90 days	9 weeks	11 weeks	Harvest	9 weeks	11 weeks	Harvest	No. *Striga flowers* at harvest
CMDT-38	Mali	73	3.3	1	1184	1	1	1	3.7	9.7	21.7	1.0	4.0	9.7	18.7
CMDT-39	Mali	74	3.3	1	667	3	3	3	1.7	4.7	17.7	1.3	3.3	10.3	16.3
Seguetana	Mali	78	3.2	1	1481	1	0	0	0	3.0	9.3	0	2.3	6.0	9.3
CMDT-45	Mali	73	3.5	1	1037	3	2	3	1.7	12.0	28.3	0.7	4.7	15.7	28.0
97-SB-F5DT-63	Mali	72	3.4	1	1481	4	5	4	0	0	2.0	0	0	2.0	2.0
97-SB-F5DT-64	Mali	72	3.0	1	1037	3	2	5	0	0	1.3	0	0	1.0	1.7
N'Tenimissa	Mali	74	3.4	2	963	4	5	5	0	0.7	4.7	0	1.0	4.3	4.3
97-SB-F5DT-65	Mali	74	3.1	1	1185	4	5	5	0	0.7	6.0	0	0.3	5.3	4.3
Malisor 92-1	Mali	71	1.8	2	1556	5	6	7	0.3	0.7	2.7	0.3	0.7	2.3	2.3
Malisor 84-1	Mali	66	1.8	1	1556	3	3	2	0.3	3.0	7.3	0.3	2.7	3.3	6.7
CE151-262-A1	US/Senegal	73	1.3	3	1407	7	9	7	0.3	3.7	8.0	0.3	2.0	4.3	7.7
SRN39	US/Purdue	64	1.2	1	889	3	5	4	0	0	0.7	0	0	0.7	0.7
Samsorg 41	Nigeria	65	2.0	1	1556	17	30	4	0	0.7	0.3	0	0.7	0.3	0.3
Samsorg 14	Nigeria	82	2.8	3	815	10	18	20	1.7	9.0	26.7	1.3	6.0	13.3	26.7
Sariaso 1	Burkina Faso	87	3.4	4	593	4	6	8	—	—	—	—	—	—	—
Sariaso 2	Burkina Faso	89	3.2	4	222	8	7	8	—	—	—	—	—	—	—
IS7777	US/Purdue	—	—	2	148	—	—	—	—	—	—	—	—	—	—
KP33-2	US/Purdue	60	0.9	4	709	2	0	2	—	—	—	—	—	—	—
Mean				1.91	1027	4.8	6.0	5.5							
CV (%)				31.8	46.3										
Significance				**	**	NS	NS	NS	NS	NS	*	*	*	*	*

* Number of *Striga* plants in plot

Table 5. Performance of selected sorghum varieties in *Striga* infested field at SARI, Ghana in 2001.

			Striga count 28 days		*Striga* count 42 days		*Striga* count at harvest			
Designation	Days to flower	Plant height (cm)	Raw	Transformed[1]	Raw	Transformed[1]	Raw	Transformed[1]	Psmicle weogjt kg ha^{-1}	Grain weight lg ha^{-1}
CMDT-38	86	171	0.00	0.707	0.33	0.880	7.33	2.735	1534	568
CMDT-39	88	203	0.33	0.880	1.67	1.386	8.33	2.965	1187	578
SEGUETANA	84	192	0.00	0.707	2.67	1.738	9.00	3.063	1084	472
CMDT-45	85	207	0.67	1.052	7.00	2.735	32.00	5.695	1455	711
97-SB-F5DT-63	87	187	0.00	0.707	5.00	2.262	27.67	5.228	1768	395
97-SB-F5DT-64	86	209	0.00	0.707	0.33	0.880	6.00	2.529	5284	2232
N'TENIMISSA	87	223	2.00	1.470	11.67	3.480	47.33	6.910	1494	474
97-SB-F5DT-65	83	193	0.00	0.707	0.00	0.707	2.33	1.544	1673	690
MALISOR-92-1	76	159	0.00	0.707	3.33	1.932	12.33	3.560	1214	1011
MALISOR-84-1	76	165	0.00	0.707	0.00	0.707	2.00	1.470	1333	627
CE-151-202-A1	87	142	0.00	0.707	0.00	0.707	0.00	0.707	-*	-*
SRN 39	78	146	0.00	0.707	0.33	0.880	2.33	1.544	1218	362
SAMSORG 41	77	149	0.00	0.707	0.67	0.998	17.67	4.214	-*	-*
SAMSORG 14	89	167	1.00	1.171	9.33	3.091	45.00	6.723	2120	733
33-2	89	102	0.00	0.707	6.67	2.671	13.67	3.744	-*	-*
IS 7777	89	177	1.00	1.171	6.67	2.617	39.00	6.283	1459	341
Grand Mean	84	175	0.313	0.845	3.48	1.729	17.00	3.682	1756	707
CV(%)	2.0	2.0	210	31.2	51.8	22.2	26.4	15.1	73.2	56.5
LSD(0.05)	3	6	1.10	0.439	3.00	0.640	7.491	0.925	2164	673.8

[1] Square Root Transformation of original values
* These did not produce any harvestable heads and were not included in the analysis of those parameters.

At Bougouni, low and erratic rainfall resulted in low yields. Although not significant, the grain and stover production tended to be lower when various nutrients were eliminated (Table 6). In the Kita area, grain and stover yields were reduced whenever nutrients were withheld, except for potassium, with grain yields being significantly different (Table 6). In both regions, phosphorus appears to be the most limiting nutrient in the soil and potassium the least limiting soil nutrient. Village fertilizer interactions were not significant in either region.

Mali-Acid Soil

Several exotic sorghum genotypes, promising breeding lines, local cultivars, and improved varieties were tested for tolerance to acid soils in a naturally occurring toxic plot on the Cinzana Station in 2000 and 2001. Data on the survival of healthy plants are presented in Table 7. Local cultivars well adapted to low rainfall, sandy soils, (and presumably acid soils) from Niger, Mali, and Nigeria have shown good performance over several years. However, all are Durra or Caudatum types and do not have acceptable grain quality traits for use in the major production zones of West Africa where Guineense type sorghums are commonly used. Seedlings of some of the improved, exotic, and new breeding genotypes appear to show a useful level of tolerance, including N'Tenimissa, the new white-seeded, tan-plant Guinea types cultivar recently developed and released by IER in Mali.

Mali-Cinzana

A study of effectiveness of microdoses of inorganic fertilizer on millet production on sandy soils was initiated in 2001 at Cinzana. The recommended dose of chemical fertilizer is not economical to farmers in the context of the current free market prices. Microdoses, if successful, would reduce

Table 6. Sorghum yield response to fertilizer treatments in on-farm trials in villages in the Bougouni and Kita areas of Mali, 2001.

Fertilizer[1/] treatment	Stover kg ha^{-1}	% of NPKS	Grain kg ha^{-1}	% of NPKS
Bougouni Region				
NPKS	19184	100	698	100
NPS(-K)	15790	82	866	124
NKS(-P)	10645	55	391	56
NPK(-S)	13909	73	580	83
PKS(-N)	14141	74	675	97
Check	13163	69	396	57
	NS		NS	
Kita Region				
NPKS	6818	100	3054a	100
NPS(-K)	7671	113	3433a	112
NKS(-P)	5587	82	2249b	74
NPK(-S)	6132	90	2983ab	98
PKS(-N)	5185	76	2657ab	87
Check	3291	48	2438 b	80
	NS		*	

[1/] N = Nitrogen, P = Phosphorus, K = Potassium, S =Sulfur

Table 7. Percentage of planting hills containing at least one healthy plant at different stages.

Sorghum cultivar		50% flowering 2001	Physiological maturity 2001	Physiological maturity 2000
El Mota	Local (Niger), acid soil tolerant, Caudatum	100	100	100
Bagoba	Local (Niger), acid soil tolerant, Durra	94	90	71
Gadiaba/CZ	Local (Mali), acid soil tolerant, Durra	90	87	63
Kenike-ba	Local (Mali), acid soil tolerant, Guinea	56	55	57
Malisor 84-5	Improved (Mali), acid soil susceptible	17	14	20
OH84-3/5	Local (Nigeria), acid soil tolerant, Durra	54	52	67
IS 3553	Exotic, accum. low Mn	98	98	100
IS 6902	Exotic, Accum. high Mn	47	23	36
IS 8577	Exotic, accum. low P	47	21	29
IS 9138	Exotic, accum. high Si	34	19	33
IS 9277	Exotic, accum. low Mn	74	74	59
MN 4508	Exotic, accum. high Al	46	46	48
SRN 39	Exotic, Striga tolerant	79	74	88
97-BE-F5P-4	Mali promising new breeding line	64	58	69
97-SB-FS-DT-63	Mali promising new breeding line	53	52	49
97-SB-F5-DT-74-2	Mali promising new breeding line	56	56	51
98-SB-F2-78	Mali promising new breeding line	70	62	57
98-SB-F2-82	Mali promising new breeding line	53	51	41
98-BE-F5P-84	Mali promising new breeding line	49	48	58
N'Tenimissa	Improved released Guinea Cultivar (Mali)	85	82	71

the total fertilizer needed per unit area. Microdose fertilizer (2 grams of Di-Ammonium Phosphate) per hill was applied at planting. Data in Table 8 indicates that all the treatments produced more grain, biomass, and panicles than the control. The microdose treatment alone resulted in a significant increase in production, while the addition of 20 kg ha^{-1} of P+ 30 kg ha^{-1} of N or 40 kg ha^{-1} of P+ 60 kg ha^{-1} of N produced the most grain, biomass, and panicles. The addition of supplemental P to a microdose resulted in greater millet production than the addition of only supplemental N. However, the addition of both P and N had the greatest synergistic effects on overall millet production. These preliminary results indicate, that the application of microdoses alone is not sufficient to give full millet grain and biomass under the 2001 conditions.

Microdose treatments and recommended fertilizer on millet and sorghum on heavy soil had no significant effect on growth and yield. This may have been due to the very bad distribution of rainfall with severely stressed plant growth during the flowering stage greatly reducing yields.

Ghana-Sorghum

With phosphorus deficiency being a major limiting factor in crop production, research was conducted to look at the effect of phosphorus application in a sorghum-cowpea rota-

Table 8. Effect of microdoses on millet grain and biomass production on sandy soil at Cinzana, 2001.

Treatments[1/]	Number of panicles/ha (at harvest)	Biomass yield Kg ha^{-1}	Panicle yield Kg ha^{-1}	Grain yield Kg ha^{-1}	Plant population at harvest/ ha
T1	20312	1458	604	390	25729
T2	20312	2995	1073	608	35208
T3	26458	3151	1104	671	31562
T4	29479	4323	1271	765	36042
T5	29375	3281	1062	640	40312
T6	28646	3411	1167	681	38333
T7	39687	4375	1635	962	46771
T8	38646	5312	1604	890	54429
Significance	**	**	**	**	**
LSD	6639	1130	331	225	6720
C.V.(%)	14.9	21.7	18.9	21.8	11.8

* T1 = Control (no fertilizer)
T2 = 2gr of DAP
T3 = 2grDAP+20kg/ha of TSP
T4 = 2grDAP+40kg/ha of TSP
DAP = 2 grams of Di-Ammonium Phosphate per hill
TSP - Triple Super-Phosphate
T5 = 2grDAPP+30kg/ha Urea
T6 = 2grDAP+60kg/ha Urea
T7 = 2grDAP+20kg/haTSP+30kg Urea
T8 = 2grDAP+40kg/haTSP+60kg Urea

Table 9. Sorghum and cowpea yields and yield components as affected by P fertilizer rate and frequency, Wa, 2002.

	Sorghum			Cowpea			
Frequency of P application	Stover yield kg ha^{-1}	Kernels no. m^{-2}	Grain yield kg ha^{-1}	Stover yield kg ha^{-1}	Seed no. m^{-2}	Pod weight kg m^{2}	Grain yield kg ha^{-1}
Cumulative	3901	8761	2309	2720	1516	288	1870
Direct	3703	8195	2155	2533	1471	277	1809
Residual	3310	7871	2105	2556	1370	246	1696
	NS	NS	NS	NS	NS	NS	NS
P rate (kg/ha)							
0	3110	5978	1428	2012	1070	192	1272
30	3330	8847	2195	2824	1549	278	1885
60	4027	9039	2512	2817	1575	302	1983
90	4091	9239	2625	2761	1615	309	2022
Significance	0	**	**	**	**	**	**
CV(%)	28.0	20.1	23.7	19.7	13.4	15.2	13.7

tion at the Wa station. Treatments were three frequencies of P application: (1) Direct (applied to the current crop); (2) Residual (applied to the preceding crop); and (3) Cumulative (applied to both current and proceeding crops - both sorghum and cowpea). Also, sorghum plots received a uniform application of 40 kg N/ha each year. Both sorghum and cowpea grain yields and yield components responses to frequency of P application were negligible and not significant (Table 9). Added P fertilizer at the various rates, and under the frequencies mentioned above increased grain and stover production in both sorghum and cowpea. On average, the greatest net benefits (per ha) were obtained from residual P fertilizer. The results so far suggest that there is no need to apply P fertilizer on an annual basis when sorghum and cowpea are grown in rotation.

In another agronomy trial on the Wa Station, the effect on sorghum of rotation with three legumes, cowpea, peanut, and soybean, and different N rates was studied. All plots received a uniform application of Phosphorus at 30 kg ha^{-1}. Sorghum following any legumes produced significantly higher grain yield, averaged across all N rates. Sorghum grain yields following the previous crop were Cowpea - 2760 kg ha^{-1}; Peanut - 3101 kg ha^{-1}; Soybean 2775 kg ha^{-1}; and Sorghum - 2262 kg ha^{-1} with LSD of 333 kg ha^{-1}. Likewise, N fertilization had a significant effect on sorghum grain production averaged across all rotations with grain yields of: ON - 1737 kg ha^{-1}; 4ON-2561 kg ha^{-1}; 8ON-3191 kg ha^{-1}; and 120N-3409 kg ha^{-1}. The greatest effect was on kernal number rather than size. The response of grain yield of sorghum to previous crop and N rates is presented in Figure 1.

A third agronomy experiment at Wa studied the effect on sorghum of crop residue management (0, 50, and 100% of stover return) and fertilizer use (0 versus 64-38-38 kg ha^{-1} of N, P_2O_5 and K_2O. Crop residue return rate had no effect on sorghum production, while fertilizer increased grain yield by 1183 kg ha^{-1} (224% more grain) over unfertilized plots averaged across crop residue rates. This experiment as well as the other two discussed above will be continued in 2002.

Pathology

Mali

Out of 180 sorghum breeding lines or improved cultivars screened for anthracnose at Sotuba, only the following showed good resistance: 00-K0-F5-80,, 99-SB-F5-DT-51, 99-SB-F5-DT-188, 99-SB-F5-200, 98-SB-F5-DT-25, 98-SB-F5-DT-59, 98-KI-F5T-45, 98-SB-F2-7 (all from

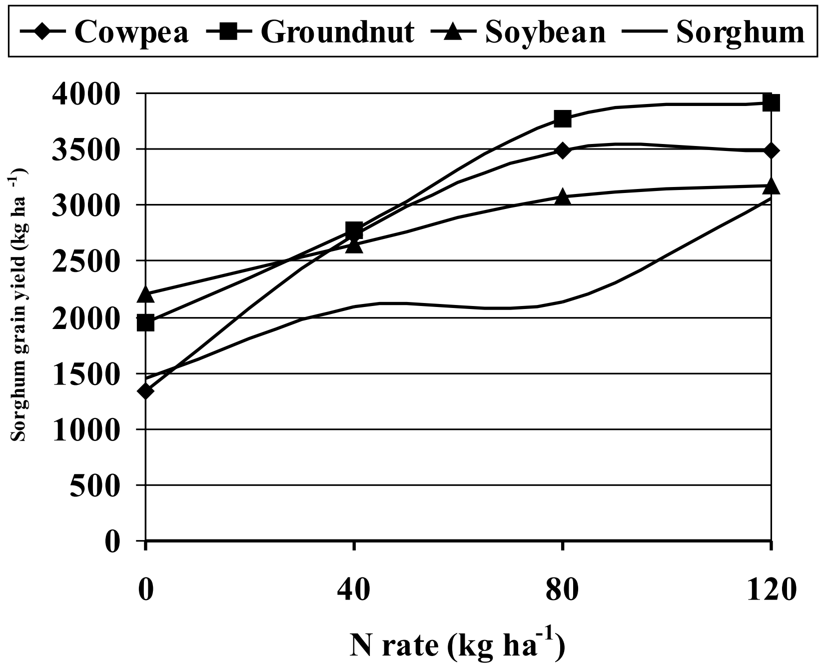

Figure 1. Grain yield of sorghum as influenced by previous crop and different rates of fertilizer N rates, Wa, Ghana, 2001.

Mali), and Ouedzoure from Burkina Faso. In the ADIN, most accessions showed resistance to leaf anthracnose except RTx2914 (88B943), Tx2911 (92B1941), and TAM 428 and most accessions were susceptible to sooty stripe. In the ISAVN (International Sorghum Anthracnose Virulence Nursery), Tx2536 and SC414-12E showed good resistance to leaf anthracnose. This contrasted some with anthracnose ratings on the ISAVN of Samaru, Zaria, Nigeria where Tx2536 was rated as susceptible, while SC326-6, IS18760, SC748-5, and IS854 had a good deal of resistance, indicating the probable presence of different pathotypes of anthracnose in West Africa. This was also suggested in Senegal where at the two sites, Kolda and Sinthiou, some genotypes in the ISAVN showed different reaction to anthracnose namely IS18758, TAM 428, IS12567, SC120, Tx434, and IS6959. At Kolda, only a local check F2-20 was not affected, while at Sinthiou only IS18758, IS12467, SC120, and Tx2536 were diesase free.

In a study in 14 farmer fields at Kolokani and Banamba, the effect of seed treatment on the incidence of covered kerned smut was studied. DNN (Dire+Nguo+Néré) and Apron star, were evaluated on an improved variety and on farmer seed. All treated seed effectively controlled the smut and significantly increased grain yield from 53 to 64% over the farmer non-treated seed.

Some new research was initiated in 2001 cooperatively with John Leslie and Wally Marasses (South Africa) to evaluate the toxins from *Fusarium* spp. on grain samples from Mali.

Senegal

In Senegal, the ISAVN, WASDON (West Africa Sorghum Disease Observation Nursery), ADIN (INTSORMIL/Texas All Disease and Insect Nursery, and GWT (INTSORMIL/Texas Grain Weathering Test) were evaluated. Results of the ISAVN are presented above. In the WASDON, anthracnose, long smut, sooty stripe, and grain mold severity was low. In the ADIN at Kolda only 4 entries, 99GWO92 (86EO361*98E0343), OOCA 4654 (Sureño*SRN39), B8PR1059 (88B885*GB108B), and 96BCPOB143 (86EO361*GR107) along with the local check F2-20 were rated resistant to grain mold. Long smut, sooty stripe, and anthracnose severity was low at both sites. In the GWT, 30% of the entries were classed or susceptible while 20% showed moderate resistance, with the local F2-20 being the most resistant.

Ghana

The ADIN and WASDON were evaluated for grey leaf spot, leaf blight, and bacterial leaf stripe. Data from the WASDON are presented in Table 3. *Striga* counts on the ADIN show low numbers of 0 and 1 *Striga*/plot at harvest ranging up to a high of 16 for the entry 92BO1982-4.

Nigeria

Although not reported in detail here, the same INTSORMIL and West Africa trials ISAVN, ADIN, WASDON, WA *Striga* trial and the three WASBON trials (Early, Medium, and Late), were evluated in Nigeria. Some comments on the ISAVN are above in the Pathology (Mali) section, while the *Striga* data are presented in Table 4. The lines 97-SB-F5-DT-63, 97-SB-F5-PT-64, Malisor 92-1, SRN 39, and SAMSORG 41 (ICSV111) showed low *Striga* infestation and a low number of infected plants, thus showing good field resistance. CMDT-38, -39, and -45, along with SAMSORG 14 had high *Striga* infestation. However, SAMSORG 14 gave the highest grain yield indicating a high level of tolerance. In the ADIN, SC326-6 and 91BE7414 showed the best resistance to foliar anthracnose. It was interesting that BTx378 was moderately susceptible, and Tx7078 and TAM428 were moderately resistant, all the opposite of anthracnose ratings in Texas. In the WASDON, SAMSORG 14 showed the highest resistance, followed by A2267-2, SC326-6, 99GW092, 90L19178 with good resistance.

Entomology

Various trials were planted at several locations and at different dates to evaluate resistance to sorghum midge, head bug, and aphid. A trial of 68 entries mostly from the U.S. was planted at Samanko. Fifty genotypes were planted on two dates at Kita, and 20 entries on two dates at Cinzana, with entries from U.S., ICRISAT, and Mali. Midge, headbug, and aphid infestations and damage were low at Samanko. Only 9 entries had midge damage ratings from 2 to 3, all others being 1.5 or 1.0. At Kita, midge damage also was very low with damage slightly higher in the second planting date those 12 entries had damage ratings of 2.0 to 2.8. AT Cinzana, the primary head bug screening location, the infestation of head bugs was relatively low compared to previous years, but there was some good difference among varieties. Data from Cinzana presented in Table 10 with a few entries showing a low damage rating similar to Malisor 84-7. Damage ratings ranged from 1.3 to 5.5 in data 1 and 1.4 to 6.3 in the second data.

In another study on midge damage assessment there was no significant damage on local or improved cultivars in five farmers fields in the Cinzana area.

The use of wood ash from two local plants, *Calotropus procera* and *Acacia nigricans*, to control the storage grain insect *Rhyzopertha dominica*, was studied. Both kinds of ash resulted in reduced insect emergence, with no difference between the two kinds of ash.

In Ghana, the ADIN were evaluated for shootfly and stemborer. Shootfly incidence was high with a wide range from low of 11.5% for B.LD6 to a high of 76.9% for 9BRON125.

Food Technology

Grain from the medium cycle Advanced Sorghum Variety Trials (Cycle I, II, and III) were evaluated for food quality traits including vitreousness, 1000 kernel weight, dehulling yield, tô consistency, tô color, KOH test, density, and ash. Although there was some variation, most of the advanced breeding lines from the IER breeding program rated good on food quality traits and compared favorably to local guinea cultivars and were deemed suitable for local food uses.

Diffusion of new products was another thrust of the food technology group. Training on the use of sorghum malt, a non-alcoholic drink was given to 50 women in two villages. Also work was done promoting sorghum syrup in supermarkets and couscous in African colonies in France and U.S.

The use of flour from the tan-plant cultivar N'Tenimissa continued to show great promise with use in the Deli-ken cookies marketed by GAM, and the marketing of 1 kg bags of sorghum flour called Sorgho Phar in markets in Bamako. Also, a considerable quantity of N'Tenimissa was success-

Table 10.Head bug adults, larvae and damage on 20 sorghum varieties at Cinzana, 2001.

Variety Designation	Planting date - July 23			Planting date - July 30		
	Mean No. larvae/ 5 panicles	Mean no. Adults/ 5 panicles	Head bug[1/] damage rating	Mean no. larvae/ 5 panicles	Mean no. adults/ 5 panicles	Head bug[1/] damage rating
CSM63	0.76	0	2.5	0.30	0.30	2.1
P99	0.74	0.31	1.3	6.19	1.42	2.3
ICSR14	5	33.57	4.5	5.83	4.16	3.5
ICSR15	3.33	8.33	5.5	0	0	4.5
DT120	9.73	0.52	4.5	25.55	3.33	5.5
PM2898	1.56	3.75	4.0	0	0	2
ICSV75	2.69	6.15	5	1.25	31.25	6
DT111	7.05	2.23	4.3	7.5	37.5	3.4
RSP110	0	10.0	5.15	12.29	7.29	5.0
ICSV13	6.47	4.11	4.8	18.42	11.56	4.3
M84-7	5.47	9.42	2.1	0.95	0.71	1.9
RST 107	2.89	6.84	1.8	9.37	3.12	2.5
RSP111	35.71	23.57	4.6	0	0	1.4
ICSV63	5.41	35.83	4.5	0	2.30	2.4
DT101	25.83	17.5	3.7	0	0	2.5
ICSR02	8.81	5.0	2.7	1.11	7.50	2.4
RSP112	1.56	2.81	2.5	5.71	55	3.6
Tx7000	5.33	6.66	4.4	110	250	6.3
DT 143	11	24	3.4	25.5	5.0	3.5
F2-79	32	8.83	4.3	0	0	2.5
Mean	8.56	10.4	3.77	11.49	21.02	3.38

[1] Damage raring where 1 - no damage to 9 extreme damage.

fully contracted for production with local farmers, and the Identity Preserved Grain marketed and made into flour by a private entrepreneur. The new tan-plant Guinea cultivars from the breeding program should be useful for such uses as they have slightly superior food quality to N'Tenimissa and are more agronomically susceptible.

Economics/Marketing

In an evaluation of the progress on Identity Preserved Marketing of N'Tenimissa, it was found that a local entrepreneur, Mr. Diawara was successful in producing through contracting 13.8 metric tons of N'Tenimissa grain from three villages. When the demand for N'Tenimissa flour from GAM declined due to the removal of tariffs on wheat, causing wheat prices to fall, the entrepreneur created an alternative market. He sold 1 kg bag of sorghum flour called Sorgho Phar for CFA 500 in markets in Bamako. The product was so popular that he had trouble keeping supplies stocked. Plans are to contract produce N'Tenimissa in four villages in 2002 with a goal of 100+tons of grain.

In his Ph.D. research, Jeffrey Vitale studied, under the supervision of John Sanders, the introduction of new technology in Mali. The study suggested that new technology in traditional cereals such as sorghum and millet would provide a greater increase in benefits compared to new technology introduction in the new cereals, maize and rice. Two advantages of the traditional cereals is that although the new cereals have higher productivity, traditional cereals have larger potential yield increases. Diminishing returns will likely accompany further technology introduction in the new cereals given the considerable intensification they have already experienced. The other advantage is that the traditional cereals require less stringent growing conditions. Mali's dry climate and poor soils are better suited to the traditional cereals, so benefits from new technology introduction in the traditional cereals would be realized over a wider area and extended to more farmers.

Institution Building

IER sorghum and millet programs received, through INTSORMIL collaboration, a vehicle, two computers, a printer, a copy machine, a fax machine and various field and laboratory research equipment and breeding supplies.

Many Malian scientists trained at INTSORMIL institutions are senior staff making important contributions in sorghum and millet research within the IER including:

Dr. Aboubacar Touré (Texas A&M) - Currently Sorghum Breeder, Mali National Coordinator for sorghum, Mali INTSORMIL Coordinator, and on INTSORMIL Technical Committee.

Dr. Mamourou Diourté (Texas A&M and Kansas State) - Currently Head Sorghum Pathologist.

Dr. Samba Traoré (Nebraska) - Currently Agronomist and Mali National Coordinator for Millet.

Dr. Niamoye Yaro Diarisso (Texas A&M) - Currently sorghum entomologist, and head of the Vegetable Station in IER.

Dr. Mamadou Doumbia (Texas A&M) - Currently Director of Soil Laboratory and soil scientist with IER.

Mr. Abdoul W. Touré (Nebraska) - Currently sorghum agronomist.

Mr. Sidi Bekaye Coulibaly (Nebraska) - Previously sorghum physiology/agronomy and sorghum breeding and INTSORMIL Coordinator. Currently working on Ph.D. at Texas A&M/Texas Tech.

Students currently in training include Niaba Témé who successfully completed his B.S. and is currently an M.S. student at Texas Tech University and Sidi Bekaye Coulibaly, who has served as INTSORMIL Host Country Coordinator, is now a Ph.D. student at Texas Tech/Texas A&M University. Karim Troaré, former IER millet and sorghum breeder is now a Ph.D. student at Texas A&M University.

Bocar Sidibé, Abocar Toure, Kissima Traore, Sibène Déna, and Moussa Sanogo received short term training in the U.S. provided by INTSORMIL in breeding and plant pathology.

Dr. Aboubacar Toure, sorghum breeder, is a member of the streering committee of the West and Central Africa Sorghum Research Network, WCASRN (ROCARS).

U.S. scientists traveling to Mali included: Dr. Carl Nelson (April, 2002), Dr. John Leslie (Sept., 2001, Mali and Ghana), Jeffrey Wilson, USDA-ARS Millet Pathologist/Breeder (Sept., 2001), Tom Crawford (Aug.-Sept., 2001 - Mali), and (March-April, 2002 - Ghana and Senegal). Other planned travel in October was cancelled due to the Sept. 11 terrorist tragedy.

Host country scientists travel included: Dr. Aboubacar Toure to U.S. for INTSORMIL Technical Committee Meetings, Nov., 2001 and April, 2002; to ASTA (American Seed Trade Association) Annual Corn and Sorghum Research Conference, Chicago December 5-7, 2001; to Lincoln, NE April, 2002, to Lubbock, TX, December 1-4, 2001 and May 10-15, 2002; to College Station, TX, May 8-9, 2002; and to Cornell University, May 5-7, 2002. Dr. Ibrahim Atokple to Lubbock, TX, August 13-September 19 for short term training in hybrid sorghum breeding and learning sorghum germplasm. Dr. Niamoye Diarisso to Quito, Equador, April, 2002, for a CGIAR system wide IPM meeting. Mr. Abdoul Waheb Toure to Montrieuil, France, Nov. 14-23, 2001. Mr. Kissima Traore, sorghum breeding technician at Cinzana, Mali, to Lubbock, TX, September 2 - October 6, 2001 for short term training in breeding and crossing.

Networking

An efficient sorghum and millet research and technology transfer network exists though the West African regional sorghum and millet networks, WCASRN and ROCAFREMI. The INTSORMIL/IER collaborative program is integrated on a regional basis. Technologies developed in Mali are transferable to most countries in West Africa particularly in the areas where head bugs, drought, and grain mold which are common. Exchange of elite germplasm with useful traits is ongoing among breeders in the region. The emerging interaction with NGO's, the University of Mali (IPR de Katibougou), farm organizations, and extension in conducting on-farm research and tests is a positive one that efficiently utilizes scarce resources and personnel. The program is using this approach to evaluate new improved breeding cultivars and other technologies in the West Africa Region. Efforts are underway to reinforce coordination of research programs and activities with other countries in West Africa. Collaborative INTSORMIL research was initiated in Ghana and Senegal in the 2001 season, and some initial efforts have been taken to tie some of this in with researchers and programs in Burkina Faso, Nigeria, and Niger.

The program has also interacted with ICRISAT, TROPSOILS, NOVARTIS, etc. There has been a long history of collaboration with ICRISAT in Mali especially in breeding, entomology, and weed science. The program has assembled, planted, increased and characterized the Mali Sorghum Collection in collaboration with USDA-ARS, ICRISAT, ORSTOM, CIRAD, and seed is in storage in Mali and has been introduced into the U.S. and grown out under quarantine. The seed increase and characterization were completed in 2001 and the complete set of data on the over 40 grain, glume, and plant characters was compiled and sent to the USDA/ARS for entry in the GRIN system. The development of a working group for active use is ongoing. After the seed is processed, complete sets will be sent, as appropriate to ICRISAT, ORSTOM, and Mali.

New Ghana and Senegal Collaboration

Plans to initiate INTSORMIL collaborative research in Ghana and Senegal began in November 2000, with arrangements to bring two scientists each from Ghana (Drs. S. Buah, Agronomist and I. Atokple, Sorghum Breeder) and Senegal (Ndiaga Cissé, Sorghum Breeder and Demba M'Baye, Pathologist) to Bamako to meet with Darrell Rosenow, Aboubacar Toure, and other key Malian IER scientists. Dr. Buah already had previously initiated a collaborative program in agronomy with Dr. J. Maranville. The discussions were all very fruitful and positive with three initial areas of collaboration among Malian, Ghana, and Senegal scientists agreed upon: 1) Sorghum Breeding with the establishment of a germplasm exchange program centering on a West African Regional Breeding Nursery to which all breeders would contribute new breeding germplasm or cultivars annually, and would be assembled and distributed by Dr. Toure in Mali; 2) Sorghum Pathology centered initially on a West African Disease Nursery to which all pathologists and breeders would contribute entries annually and would be assembled and distributed by M. Diourte in Mali; and 3) *Striga* research with initially a *Striga* nursery of known or suspected *Striga* resistant local cultivars and selected lines from Gebisa Ejeta evaluated at several sites. The lines will be assembled in Mali and distributed by Acar Toure. Also Dr. Ejeta will look at some of the sources for types of resistance involved. In addition, INTSORMIL scientists in the U.S. will provide breeding germplasm for midge resistance, drought resistance, grain mold resistance, other disease resistance, and elite sources fo worldwide germplasm for the new breeding programs in Ghana and Senegal. Requests were made by scientists in Ghana and Senegal for the future development of collaboration in millet breeding, entomology (head bugs and midge), cereal technology and utilization, and agronomy. Dr. Buah continued his collaborative activities in Ghana in 2001 based on already developed cooperation with Dr. Maranville.

Research Accomplishments - Summary

The most significant impact of INTSORMIL has been the strengthening of the IER both through staff training and research capacity building. Interdisciplinary and cooperative research in sorghum and millet which are in place at the IER are mainly due to INTSORMIL/IER collaborations. The multidisciplinary approach to solving technical problems have been promoted by the INTSORMIL, and is functioning well in Mali.

Breeding

From on-farm trials, the cultivar 97-SB-F5-DT-63 (N'Tenimissa*Tiemarfing) has been selected, seed saved, and grown by local farmers and named "Uassa" which mean 'satisfaction' in Bambara. Farmers like it over N'Tenimissa because of its whiter, higher quality grain.

Eight local photosensitive sorghum cultivars have been improved through mass selection and are grown by farmers on a significant area in Mali (CSM 388, CSM 219E, CSM 63E, Foulatiéba, Séguétana CZ, CMDT 45 , CMDT 39).

The white-seeded, tan-plant Guinea type breeding cultivar, N'tenimissa, was released. It's yield is equal to or slightly superior to local checks. It has good farmer acceptance regarding yield and food use. Flour from N'tenimissa is currently being marketed commercially (20% N'tenimissa and 80% wheat flour) in a cookie called déli'ken by the private company, G.A.M., in Bamako.

A local entrepreneur in Mali successfully produced over 11 tons of grain of the white, tan plant guinea cultivar, N'Tenimissa, under identity preserved (IP marketing procedures. This grain trader also developed a new market by packaging and selling one kilo bags of flour (Sorgha Phar) in Bamako markets, with a demand so strong he was having trouble keeping the product on the shelf.

Several white, tan plant true Guinea breeding lines were identified: 96-CZ-F4-99 (late maturity); 97-SB-F5-74-1, 97-SB-F5-74-2 (medium maturity); and 97-SB-F5-63, 97-SB-F5-64 (early maturity), all from the cross (N'ténimissa*Tiémarifing). They have been evaluated on-farm with promising results. They have somewhat superior grain quality and show less stem breakage than N'tenimissa.

Varieties of millet selected for the tallest expression of the D2 dwarfing complex (1.7 to 1.9 m) have given good performance in millet/legume intercropping studies.

Testing in Texas and Mali has demonstrated that the drought response in Mali is similar to the drought response in West Texas increasing probability of success in breeding for enhanced drought tolerance.

The Mali Sorghum Collection of indigenous cultivars from Mali was successfully grown in 1997, was characterized and seed increased and distributed. A small working collection has been identified. There was greater diversity in the collection than anticipated. Approximately one-third of the collection was grown in St. Croix in the spring of 2000 with seed increased and characterization completed. The remaining two-thirds was grown in a St. Croix quarantine growout in winter, 2000-2001, and seed increased and characterization completed. A tentative working collection was identified.

Entomology

The adverse effect of head bugs on the grain food quality of introduced sorghum across West Africa was first recognized and documented in Mali.

The INTSORMIL collaborative sorghum entomology research program in Mali has discovered the best source of genetic resistance to head bug (*Eurystylus marginatus*), a major constraint to the quality of grain sorghum in Mali, in an IER Malian developed cultivar, Malisor 84-7.

An easy, efficient technique for screening for head bug resistance using bagged vs. non-bagged heads has been developed and is used cooperatively by the breeders and the entomologists.

Observations indicate that head bug infestations in on-farm trials is much lower than in Station Nurseries. This means that sorghum with somewhat lower levels of head bug resistance may well work at the farm level, even though they may show significant damage under certain Station infestations.

Pathology

Grain yield increase of 20% can be obtained by treating millet seed with Apron plus.

Protection from head bugs will be a requirement for evaluation of grain mold resistance.

Long smut (*Tolyposporium ehrenbergii*) is severe in the drier regions of Mali. Anthracnose (*Collectostrichum graminicola*) is a very serious sorghum disease in Mali.

Studies were conducted on covered kernel smut (*Sphacelotheca sorghi*) by using traditional fungicides and the results showed that "Gon" (*Canavalia ensiloformis*) used in seed treatment had the same effects as Apron Plus 50DS and Oftanol.

Agronomy

INTSORMIL/IER research has demonstrated that millet or sorghum planted after peanut or cowpea results in 36-63% yield increases.

INTSORMIL collaborative research has shown an increase in pearl millet grain yield and biomass production due to previous cowpea crops and equivalent to the application of 30 to 40 kgha^{-1} N.

The joint INTSORMIL/TROPSOILS collaborative program has addressed soil chemical properties associated with nutrient deficiencies toxicities in sandy soils of the Cinzana Station. Some Durra varieties from Niger and northern Mali show tolerance to soil toxicity (Bagoba, Babadia Fara, and Gadiaba)

A method of screening large numbers of sorghum and millet lines for early generation and selection for seedling stage drought resistance using a charcoal pit has been adapted and is used.

Nitrogen use efficiency (NUE) of improved sorghum cultivars has been better than that of local cultivars at higher N rates, while local cultivars had better NUE at zero and very low N rates.

Without fertilizer application all tested cropping systems (including legume rotations) mine the soil of nutrients.

Crop rotation with cowpea and leaving crop residues in the field (either incorporated or on the surface) increases the sustainability and productivity of pearl millet cropping systems.

Weed Science

Several *Striga* resistant lines from Purdue evaluated in Mali showed good *Striga* resistance, but had inferior grain quality compared to local cultivars.

Striga resistance using lab screening to *Striga asiatica* in the U.S. works under field conditions to *S. hermonthica* in Mali.

New sources of resistance to *Striga* were identified: Séguétana CZ, CMDT 45, CMDT 30, CMDT 39.

Grain Quality and Utilization

Mini tests for evaluating milling and tô properties were developed and currently are used in the laboratory. Sorghum with hard endosperm and thick pericarps was definitely required for efficient traditional hand pounding. The size and shape of the pearl millet kernels affects dehulling properties significantly.

Head bugs damage reduced sorghum milling yields and produced tô with unacceptable texture and keeping properties.

Parboiling can convert sorghum and millet into acceptable products. It improves dehulling yieds, especially for soft grains. The cooked milled products can be eaten like rice.

The combination of cowpea and millet flour (1:3) significantly improved the nutritional status of young children. This technology has been transferred to many villages especially in the Cinzana area.

Mileg, a weaning food using primarily millet flour has been developed by private entrerprise and marketed in stores in the Bamako area. The product was developed using technology developed in the IER Cereal Technology laboratory.

New white-seeded, tan-plant, tan-glume guinea-type breeding cultivars, have good potential for use in developing new high quality, value added food products. They posses excellent guinea traits and yield potential.

Déli'ken, a cookie using 20% N'Ténimissa flour and 80% wheat flour has been developed by private entrerprise GAM and marketed in stores in Mali.

A new market for N'Tenimissa flour has been developed with the successful marketing of 1 kg bags of N'Tenimissa flour in Bamako by a local entrepreneur.

Economics/Marketing

In Mali, a local entrepreneur successfully produced grain from the white-seeded, tan-plant Guinea cultivar, N'Tenimissa, under identity preserved (IP) marketing procedures, involving 38 ha and 50 farms in 4 villages. From 38 tons harvested, over ll tons were sold to the grain trader. When the demand for sorghum flour by GAM for cookies dropped due to reduced tariff on wheat imports, a new market for the N'Tenimissa flour was developed with the marketing of one kilo bags of N'Tenimissa flour (Sorgho Phar) in markets in Bamako. Demand was so strong, there were problems keeping the product on the shelf.

An economics study on the benefits of new technology in Mali suggests that new technology in the traditional cereals of sorghum and pearl millet would provide a greater increase in benefits compared to new technology introduction in the new cereals, maize and rice.

The domestic cereal economy has been helped by devaluation with the increased relative price of sorghum and millet to rice. A future devaluation is expected to result in much more substitution of traditional cereals now that there is only a minimal rice tariff.

In spite of substantial introduction of new sorghum and millet cultivars, there has been minimum aggregate impact on yields. Only where inorganic fertilizers and improved water retention or irrigation were combined with new cultivars, have there been large yield increases. Given the low soil fertility and irregular rainfall in semi-arid regions, both increased water availability and higher levels of principal nutrients will be necessary for substantial yield increases. Improved cultivars alone are unlikely to have a significant effect upon yield.

The lack of a consistent supply of high quality sorghum and millet grain is the major constraint limiting value-added grain processing.

Lack of farm credit for millet and sorghum, compared to cotton and maize, discourages adoption by farmers of improved millet and sorghum technology, especially in the Sudano-Guinean (higher rainfall) zone.