Host Country Program Enhancement

Central America (El Salvador, Nicaragua)

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Collaborative Program

Vision Statement

The following vision statement was developed to guide regional program activities. “INTSORMIL collaboration will support national research programs’ efforts to develop dynamic, competent institutional research programs which contribute to productivity, economic growth, natural resource conservation and improved diets for grain sorghum producers, processors and consumers. Scientists in the region will work as regional, multi-institutional, multi-disciplinary teams collaborating with extension services, NGOs, international research centers, PCCMCA, the private sector and scientists from U.S. land grant universities to increase productivity, profitability, economic growth, conservation of natural resources, and food security for producers, processors and consumers of sorghum”.

Institutions

Active INTSORMIL collaboration in Central America is occurring primarily among the following institutions: Centro Nacional de Technología de Agropecuaria y Forestal (CENTA), El Salvador; Instituto Nicaragüense de Tecnología Agropecuaria (INTA), Nicaragua; Universidad Nacional Agraría (UNA), Managua, Nicaragua; Kansas State University, Mississippi State University, Texas A&M University; and the University of Nebraska. In addition, INTSORMIL has a current MOU with the Universidad Nacional Autónoma de Nicaragua (UNAN), Leon, Nicaragua, and maintains ties with the Escuela Agrícola Panamericana (EAP), Honduras based upon past collaboration. During 2003 a new Memorandum of Understanding was signed with the Dirección de Ciencia y Tecnología Agropecuaria (DICTA) in Honduras, and program activities were initiated in Jan. 2004. INTSORMIL has developed linkages with the regional seed companies Cristiani Burkart and Productores de Semillas, allowing new activities in Guatemala, testing of hybrids/varieties and support of the sorghum industry in Central America. Also informal collaboration with the Universidad José Matías Delgado (in food science) and the Universidad de El Salvador (entomology) has been established during the past two years.

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. In Feb. 2002 scientists met to present two-year research results and develop priorities for collaborative research for 2002-2006. In Oct. 2002, the research directors of collaborating institutions met to develop a regional training priorities for sorghum programs which is being implemented. These research and training priorities are the focus of regional efforts.

Financial Inputs

Primary financial support for the program is from the INTSORMIL Central America Regional Program budget, which was $130,000 during the past year. The four collaborative research projects (plant breeding, utilization, plant protection, and agronomy) were budgeted at $8,000 to $25,000 for activities 2003 - 2004. In addition, regional funds were used to support English study and costs of taking the TOEFL and GRE tests in preparation for graduate study, with the balance maintained at the INTSORMIL Management Entity to cover regional expenses. These regional expenses included expenses associated with short-term training, equipment purchases and administrative travel.

Collaboration

INTSORMIL's Central America program has collaboration with many non-governmental organizations mainly in validation of new sorghum varieties on-farm (see form for complete list), and formal collaboration with national extension services, and it has served as a catalyst for Central American grain sorghum research and technology transfer. Collaborative relationships have been established with a number of universities in El Salvador and Nicaragua, and undergraduate students often complete thesis research on INTSORMIL-supported experiments. In addition, René Clará Valencia coordinated the regional grain sorghum yield trials conducted by the PCCMCA, and provided technical assistance for seed production to the private seed company Productoras de Semillas in Guatemala. A strong collaborative relationship has been developed between INTSORMIL's regional sorghum research program and ANPROSOR, the Nicaraguan grain sorghum producers association, which has assisted in identifying research priorities and has collaborated with a number of research studies since 2002. Regional scientists have collaboration with the CIRAD-CIAT project on participatory plant breeding for sorghum (and upland rice), and ICRISAT provides germplasm for breeding use as requested.

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 2003 was 225,897 ha^{-1} with an average grain yield of 1.5 Mg ha^{-1} (FAO, 2004). 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 maicillos 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 both maicillos criollos and other sorghum varieties 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) other than maicillos criollos.

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 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 Utilization for Feed Workshops

One-day workshops were held Jan. 12, 2004 in Managua, Nicaragua and Jan. 14 in San Salvador, El Salvador with presentations on sorghum use as livestock feed by Drs. Lloyd Rooney and Joe Hancock. The workshops were attended by 30 to 45 participants per workshop largely from the private livestock feed sector, but also included sorghum scientists from national programs and the national sorghum producers association in Nicaragua. The workshop in El Salvador was sponsored by AVES (Asociación de Avicultores de El Salvador). ANPROSOR in collaboration with INTA scientists and Drs. Lloyd Rooney and Sergio Serna-Saldivar are making plans for a broader sorghum utilization workshop to be held in Managua in early 2005.

Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales (PCCMCA) [Cooperative Central American Program for Crop and Animal Improvement] Annual Meeting

Regional coordinator René Clará; Drs. Larry Claflin, Lloyd Rooney and Bill Rooney; and 10 collaborating scientists participated in this annual meeting April 16 -20, 2004. Most oral papers on grain sorghum were presented by INTSORMIL collaborators, and Orlando Téllez Obregón won the award for outstanding paper in the sorghum and rice section. Dr. Lloyd Rooney gave an invited presentation on grain utilization to the sorghum/rice section. The meeting provided a forum for broadening contacts with programs in other countries and with the private sector. In addition, it was useful for regional planning of the 2004 growing season research and technology transfer plans.

External Evaluation Panel (EEP) Review

The EEP visited El Salvador and Nicaragua Dec. 8-12, 2003. Collaborators from Honduras assisted the review in El Salvador. The review team met with regional scientists and administrators, NGOs involved in technology transfer, producers and utilizers of sorghum grain.

Undergraduate Research Theses at the Universidad Nacional Agraría, Nicaragua

Undergraduate students are required to complete a research thesis as part of the Bachelor of Science degree. During 2003-2004, 14 students completed thesis research at the Universidad Nacional Agraría on grain sorghum with support from agronomy projects. These included the following:

Chepita Garcia y Yolanda Herrera.2004. Evaluacion de 16 lineas de sorgo en Zambrano, Masaya (Evaluation of 16 sorghum lines for nitrogen use efficiency at Zambrano, Masaya).

Ajax Fonseca, Lenin Lopez, Eliezer Manzanares y Francisco Calero. 2004. Evaluacion de 25 lineas de sorgo en San Ramon, Matagalpa (Evaluation of 25 sorghum lines for nitrogen use efficiency at San Ramon, Matagalpa).

Ruby Altamirano y Mario Gadea..2004. Evaluacion del uso de frijol Mungo como fuente alternativa de N en sorgo en San Ramon, Matagalpa (Evaluation of mungbean as an alternate N source for sorghum at San Ramon, Matagalpa).

Ramiro Manzanares y Roberto Hernadez. 2004. Evaluacion del uso de frijol Mungo como fuente alternativa de N en sorgo en Tisma, Masaya [Evaluation of mungbean as an alternate N source for sorghum at Tisma, Masaya].

Alex Gonzalez y Willar Green. 2004. Evaluacion de 25 lineas de sorgo en Posoltega, Leon. [Evaluation of 25 sorghum lines for nitrogen use efficiency at Posoltega, Leon].

Maury Gurdian. 2004. Evaluacion de 16 lineas de sorgo en Posoltega, Leon. [Evaluation of 16 sorghum lines for nitrogen use efficiency at Posoltega, Leon].

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 (for relay intercropping systems with sorghum planted into the existing maize crop) or insensitive varieties for grain production or dual use as grain and forage. Photoperiod-insensitive lines may also serve as parents for hybrids. During 2002 - 2003, the Nicaraguan program took regional leadership for the hybrid development program, while El Salvador took regional leadership for the photoperiod sensitive variety program. 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. In 2003-2004 varieties from CENTA were evaluated in Honduras. Each year, grain sorghum hybrid tests have been conducted in three to seven countries in Central America. Collaborative ties have been made with Dr. Gille Trouché, CIRAD-CIAT project, with focus on a participatory sorghum breeding program in Nicaragua. Technical support is provided to regional sorghum seed companies headquartered in Guatemala, who are also assisting with the PCCMCA hybrid trials and evaluation of grain/forage sorghum hybrid/varieties for future release.

Research Results

Regional PCCMCA trials were conducted for sorghum hybrid entries from Christiani Burkart, Sefloarca and Prosemillas, a common check hybrid and a local check hybrid at 6 locations in El Salvador, Guatemala and Nicaragua. No hybrid differences in grain yield, plant height or days to flowering were found. Grain from all hybrids were tested for tannin level, which were all low with no potential to reduce feed efficiency for monogastric animals.

Plant breeding programs in El Salvador and Nicaragua are evaluating photoperiod sensitive sorghum varieties (maicillos criollos and millón) for intercropping systems with maize, and in some cases, with dry beans. In El Salvador the varieties 85-SCP-805 and ES-790 were promoted through 430 on-farm validation trials in cooperations with various NGOs. A set of these photoperiod sensitive varieties was sent to Honduras for testing and seed increase. On photoperiod sensitive populations was intercropped with maize, and 49 new uniform F8 lines were selected for future use. Fifty-two new crosses between nine photoperiod sensitive varieties and nine three-dwarf elite photoperiod sensitive elite lines for selection and evaluation in the future.

Evaluations of photoperiod-insensitive varieties continues in both countries. Several evaluation trials for white and red grain were conducted to select lines for potential release as varieties. The white grain varieties Macía (locally called 'Africana'), CENTA-RCV (El Salvador) and (TXP)-12, and the red grain varieties (SR17)-10-2-2-2, (SR-16)-10-1-1-3 and (SR-6)-1-5-1-1 were grown in on-farm validation trials.

Seed production of the four best forage hybrids selected in 2002 plus the check ATX623 was determined to select the female with best seed production. The lines ICSA275 and ICSA264 were 100% or more better than the check for seed production in El Salvador and Nicaragua with yields of 2597 to 3247 kg ha^{-1}.

In Nicaragua, the forage hybrid ATX623(BMR)*WRAY had the best green-chop forage yield, and shows potential for future use.

Four male-sterile populations from Texas A&M and ICRISAT were evaluated. The lines K82 and TX288 were found to have the highest potential to generate new varieties or lines for making hybrids.

For hybrid grain sorghum development the A and B lines AES-1, BES-1, AES-2, BES-2 were generated from Texas A&M germplasm. All lines have red grain color, light brown plant color, tropical adaptation and three-dwarf characteristics. In addition 15 new B lines and nine new R lines were selected from Texas A&M germplasm for developing new hybrids with tropical adaptation.

In Honduras, the varieties Sureño, RCV and Soberano were evaluated at La Lujosa Experiment Station near Choluteca. All three produced grain yields between 5.2 and 5.5 Mg ha-1. RCV and Soberano were earlier maturing and had shorter plants with less lodging, but produced less forage. All three are being tested on farm, and show potential to increase sorghum production in Honduras.

Broom production is an important enterprise in Honduras with a potential annual market of three million dollars, but local production of broomcorn is inadequate to meet demand. The broomcorn varieties 162474-1-8-2-8, 18137NSS228, 18132NSS222, and 22025INDIA were tested on-farm using sustainable production practices of minimum tillage, using crop residues for mulch, no burning, and soil conservation practices. The variety 18132NSS222 showed good potential based upon plant height, lodging and panicle size. The large panicle size is particularly beneficial since larger brooms can be produced which have higher market value.

Plant Protection Research

Research Methods

Efforts to move beyond disease identification to determining the economic loss and control methods has been an objective. Meetings organized by UNA, INTA, CIRAD-CIAT and ANPROSOR were held in 2003 with 70 farmers from the Pacific Region of Nicaragua to learn about the main sorghum production constraints in Nicaragua. ADIN nurseries are planted to identify host-plant resistant germplasm, and insecticide fungicide application studied to determine economic loss and potential use for control of pests. The effects of chemical application (diazinon), non-chemical controls (Neem spray and the fungal biological agent *Beauveria bassiana*), and cultural planting system using pigeon pea barriers on insect and disease pests was conducted in Nicaragua.

Research Results

In Nicaragua, farmer meetings identified the need for training in integrated pest management of grain sorghum, especially with diseases, and agronomic management. In addition, fertilizer management (particularly rates and application timing), weed control and additional utilization options beyond being a poultry feed. They indicated a need for a simple grain sorghum production manual. Technical training workshops are being planned. Many of the farmers offered their farms to be used for research studies.

Evaluations in the ADIN in two farmer fields and on the CENTA experiment station at San Andrés in El Salvador and indicate that the most prevalent diseases were rust *(Puccinia* species), *Helmintosporium*, zonal spot (*Gloeocercospora*) ergot (*Clavcep*), *fuscarium, gray leaf spot (Cercsopora)*. The lines MB198B, 96GCPDB172, D2CA4624, Sureño, BTx635, Tegemeo, 86EON361, GR108-90M-24, 90EON328, and 99GW092 exhibited the best resistance to diseases.

Studies in El Salvador using improved (RCV and Soberano) and traditional (leche) varieties for with fungicide (Daconil) and without fungicide showed the fungicide increased yield of the susceptible local variety from 500 to 4400 kg ha^{-1}, but had little influence on the improved varieties which produced similar yield to the traditional variety with fungicide applied. This shows that these improved varieties have disease resistance, making fungicide application unnecessary. Improved variety use without fungicide application was the most economic alternative.

Insecticides were applied to the varieties RCV and SOBERANO to control stalk borers and sorghum webworm in El Salvador. The sorghum variety RCV had higher yield than SOBERANO, but insecticide application had little effect on grain yield or quality since infestation levels were low. Insecticide application had little effect on sorghum webworm infestation. Planting RCV without insecticide application gave the highest economic return.

A chemical, non-chemical and barrier crop study in Nicaragua produced inconclusive results. Treatments had no effect on insect larvae, thus no influence on grain yield. Plot sizes were too small, Neem and *Beauveria bassiana* were not effective on sorghum midge, and the pigeon pea barrier was not used in practical manner on the small plots.

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 Agrícola Panamericana 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 by CENTA, with undergraduate students from the Escuela Agrícola Panamericana, or graduate students at Texas A & M University or the Instituto Tecnologico y de Estudios Superiores, Monterrey, Mexico. In 2002, CENTA established collaboration with the Universidad José Matías Delgado in El Salvador, and conducted research on decortification of sorghum grain, development of new sweet bread recipes, and determination of shelf life of sweet breads made with whole sorghum grain.

Availability of milling equipment, especially for decortification, for production of sorghum flour continues to be a limiting factor. Five rice milling units were tested during the year for production of decorticated sorghum flour, and the resulting particle size, grain breakage and nutritional content were determined.

Research Results

The rice mill Suzuki MT-99 used by the GUMARSAL company was found to be the best equipment available, producing 84% decortication with 2.4% breakage by abrading for 30 seconds. This produced slightly smaller particle size and nutritional value than whole-grain flour, but should produce superior baked products with a longer shelf-life. We have also determined that a small mill produced in Senegal would likely be appropriate technology for producing sorghum flour, and proposals are being prepared for funding to set up a mill in collaboration with ASOPAN, the association of bread bakers. Contacts have been made concerning mills for decortication and grinding of sorghum grain available in Senegal, South Africa and India. Project proposals are being written in hopes of obtaining additional funds to obtain the processing equipment made in Senegal.

Agronomy Research

Research Methods

A three-year study was conducted at two locations in El Salvador and two locations in 2002 - 2003 in Nicaragua in 2002 - 2003, and three locations in Nicaragua and one in El Salvador in 2003 - 2004 with the objective to determine if NUE differences exist among photoperiod insensitive sorghum varieties, determine optimal N fertilizer rates for grain sorghum in a randomized complete block design with four replications. Grain and stover yield, and N concentration of grain and stover at harvest were collected, and agronomic characteristics.

Previous research in El Salvador indicated that the photoperiod sensitive variety 85SCP805 was high yield and had high NUE. Validation trials versus a local check variety and with

(47 kg ha^{-1}) and no N fertilizer was conducted on 40 farms. In addition, technology transfer trials for the varieties RCV, SOBERANO, 85SCP805 were conducted with collaborating NGOs on 430 farms.

Research Results

The El Salvador location in 2003 provided little useful information due to site selection of a soil with relatively high nutrient level. In Nicaragua, large differences among sorghum lines and locations were present, but a line by N level interaction was only present for one-out-of three locations. It appears likely that a wider range of germplasm will be needed to incorporate high nitrogen use efficiency into photoperiod insensitive varieties in Central America.

In the Pacific Increasing N application from zero to 194 kg ha^{-1} increased sorghum grain yield quadratically from 2.1 to 3.9 Mg ha^{-1}, and the response would suggest that yields would be further increased with higher application rates. This yield response to N fertilizer application was consistent across varieties, except Tortillero Precoz had a smaller yield increase than other varieties between the highest N rates of 129 and 194 kg ha^{-1}. Economic marginal return analysis indicated that the optimal rate to recommend to producers is 129 kg ha^{-1}.

In on-farm validation trials, the improved variety 85SCP805 produced 130 kg ha^{-1} more grain than the local check without N application. Nitrogen application increased grain yield of 85SCP805 by approximately 700 kg ha^{-1}, and of the local check by approximately 300 kg ha^{-1}. In spite of the clear yield advantage of using the improved variety 85SCP805 with N application, the economic analysis indicated that the improved variety without N fertilizer application had the greatest net return due to the high local cost of N fertilizer. In the improved variety transfer plots (Table 1), all improved varieties produced higher yields than the local check variety, with the previously released RCV consistently yielding better than the local check.

Mutual Research Benefits

Many constraints to sorghum production 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 effects of some of these constraints. The maicillos criollos are a unique type of grain sorghum and can potentially contribute useful food quality traits to U.S. germplasm. Several maillos criollos 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 re-

Table 1. Technology transfer on-farm test results conducted in collaboration with NGOs in El Salvador.

NGO Responsible	Municipality	Community	Variety 85SCP 805	ES790	CENTA S3	RCV	Local Check
			---- kg ha^{-1} ----				
Ramírez Consultores S.A. de C.V.	Victoria	Rojitas	1948			3247	1234
		La Uvilla	1818			2597	1104
		Suburbano Victoria		1623			1169
		Caracol	1948			2922	1299
		Victoria Average	1905	1623		2922	1169
	San Isidro Guacotecti	Potrero Batres				2273	1104
		Agua Zarca				2922	1558
		Bañadero	2273		779	2597	1494
		Tempisque	1039		779		1558
		Guacotecti Average	1656		779	2760	1537
ESBESA	Sensuntepeque	Rojas	2597				974
		Tronalagua	1883	1888	3247	3506	1169
		Rio Grande	1883	1818	3247	1429	1234
		Llano Grande	2078		2597	1948	1429
		Sensuntepeque Average	2110	1853	3030	2294	961
Consorcio	Nuevo Eden de San Juan	Cucurucho	844				1039
		Jardin	974				909
		Nuevo Eden Average	900				974
PRODESO	Llobasco	San José				3377	1429
		Aqua Zarca				1688	1299
		Nanastepeque				1494	1299
		Llanitos				3247	1299
		Llobasco Average				2452	1332
FUMPROCOOP	Llobasco	San Benito			2403	2468	1299
		El Tule				2078	1429
		San Francisco			1234	2143	1299
		San Nicolas				1883	1169
		Llobasco Average			1819	2143	1299
	Average Across Locations		**1645**	**1738**	**1876**	**2330**	**1196**

sistance, wide adaptation, and improved food quality. INTSORMIL's collaborative research in entomology and plant pathology research includes pests that affect grain sorghum both in Central America and in the U.S., such as sorghum midge, fall armyworm, gray spot and ergot. Economic development of Central American countries will increase food security in the region, and potentially increase U.S. exports to the region.

Institution Building

Equipment and other support

INTSORMIL has provided pass-through funding and supplies for pathology laboratories in El Salvador and Nicaragua. INTSORMIL has facilitated donation of complete sets of Agronomy Journal and Crop Science to the library at CENTA.

Training and education

Johnson Zeledón (Nicaragua) completed a Ph.D. degree in entomology at Mississippi State University, Rafael Mateo (Honduras) is pursuing a Ph.D. in plant breeding at Texas A&M University and Sergio Pichardo Guido is pursuing a Ph.D. in plant pathology at Mississippi State University. Mario Parada Jaco (El Salvador) is in English language study in preparation for a Ph.D. program in entomology at Mississippi State University. In January 2005, Vilma Ruth Calderón (El Salvador) will start a M.S. degree in food science at Texas A&M University, and Otho Ludwig Argueta (El Salvador) will start a M.S. program in agricultural economics at Purdue University. Eliette Palacio (Nicaragua) is being funded for English language study by World Bank/INTA in hopes that she can enter a graduate degree program in food science at Texas A&M University. Short-term training on experimental design, data analysis and scientific communication was provided to 30 participants (primarily INTSORMIL collaborators) in October 2003.

Networking

Institutions/Organizations

INTSORMIL support has contributed to increased collaboration among CENTA, INTA and UNA during the past four years. In El Salvador, increased collaboration with the non-governmental organizations Ramírez Consultores S.A. de C.V., Escobar-Betancourt S.A. (ESBESA), ESBESA-Ramírez Consultores (Consorcio), Profesionales de Desarrollo Sostenible (PRODESO), Asosición de Añileros de Cabañas (ASEÑICA), MAG/AVES, FUNPROCOOP, PRODAP (Proyecto de Desarrollo Rural en la Región Paracentral), and FUNDESYRAM (Fundación Para E Desarrollo Socio-Económico y Restauración Ambiental) primarily with validation testing of sorghum varieties to be released. A collaborative relationship has also been established with the Universidad José Matías Delgado. In Nicaragua, increased collaboration with the CIRAD-CIAT Watershed Project at San Dionisio has been strengthened, especially collaboration with Dr. Gilles Trouché, sorghum breeder. Also collaboration with the universities of Campesina (UNICAM), Centroamericana (CSA) and Católica del Tropico Seco de Estelí (UCATSE), and with the non-governmental organizations ADRA-Ocotal (Adventist Development & Relief Agency), CARITAS-Matagalpa and CARE-Estelí have been developed. National programs have strong linkages to private seed companies, and are developing closer ties with feed and food utilization companies. Particularly noteworthy is providing technical assistance to the seed company Productora de Semilla in Guatemala. C, and new initatives with Cristiani Burkart. Close working ties with the Asociacíon Salvadoreña de Panifacadores (ASPAN) in El Salvador continues. Improved networking with INTSORMIL universities and Instituto Tecnologico y de Estudios Superiores, Monterrey, Mexico is desired through graduate education and collaborative research efforts. INTSORMIL is actively working to promote and strengthen collaborative linkages.

Travel

Regional coordinator René Clará, U.S. Principal Investigators Bill Rooney, Lloyd Rooney and Larry Claflin, and 10 collaborating scientists attended the PCCMCA meeting Apr. 16-20, 2004 in San Salvador, El Salvador. Most papers in the sorghum session were presented by INTSORMIL Collaborators.

Drs. John Sanders and Lloyd Rooney, and graduate student Felix Baquedano traveled to El Salvador and Nicaragua in Aug. 2003 to study sorghum grain production, marketing and utilization.

Drs. Larry Claflin and Henry Pitre visited El Salvador and Nicaragua in Nov., 2003 to assist with collaborative research.

Drs. Lloyd Rooney and Joe Hancock gave seminars on sorghum utilization for livestock feed in Nicaragua (Jan. 12, 2004) and Nicaragua (Jan. 14, 2004).

Regional coordinator René Clará visited Nicaragua and Honduras several times to coordinate regional activities and assist with the plant breeding programs. He also visited Productora de Semillas in Guatemala to provide assistance on sorghum seed production.

The External Evaluation Panel (EEP) visited El Salvador and Nicaragua Dec. 8-12. 2003. Collaborators from Honduras participated in the El Salvador portion of this visit.

Dr. Stephen Mason, Regional Coordinator, made an administrative trip to El Salvador and Nicaragua in Dec. 2003.

Dr. John Yohe, Director, and Dr. Stephen Mason and Ing. René Clará traveled to Honduras to sign a new Memorandum of Understanding between INTSORMIL and DICTA in Oct. 2003.

Horn of Africa
(Ethiopia, Eritrea, Kenya, Uganda)

Gebisa Ejeta
Purdue University

Coordinators

Gebisa Ejeta, Regional Coordinator, Purdue University, Dept. of Agronomy, West Lafayette, IN 47907
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Collaborative Program

INTSORMIL/Horn of Africa is a regional collaborative research program on sorghum and millets in Eastern Africa between INTSORMIL and national agricultural research centers (NARS) in the region. The program strives to develop fruitful collaborative engagements between and among a group of scientists to address sorghum and millet production and utilization problems of mutual interest. Before the start of the current regional effort, INTSORMIL had had a productive collaborative program with the Agricultural Research Corporation (ARC) in Sudan. Collaboration resulted in an array of technical developments that have impacted on sorghum agriculture in Sudan and the region. Technologies have been generated as a result of the collaborative effort that has significantly impacted sorghum and millet production and utilization in Sudan. The long-term collaborative association has also resulted in several Sudanese scientists being trained in INTSORMIL institutions. U.S. scientists 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 were signed with NARS in Ethiopia, Eritrea, Kenya, Tanzania, 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 developed in the Horn of Africa. With each national program, we have a traditional bilateral 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. 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, initially to catalyze exchange of information and ideas among member NARS and INTSORMIL scientists, and currently, to work through the regional sorghum and millet network, ECARSAM. A major initiative that has been implemented as a regional effort has been the integrated *Striga* management (ISM) project for effective control of *Striga* at the farm level. We focused on *Striga* because it is a major regional constraint upon which considerable research has been undertaken by one or more of the NARS in the region. The ISM program has been implemented first in Ethiopia, and since expanded into Tanzania and Eritrea. In each country, we combined three proven technologies (*Striga* resistant cultivars, nitrogen fertilization, and water conservation measure of tied ridges) for a synergistic effect in the control of *Striga*. The ISM project has been widely accepted as a major regional initiative. Other similar regional initiative may also be identified. Once agreed upon, collaborative research projects among NARS in the region will be developed, in consultance 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 very many scientists in the region. Scientists from the region will also have 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 in the region, such as ASARECA, ICRISAT/East Africa, World Vision International, Sasakawa Global 2000, and the IPM CRSP have been good with some joint activity underway 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, a few years ago, 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 –Tewodros Mesfin Abebe/Gebreyesus Brhane Tesfahunegn, EARO; Charles Wortmann/ Martha Mamo, INTSORMIL.

Striga Management – Tesfaye Tesso/Fasil Redda, EARO; Gebisa Ejeta, INTSORMIL.

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

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

Sorghum Utilization – Senait Yetneberk, EARO; Bruce Hamaker and Gebisa Ejeta, INTSORMIL.

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

Pathology – Girma Tegegne, EARO

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.

Sorghum Agronomy – Kayuki Kayyizzi, NARO; Charles Wortmann, INTSORMIL.

Eritrea:

Sorghum Breeding – Tesfamichael Abraha, NARI; Gebisa Ejeta, INTSORMIL.

Millet Breeding – Neguse Abraha, NARI; Gebisa Ejeta, INTSORMIL

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

Striga Management – Goitom Ghobezai, NARI; Gebisa Ejeta, INTSORMIL.

Tanzania:

Sorghum Breeding: Hamis Saadan, DRD; Gebisa Ejeta, INTSORMIL

Striga Management: Ambonesigwe Mbwaga, DRD; Gebisa Ejeta, INTSORMIL

Agronomy: E.A. Letayo, DRD/ARI

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. 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 production and utilization constraints are generally common to all countries." (Table 1 and 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

Table 1. Sorghum and Millet Production

Countries	Sorghum Area 1000 ha	Yield Kg ha^{-1}	Production 1000 mts	Millet 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	Uganda
Varietal Development	X	X		X
Striga	X	X	X	X
Crop Protection				
Pest	X	X	X	X
Diseases	X	X	X	X
Drought	X	X	X	X
Production	X	X	X	X
Technology Transfer	X	X	X	X
Training – Long-term	X	X	X	X
- Short-term	X	X	X	X
Socio-economics				
Utilization	X	X	X	X
Information Exchange				X
Germplasm Introduction	X	X	X	X
Soil/Water Conservation	X		X	
Seed Production & Marketing	X	X	X	X

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.

Progress Report

Integrated *Striga* Management on Sorghum in Tanzania

Mbwaga, H. Saadan, E. Letayo

Striga is one of the major constraints to crop production in Tanzania. *Striga* species of economic importance in Tanzania include *S. asiatica*, the most widely spread species, *S. hermonthica* which is found in the Northwest of the country around Lake Victoria and *S. forbesii* found mainly in the eastern part of Tanzania. Cereal crops affected by *Striga* include sorghum, maize, upland rice and finger millet. It has been observed that pearl millet is not attacked by any of the *Striga* species found in Tanzania. Though several control methods have been suggested, none has been effective in eradicating *Striga*. Recently, an integrated approach to *Striga* control, bringing in multiple control options to systematically address the issue of control and reduction of the parasite, appear to be successful.

In Tanzania, *Striga* resistant sorghum varieties have been identified, verified on farmers' fields, and released for commercial use in the country in 2002. We have found that resistance alone is not a 100% solution to the problem of *Striga*; it needs integration with other *Striga* control options. Other options of *Striga* control include hand weeding, intercropping with legumes, improving soil fertility through application of inorganic/animal manure, green manure and improvement of available soil moisture to the plants by using tied-ridges. In this project we had demonstration on the use of inorganic fertilizer/animal manure, tied-ridges and resistant sorghum varieties for control of *Striga* and increase sorghum grain yield under farmers' field management.

In collaboration with INTSORMIL, we conducted during the 2003 and 2004 crop seasons an integrated *Striga* management (ISM) in three districts, namely, Singida, Kongwa, and Lake Zone.

In the Singida district, two locations were identified for carrying out this project. The first location was Sepuka ward, where two villages, Musungua and Musimi, were selected. Each village formed a farmer research group of 12 farmers for conducting the evaluation.

Sepuka Ward:

Treatment included the following demonstrations:

- Local sorghum variety plus their local cultivation practice
- Sorghum variety Hakika plus tied-ridges,
- Sorghum variety Hakika plus tied-ridges plus animal manure,
- Sorghum variety Hakika plus tied-ridges plus inorganic fertilizer (urea).

Farmers were provided each with 1kg of sorghum variety Hakika (*Striga* resistant) per treatment.

Mtinko Ward:

In the Mtinko ward two villages were also selected with the same number of farmer research groups as from the Sepuka ward. The villages were Mpipiti and Malolo; these villages lie in a relative moist area. Farmers in the Mtinko ward plant sorghum on flat land, hence ridging was a new technology for them. They were given each 1kg of sorghum variety Wahi (*Striga* tolerant variety) and the following were the treatments:

- Farmer variety plus flat planting
- Wahi plus flat planting
- Wahi plus tied-ridges
- Wahi plus tied-ridges plus animal manure

The size of each demo plot for Sepuka and Mtinko wards was 10 x 35m and 10 x 70m respectively. Data was collected from an area of 5 x 5 m from each treatment. Farmers did the management and running of the demonstrations themselves through their group leadership and with assistance from the extension officer.

Farmers responded very well to growing the new varieties. From Sepuka out of 23 farmers 16 farmers had established the demo plots, while from Mtinko ward 20 farmers out of 22 established the demo plots. There was drought immediately after planting in February. This affected the crop establishment and effect of inorganic fertilizer. Some of the farmers had to replant the crop. Later, normal rain resumed and the performance of the crop was very attractive especially when we made a mid-season evaluation with farmers at milk dough stage of the crop. This year was a non- *Striga* year and very few *Striga* plants were observed on the plots hence those farmers did not even bother to count them.

From the treatments at the two villages of Sepuka ward tied-ridges plus animal manure produced the same grain yield as the demo plots applied with urea and the difference was not statistically significant. The difference was significant between the use of fertilizer and without fertilizer (Table 3). The question for further expansion of the best treatment should consider the cost and availability of fertilizer.

From the Mtinko ward the combination of sorghum variety Wahi, tied-ridges and animal manure/urea application had the highest grain yield. Flat planting for both local and improved variety did not differ from each other in terms of grain yields (Table 4).

Tentative conclusions are as follows: farmers have liked the improved varieties because of the short texture, early maturity, bold white grains, easier to scare birds, they also stay green hence good for animal fodder.

From crop management practices, most of the farmers are convinced in using the new varieties, tied-ridges and animal manure. Farmers in this area are said to have enough animal manure; meanwhile urea is very expensive and not readily available at the village level. The urea we used for demonstrations cost 30 US$ of 50kg bag and it was only available at the district level. (Figure 1)

Plans made for future efforts in the ISM project in Singida district will include the following:

- Many farmers have asked for seed in the coming season and from the available seed we expect to reach up to 400 farmers.
- From the participating villages 100kg seed of each of the sorghum varieties have been harvested from isolated fields, bought by the project and treated for distribution to more farmers in the coming season.
- In the district there is a seed farm, which has agreed to produce seed of the two sorghum varieties Wahi and Hakika. We have promised to provide the seed farm with 100 kg and 50 kg of Hakika and Wahi respectively to multiply for the coming season.
- We expect to hold a stake holder's workshop late September on the marketing and utilization of sorghum for the two districts, Singida and Kongwa districts. We hope this

Table 3. Performance of Sorghum Variety Hakika against local variety under different crop management: Sepuka-Singida 2004.

Treatment	VILLAGES	
	Msungua	Musimi
Farmer variety and flat planting	1.7B	1.4B
Hakika flat planting	1.8B	1.4B
Hakika + tied-ridges + animal manure	2.7A	2.0A
Hakika + tied-ridges + Urea	3.0A	1.9A
Grand mean	**2.3**	**1.7**
CV	**25.0**	**19.2**

Numbers followed by the same letter did not differ significantly from each other at $p \leq 0.05$. NB I bag (50kg) of Urea cost 30 US $

Table 4. Performance of Sorghum Variety Wahi under different crop management: Mtinko-Sngida 2004

Treatment	VILLAGES	
	Malolo	Mpipiti
Farmer variety and flat planting	1.4B	0.8B
Wahi + flat planting	1.4B	1.3B
Wahi + tied-ridges	2.6A	2.2A
Wahi + tied-ridges + Animal manure	2.9A	2.9A
Grand mean	**1.7**	**1.44**
CV	**45.55**	**34.74**

Numbers followed by the same letter did not differ significantly from each other at $p \leq 0.05$

Figure 1. A farm family in Sepuka Ward in a plot of *Striga* resistant variety, Hakika, Singida 2004

will motivate farmers to produce more sorghum in the area because the major bottleneck of growing sorghum has been the availability of markets for sorghum. The participants will include those from the brewing industry, animal feed, food processors, traders, stockists, farmer research groups NGOs as well as policy makers.

Table 5. Amount of seed produced at the research station for on-farm demonstrations 2004-05

Variety	Quantity kg
Hakika	586
Wahi	338

Figure 2. A farmer in the Mtinko Ward , Singida in a plot of *Striga* resistant sorghum variety, Wahi, just prior to harvest, Singida, 2004.

- Amount of seed produced at the station during the 2004 season to be used for on-farm demonstration at the three sights Singida (Figure 2), Kongwa and Missungwi-Mwanza for 2004/2005 season as shown in Table 5.

In Kongwa district, a total of 16 farmers were recruited to participate in the ISM on-farm trials, but only 15 farmers eventually succeeded in implementing the project as agreed. The season was not a normal one because rainfall was below the mean annual rainfall normally received for the area. Urea fertilization was used on all plots with *Striga* resistant cultivar, but because of the severe drought the biggest performance was shown due to use of flat versus ridge plots. The following data were collected from 15 farmer plots in three villages (five farmers from each village), and samples were collected from a plot area of 20m^2:

Village	Tied-ridges (Kg)/plot	Flat (Kg)/plot
Sejeli	4.24	3.24
Manuugu	5.22	3.69
Vilundilo	5.00	3.84

In the Lake Zone area, demonstration of the ISM package involving the *Striga* resistant sorghum cultivar (Hakika), nitrogen fertilization (urea), and a water conservation measure (tied ridges) was conducted in the Misungwi district and it started with 20 volunteer farmers from the division of Usagara.

The Division Extension staff and the office of the Executive Division in Usagara at their annual agriculture campaign motivated farmers in villages to volunteer in demonstrating technology packages where Hakika, a newly released sorghum variety, was selected. In this operation both researchers and extension staff were able to select only 20 farmers and were provided with seeds and fertilizers. These farmers came from Fela, Bujingwa, Kanyelele, Mwakalima, Nyamatala and Mwagala villages

Researchers and extension officers participated on enhancing the demonstration of technology packages through group seminars. Each farmer was advised to provide an area of about one acre but unfortunately we were late because most farmers had already prepared their land for planting during the short rains. Therefore farmers who prepared their land but not planted are the ones who participated in the demonstration and most of them had various sizes of land, which was less than one acre.

The inputs that were provided for each farmer were 2.5 kg of sorghum seeds, 7 kg of TSP and 20 kg of Urea. From land preparation till harvest extension staff, farmers and researchers all together supervised operations.

- Tied-ridges were among the package to be demonstrated to farmers; however few farmers were able to practice it because of the nature of their land/soil type selected for demonstration. For instance few farmers selected black *mbuga* or clay soils that are difficult to work in making ridges.
- Little knowledge of farmers on the actual area that covers 1 acre. Most of the volunteer farmers did not know what the actual size of an acre is. Areas they allocated were less than an acre. As a result, we decided that for uniformity, each participant would have half an acre. Other farmers planted their sorghum seeds in a very highly exhausted soil (poor sandy soils) coupled with poor management and received low or no yields at all.
- Severe drought this year affected grain yields.
- We had already organized one farmers meeting to share experience gained regarding demonstration of Technology Package
- Farmers had already sold sorghum grain they harvested as seeds to different stakeholders amounting to a total of about 1.5 metric tons at a price of T Shs 600 ($ 0.6) per kilogram

The Regional Commission of the Mara requested 10 tons of sorghum seed (Hakika) to be distributed to farmers in Mara region following similar procedure used in Usagara division-Mwanza region. In Usagara division where demonstration was conducted, farmers sold each kilo of sorghum at 600/= ($0.6) as seed a condition which motivated other farmers to join to be as a group for production of Hakika. So it showed that the price was the driving force to increase the number of farmers in the coming season.

Future plan

We need to promote sorghum utilization (products) to different stakeholders as we realize that many people are not aware of the white sorghum variety products in the Lake Zone. Many people perceive sorghum is 'brown' in color and produce brown hard porridge "Ugali". The Agricultural Research Institute at Ukiriguru will prepare different white sorghum varieties and some food products to be displayed during the Zonal Agricultural Show which will take place August 8th 2004 known as Nane nane show.

Since we know that in the lake zone there are two cropping seasons, the first season-short rains, starts mid October to mid November while the second season starts late January to early February. In our planning we concentrated with the short rains and took the crop calendar which goes along with the season.

Integrated *Striga* Management (ISM) Pilot Project in Eritrea

Tesfamichael Abraha, Goitom Ghobezai, and Tewolde Gebreselassie

Sorghum [*Sorghum bicolor* (L.) Moench] is the most important cereal crop in Eritrea. It is the staple food for the majority of the people in the country. The parasitic weeds *Striga hermonthica* (Del.) Benth. are a major biotic constraint to cereal production in general and sorghum production in particular, especially in the potential sorghum growing areas where continuous cropping as a result of increasing population density and mono-cropping has led to widespread soil infertility. The *Striga* problem is more aggravated by stress condition where the country faces moisture stress once in every three years. Yield losses due to *Striga* can be up to 100%. *Striga*-resistant sorghums would be an important component of integrated *Striga* Management.

Adoption of the improved *Striga*-resistant sorghum varieties by farmers in each target region and their cultivation using integrated *Striga* control practices will improve household food security and income stability.

Based on these aspects the following *Striga* control measures were suggested and proposed by the INTSORMIL-NARI collaboration programs.

- Advanced sorghum varieties that show better resistance to *Striga* (P-9401, P9405, P9406 and P 9407)
- Water conservation methods (tied ridges or other alternative conservation techniques)
- Fertility improvement through fertilizer application (DAP and Urea)

The overall objectives of the program are:

- To minimize yield loss due to *Striga*
- To maximize sorghum production and thereby enhance food security.

This *Striga* project is purely participatory approach, which will be sustainable and demonstrate to the farmers whose field is severely affected by *Striga*. In the year 2003 rainy season it was planned initially to start the project with 100 farmers to be selected from different sub zones of Gash Barka and the Southern zones. After this initial popularization of the program many farmers are expected to be involved in the project. The following considerations were taken while selecting farmers' field:

- The selected farmer's field should be a *Striga* infested site
- The site selected should have an access to transport for supervision and observation by the farmers community
- The selected farmer will cooperate in implementing the

project successfully in his ½ hectare of land

- Selected farmers will receive different packages for *Striga* control measures, and be fully involved in all the management and popularization of the practice

The Pilot Project was started late in July and planting at farmers field was done between the end of July and the first week of August. The main reasons for the late planting were:

- Budget for the project implementation was delayed
- The additional advanced sorghum varieties for *Striga* resistance were sent in mid-July
- Farmers' and site selections for *Striga* infested plots were carried out later than the normal planting time

Because of these reasons most of the farmers, particularly in the *Striga* -infested sites, planted before the project was started. Though we were late it was decided to minimize the number of farmers to be 50-60 in Gash Barka (Sub zoba Goluj and Shambuko) but to postpone the Southern zone program. (Tables 6, 7 and 8)

Conclusion:

The project is at its starting point and much work still remains to be done. From the preliminary observation of the 2003 cropping season the integrated *Striga* management packages as well as the *Striga* resistant varieties are well accepted by the farmers who were involved in the pilot project. It is recommended therefore to further push the project among additional farmers.

For the coming 2004 rainy season we have collected from specially selected farmers' fields for all the agronomic and isolation practices about ten quintals of the four Purdue *Striga* resistant varieties. Much of the seed collected was for the variety P9407 that performed better in the previous ISM pilot project program.

For the sustainable continuation of the project we strongly recommend the following points:

- In the cropping season of 2003 only four members of the task force actively participated in implementing all the ac-

Table 6. Farmers Involvement in Integrated *Striga* Management in Zoba Gash-Barka, Variety by area planted, 2003 rainy season

Sub Zoba	Variety Type given	Villages	Farmers involved	Area covered (hectares)
Goluj	P-9401	1. Tebeldia 2. Omhajer 3. Goluj	3	1.5
Goluj	P-9405	1. Tebeldia 2. Gergef 3. Omhajer 4. Goluj 5. Sabunite	12	8.5
Goluj	***P-9406***	1. Tebeldia 2. Gergef 3. Omhajer 4. Goluj	10	7.0
Goluj	***P-9407***	1. Tebeldia 2. Gergef 3. Omhajer 4. Goluj	11	8
Shambuko	*P-9401* P-9405 P-9406 P-9407	Dembe Asmara	10	5
	Total		46	30

Table 7. Farmers Involvement and input Distribution in Integrated *Striga* Management in Zoba Gash-Barka

Zobas	Sub Zoba	Area Covered (hectares)	No. of farmers involved	Seed distributed (quintals)	Fertilizer (DAP and Urea distributed (quintals)
Gash Barka	Goluj	25	36	3.0	25 (DAP) and 12.5 (Urea)
	Shambuko	5	10	0.7	5 (DAP) and 2.5 (Urea)
	Total	**30**	**46**	**3.7**	**30 (DAP) and 15 (Urea)**

Remark: Seven farmers in sub zoba Goluj were given inputs for one hectare.

Table 8. Demonstration ISM in Zoba Gash Barka 2003 Cropping Season

Sub Zoba	Varieties	No. of sorghum plants/plot ($2m^2$)	*Striga* count/plot ($2m^2$)	Yield ranges Quintal/hectare
Goluj	P-9406	20	8	0.3 – 3.3
	Local	20	68	0.0 – 1.2
	P-9407	30	9	2.0 – 13.0
	Local	34	88	0.0 – 3.0
	P-9405	21	2	1.0 – 2.0
	Local	26	127	0.0 – 1.5
	P-9401	25	43	1.0 – 5.0
	Local	30	249	0.0 – 1.5
Shambuko	P-9407	NA	NA	3.0 – 8.0
	Local			0.0 – 2.0

N.B

1. The low yield levels are not only due to *Striga* infestation but also because of moisture stress, late planting and low population density that was damaged by grasshopper at the seedling stage.
2. About 15 hectares failed completely due to moisture stress and grasshoppers.

tivities. Hence all the task force members for this project should participate.

- We recommend that the Ministry of Agriculture to declare the ISM packages to be applied as a national campaign and all concerned Zoba heads, Administrators, Extension workers and NGO's to be aware and participate in this pilot project.
- Budgeting, project activities and logistics to be implemented as per the project planned.

Pearl Millet Breeding Activities 2003

Negussie Abraha

Pearl millet (Pennistum glaucum) has protogynous nature of flowering and 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 (Harinarayana, 1987).

Pearl millet is the second largest food crop in Eritrea, grown mainly by small farmers in lowlands and midlands. Landraces currently grown by the farmers contain the traits that farmers have selected for centuries, and thus represent a very valuable resource for the breeding program. However, because of the cross-pollinated nature of the crop, such desirable traits may not exist in a high frequency in landrace populations and may be accompanied by various undesirable traits, such as susceptibility to downy mildew.

Pearl millet downy mildew, caused by the fungus, *Sclerospora graminicola,* is one of the major production constraints in pearl millet in most of the semi-arid tropics (Singh et al., 1993). Downy mildew is widely spread in Eritrea and occurs in epidemic form on farmer landraces, making it the major millet disease in Eritrea. Surveys conducted in 1999 and 2000 showed high levels of downy mildew incidence ranging from 30% to as high as 70% in farmers' fields.

The Eritrean pearl millet breeding program, which started its research and breeding activities in early 2000, seeks to produce adapted, disease resistant pearl millet varieties, acceptable to farmers, that will help to increase and stabilize millet productivity in Eritrea. In this effort, local landraces and exotic cultivars were tested for their disease resistance and yield capabilities. Crosses were made between the exotic and local landraces to increase disease resistance and productivity of the landraces.

In the rainy season of 2003, landraces, exotic varieties, new population crosses and top-cross hybrids were tested on-station and on-farm trials for their adaptability, disease resistance, yield potential and to assess the farmers' perception of the positive and negative aspects of the new crosses.

The on-farm trials were conducted at 13 sites in Zoba Anseba (four in sub-Zoba Hagaz, three in sub-zoba Hamelmalo, three in sub-zoba Keren and three in sub-Zoba Elabered) and eight sites in Gash Barka (two sites in Mogollo, Gogne, Barentu, Shambiko sub-zobas). Plot size was 50 meters square (5m x 10m) and the plots were laid side by side. Extension personnel from the Ministry of Agriculture from these sub-zobas were entrusted with the responsibility of identifying farmers and conducting the trials.

The Hagaz Research site is located at an altitude of 850 m.a.s.l. with minimum and maximum temperatures of about 12°c and 42°c respectively. The average rainfall ranges from 300 – 400 mm/annum. The site has a typical arid and semi-arid climatic conditions, which is conducive for pearl millet research work. During the growing period (July 1- September 10, 2002) a total of more than 333 mm was recorded. Two hand weeding and cultivation were also done. Analysis of variance was computed using Gen-stat 5 software in all the trials.

The pearl millet breeding program in Eritrea conducts off-season nursery activities during the dry season with irrigation to initiate new experimental crosses and increase seed of breeding materials selected in nurseries during the main crop season.

Advanced Yield Trial of Exotic Varieties

The objective of this experiment was to identify genetic material that may be suitable for direct use as an introduction in some agro-ecological zones or to identify parental material with candidate traits for use in crosses with local landraces or other selections. Twenty-two experimental varieties were tested in this experiment. The design used was a RCBD with three replications. Spacing was 4m x 0.75m xs 4 rows. At the time of planting basal application of DAP at a rate of 100 kg ha^{-1} was applied. Thinning and transplanting were accomplished two weeks after planting. Top dressing of urea was applied at a rate of 100 kg per ha three weeks after planting. Observations were taken on the center two rows for days to 75% flowering, plant height, plant count, head count, head yield, ear length, and grain yield.

The results are reported in Table 9. In the analysis of variance for days to 75% flowering ($P < 0.001$) and agronomic scoring ($P < 0.001$), genotypes showed highly significant differences indicating that genetic variation influenced the maturity date and agronomic performance. Moreover, there was significant difference between genotypes for the trait grain yield ($P = 0.012$). However, there was no significant difference between the genotypes for the character plant height ($P = 0.09$).

Table 9: Result of Advanced Yield Trial of Exotic Varieties, Rainy Season, 2003.

Ent.	Entry Name	Flower Day (75%)	Plant Ht	Grain Yld Qt/ha	Agro. Score	Remark
1	ICMP 95490	48	207	25	4.7	*
2	ICMP 97754	49	207	18	5.3	
3	ICMP 98107	48	187	18	6.3	
4	EERC CO	44	161	20	6.5	
5	IAC ISC ICP 4	49	213	24	5.0	*
6	IAC ISC ICP 6	53	205	18	6.0	
7	Sudan Pop II	49	202	18	5.7	
8	EC 89 CO x MC 88 CO	45	188	28	5.5	
9	MC 89 CO x AIMP 92901	47	176	21	6.0	*
10	MC 89 CO x RCB IC 912	47	198	23	6.0	*
11	AIMP 92901 x SDMV 96063	47	200	24	5.5	*
12	SDMV 96063 x SDMV 95017	47	208	18	5.3	*
13	ICMV 97802	57	200	12	6.3	
14	ICMV 96601	48	211	24	5.0	*
15	ICMP 96611	48	200	22	5.0	*
16	ICMV 95846	43	193	13	7.3	
17	CZ IC 922	45	205	20	6.7	
18	ICMV 97801	60	220	15	7.0	
19	ICMV 91170	44	197	25	6.3	*
20	AIMP 92901	46	189	21	6.0	*
21	GICKV 93191	45	192	18	6.7	
22	ICMP 97774	46	200	22	5.7	*
	Grand Mean	48	198	20.32	5.9	
	LSD	3.183	28.77	7.9	1.13	
	Se					
	CV (%)					
	F. Prob (5%)	***	NS	*	***	

The variety EERC CO was the earliest to flower. However, it was the shortest in plant height and resulted in less biomass. This variety can be used as a source of genes for early maturity and future breeding efforts. The varieties ICMV 95846 and ICMV 91170 followed EERC CO in earliness and these materials can be used as source of genes for earliness.

When the trait grain yield was considered, the crosses EC 89 CO x MC 88 CO attained the highest grain yield. It was followed by the varieties IAC ISC ICMP 4, ICMV 96601 AND AIMP 92901 x SDMV 96063.

By considering the different traits, the following varieties were selected to advance to the coming rainy season for further evaluations. These are ICMP 95490, IAC ISC TCP 4, ICMV 96601, ICMP 96611, ICMV 91170, AIMP 92901, ICMP 97774, EC 89 CO x MC 88 CO, MC 89 CO x AIMP 92901, MC 89 CO x RCB IC 912, AIMP 92901 x SDMV 96063 and SDMV 96063 x SDMV 95017

Advanced Yield Trials of Population Crosses

The objective of this experiment was to identify the most promising population cross that can be grown in different millet growing environments. The experimental materials used were 26 with 4 landraces as checks. The experimental design used was RCBD with 3 replications. They were planted with spacing of 4m x 0.75m x 4 rows. Observations were recorded on the central 2 rows of each plot with the following characteristics: days to 75% flowering, plant height, plant count, head count, panicle count, panicle yield, panicle size, 100 seed weight and grain yield. To maintain soil fertility, 100kg ha^{-2} DAP before planting and 100 kg ha^{-2} urea three weeks after planting were applied. Thinning and transplanting were done two weeks after planting. It was cultivated once and hand weeded twice.

The analysis of variance (Table 10) or days to 75% to flowering, plant height showed highly significant difference between genotypes ($P < 0.001$) indicating that plants reach 75% flowering date at a different time and the genetic makeup had influenced the biomass production. Moreover, the trait of agronomic scoring also showed significant difference ($P = 0.025$) between the genotypes. However, there was no significant difference for grain yield ($P = 0.122$).

Comparisons between the genotypes were made. When days to 75% flowering were considered, the earliest varieties

Table 10: Result of Advanced Yield Trial of Population Crosses, Rainy Season, 2003.

Ent.	Entry Name	Flower Day (75%)	Plant ht (cm)	Grain Yld Qt/ha	Agro. Score	Remark
1	Tosho x IAC ISC TCP 1	49	218	14	6.3	
2	Tosho x MC SRC	48	225	18	6.0	*
3	Tosho x Sudan pop I	51	225	12	6.0	
4	Tosho x SOS AT C88	51	210	9	6.5	
5	Mebred x IAC ISC TCP 1	53	233	15	5.7	
6	Mebred x MC SRC	52	240	17	5.0	*
7	Mebred x Sudan pop 1	52	222	17	6.0	*
8	Mebred x SOS AT C88	54	229	21	6.0	*
9	Ashera x ICMP 91170	47	218	20	5.3	*
10	Ashera x AIMP 92901	48	214	22	6.0	*
11	Ashera x GICKV 93191	48	215	16	6.3	
12	Ashera x ICMP 97774	48	219	17	6.3	*
13	Libana x ICMP 91170	48	210	21	5.7	*
14	Libana x AIMP 92901	48	199	23	5.7	*
15	Libana x GICKV 93191	48	207	19	5.0	*
16	Libana x ICMP 97774	52	212	15	5.5	
17	Jengeren x ICMP 91170	48	228	19	6.7	*
18	Jengeren x AIMP 92901	48	212	19	5.3	*
19	Jengeren x GICKV 93191	48	225	16	6.7	
20	Jengeren x ICMP 97774	49	208	18	6.0	*
21	Mogollo II x ICMP 91170	46	191	15	7.0	
22	Mogollo II x AIMP 92901	43	187	16	6.7	*
23	Mogollo II x GICKV 93191	45	192	16	6.7	
24	Mogollo II x ICMP 97774	45	204	14	6.7	
25	Mebred x Kona (C2)	49	214	13	6.5	
26	Zibedi x Kona (C2)	49	206	16	5.3	
27	Ashera (LD)	51	220	17	6.0	
28	Libana (LD)	55	238	22	5.0	
29	Jengeren (LD)	51	234	13	6.7	
30	Mogollo II (LD)	47	181	13	7.3	
	Grand Mean	49	215	16.8	6.1	
	LSD	2.6	24.2	7.8	1.3	
	Se					
	CV (%)					
	F. Prob (5%)	***	***	NS	*	

Table 11: Results of Advanced Yield Trial with New Pearl Millet Top-Cross Hybrids, 2003, RS.

Ent. No.	Entry Name	Flower Day (75%)	Plant Ht (cm)	Grain Yld Qt/ha	Agro. Score Rank	Remark
1	Tosho x ICMA 89111	49	217	31	5.3	*
2	Tosho x ICMA 95333	48	216	26	5.7	*
3	Tosho x ICMA 97333	50	227	36	4.7	*
4	Tosho x ICMA 91222	49	214	24	5.7	
5	Tosho x ICMA 97111	52	225	25	6.0	
6	Mebred x ICMA 89111	52	223	24	6.3	
7	Mebred x ICMA 95333	55	205	29	5.7	*
8	Mebred x ICMA 97333	50	221	31	6.0	*
9	Mebred x ICMA 91222	50	215	31	6.0	*
10	Mebred x ICMA 97111	53	229	23	6.3	
11	Zibedi S x ICMA 97111	45	201	26	6.0	*
12	Zibedi S x ICMA 92444	48	202	24	6.0	
13	Kona x ICMA 95333	48	218	23	6.0	
14	Kona x ICMA 97333	54	223	21	5.0	
	Grand Mean	50	217	27	5.8	
	LSD	8.9	20.79	7.5	1.2	
	Se					
	CV (%)					
	F. Prob (5%)	***	NS	*	NS	

was Mogollo II x AIMP 92901. The latest and the tallest population cross was Libana which is one of the parents.

When the grain yield was considered the population cross Libana x AIMP 92901 attained the maximum yield (23 qt/ha) followed by Ashera x AIMP 92901 (22 qt/ha) and Libana (22qt/ha).

By considering all the characters, 15 population crosses were selected for the coming rainy season to be tested as advanced yield trial. These are: Tosho x MC SRC, Mebred x MC SRC, Mebred x Sudan pop 1, Mebred x SOS AT C88, Ashera x ICMP 91170, Ashera x AIMP 92901, Ashera x ICMP 97774, Libana x ICMP 91170, Libana x AIMP 92901, Libana x GICKV 93191, Jengeren x ICMP 91170, Jengeren x AIMP 92901, Jengeren x ICMP 97774, Mogollo II x AIMP 92901.

Advance Yield Trial of New Top-Cross Hybrids

The objective of this experiment was:

- To combine the stress-adaptive traits of farmers' own landraces with improved grain yield and disease resistance that landraces often lack.
- To develop landrace-based Topcross hybrid which exploits heterosis between adapted, dual-purpose male-sterile lines and pollinators derived from local landraces.

The experimental materials used were 10 + 8 (checks) which were developed from crosses of two selected landraces and five male-sterile lines. The experimental design used was RCBD with three replications. Spacing was 4m x 0.75m x 4 rows. At the time of planting basal application of DAP at a rate of 100 kg ha^{-2} was applied and after two weeks thinning and transplanting were done. Top-dressing at a rate of 100kg ha^{-2} urea was given three weeks after planting.

Results showed days to 75% flowering ($P < 0.001$) with highly significant difference and grain yield showed significant ($P = 0.015$) difference between the genotypes indicating that genetic variation had influenced maturity date and grain yield. However, there were no significant differences between the genotypes for the traits plant height ($P = 0.156$) and agronomic scoring ($P = 0.262$).

The earliest top-cross hybrid was Zibedi S x ICMA 97333 which attained a medium plant height with satisfactory grain yield as compared to other hybrids. It was followed by the hybrids Tosho x ICMA 95333, Zibedi S x ICMA 92444 and Kona x ICMA 9533. These hybrids had reasonable grain yield. These four hybrids can be considered as early hybrids and can be recommended during the short season.

When grain yield was considered, the hybrid Tosho x ICMA 97333 attained the highest performance (36 qt/ha). It was followed by Tosho x ICMA 89111, Mebred x ICMA 97333 and Mebred x ICMA 91222.

We can conclude that the male sterile lines (MS-Lines) ICMA 97333, ICMA 89111, ICMA 97333 and ICMA 91222 can be used as best materials for the development of Top-cross hybrids. They could be crossed with adaptable varieties from the region. This type of approach could be applied in the developing countries of Africa. Single cross hybrid development could be difficult and costly (John Withcombe and Tom Hash, personal com, Bangor Uni. ICRISAT respectively). Two rows for days to 75% flowering, plant height, plant count, head count, head yield, ear length and grain yield. The materials used in this trial are listed in Table 11.

Seed Multiplication

The pearl millet breeding program assists with multiplication of foundation seed for the Ministry of Agriculture (MOA). The MOA receives foundation seed from NARI to produce certified seed, which is produced by farmers on contract. The MOA purchases seed from farmers at the market price rate +25% premium price. Based on such an arrangement, the pearl millet improvement program produced foundation seed in three stations during the 2003 cropping season.

At the Hagaz Station, the improved variety Hagaz had wide acceptance by farmers in the region.

At Shambiko Research Station, the varieties Hagaz and Kona were sown on 6 ha for foundation seed production. At the end of the season, about 15 qt Hagaz variety and 4.5 qt Kona variety seed was produced. At Golij Research Station, the Hagaz variety was sown on 10 ha for foundation seed production. In spite of the moisture stress during the season in the area, about 60qt of foundation seed was produced.

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

Gary C. Peterson
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Collaborative Program

Organization, Management, Implementation and Financial Inputs

The INTSORMIL Southern Africa regional program involves five 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: Cultivar food quality, milling technologies, sorghum and pearl millet food nutritional value

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

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

The INTSORMIL Southern Africa program has been organized to be fully integrated with, and operate in conjunction with, SADC/ICRISAT/SMIP activities located at the ICRISAT Center, Matopos, Zimbabwe. Work plans for each INTSORMIL project are developed based on regional needs and the expertise of the scientists involved. Through the SMINET regional coordinator (located at Matopos) the SMIP Technology Transfer Program (SMINET) Steering Committee reviewed each work plan to ensure it was responsive to regional pearl millet and sorghum research needs. Through a Memorandum of Agreement INTSORMIL funds were disbursed through ICRISAT/Matopos to 10 collaborating scientists affiliated with seven research agencies in four countries. Since ICRISAT has no core funded pearl millet or sorghum scientists in the SADC region and SMIP Phase IV focused entirely on technology transfer. INTSORMIL participation in Southern Africa is critical to maintaining and improving the knowledge base of pearl millet and sorghum in the region. With the formal end of SMIP activities in December 2003, INTSORMIL will provide additional leadership to regional pearl millet and sorghum research and technology transfer. INTSORMIL will collaborate with ICRISAT regional activity as appropriate and mutually beneficial, and will continue to develop linkages with other agencies to strengthen regional research and technology transfer.

Through integration with SMINET complementary with existing regional pearl millet and sorghum programs was achieved. This complementary enabled both organizations to capitalize on their relative strengths for greater benefit to the region. Collaborating organizations for each regional project are:

Pearl millet breeding - Ministry of Agriculture, Water and Rural Development, Omahenene Research Station, Outapi, Omusati Region, Namibia; Department of Agricultural Research, Botswana;Ministry of Agriculture, Kaoma Research Station, Kaoma, Zambia

Pathology - ARC-Summer Grain Crops Institute, Potchefstroom; South Africa (SA) Crops and Soil Research, Mt. Makulu Research Station, Chilanga, Zambia; Department of Agricultural Research, Gaborone, Botswana; Medical Research Council, Tygerberg, SA

Food quality - University of Pretoria CSIR (SA); ARC-Summer Grain Crops Institute

Entomology - ARC-Summer Grains Crop Institute; Botswana College of Agriculture, Gaborone, Botswana; North West University, Potchefstroom

Sorghum breeding - Ministry of Agriculture/Golden Valley Research Trust, Zambia; Department of Agricultural Research, Botswana

With the dissolution of SMIP and SMINET work plans are now reviewed by the regional coordinators. Fund transferred through ICRISAT/Bulawayo ended on June 30, 2004.

Institution Building

Equipment

- INTSORMIL purchased a MaxiMil Roller mill and Auger for the Food Quality program at the University of Pretoria.
- INTSORMIL purchased a trailer to transport equipment, supplies, and grain for the Zambia breeding program.

Visits

- Dr. John Taylor (University of Pretoria) attended the American Association of Cereal Chemists annual meeting in Portland, Oregon in September 2003. He also visited with Dr. Bruce Hamaker and Dr. Gebisa Ejeta at Purdue University to discuss collaborative work, particularly on protein quality and injera-making quality of sorghum.
- Dr. Gary Peterson (Texas A&M University) visited Zambia, Botswana, Namibia, and South Africa to review research progress and plan the EEP review, November 2003. Dr. Medson Chisi (Zambia) participated in the meetings in Botswana, Namibia, and South Africa.
- Dr. John Leslie visited South Africa in November 2003 to review current research and plan future research with collaborators at the ARC-Grain Crops Institute at Potchefstroom and the Medical Research Council at Tygerberg.
- Dr. Tom Crawford (University of Nebraska Management Entity) participated in the closing meeting of SMINET (Sorghum and Millet Improvement Network) at Bulawayo, Zimbabwe, November 2004.
- Dr. Medson Chisi (Zambia), Dr. Gary Peterson (Texas A&M Univ.), and Dr. Tom Crawford (Univ. of Nebraska Management Entity) evaluated the Mozambique sorghum-breeding program and presented results of the evaluation to Dr. Calisto Bias, INIA Director, in February 2004. Dr. Chisi participated in the EEP review in Zambia and South Africa.
- Mr. S.A. Ipinge (Namibia) and Mr. Michael Mogorosi (Botswana) participated in the INTSORMIL External Evaluation Panel (EEP) review of their collaborative activities during the EEP visit to Zambia, March 2004.
- Dr. John Taylor (Univ. of Pretoria), Mrs. Janet Taylor (University of Pretoria), Dr. Stephen Chite (Botswana), Dr. David Munthali (Botswana), Ms. Phoebe Ditshipi (Botswana/Univ. of the Free State), Dr. Neal McLaren (ARC), Ms. H. du Plessis (ARC), and Dr. J. v.d. Berg (North West Univ.) participated in the EEP review at the Cedara Experimental Station in KwaZulu-Natal, South Africa in March 2004. The University of Pretoria hosted the EEP and INTSORMIL scientists and staff at the University of Pretoria where Dr Taylor's INTSORMIL research was re-

view. The EEP was also hosted by the Medical Research Council, Tygerberg, SA, where the research of Dr. Wally Marasas and associated was review.

- Dr. Jeff Wilson (USDA-ARS) participated in the EEP review in Zambia of regional pearl millet breeding activity. Following the review Dr. Wilson, Mr. Ipinge (Namibia), Mr. Muuka (Zambia), and Mr. Mogorosi (Botswana) toured the Nambia pearl millet growing research and research stations, March 2004. Dr. Wilson met with Mr. Simon Awala, the new Namabian pearl millet breeder, to establish collaboration and plan a short-term training assignment.
- Dr. Bonnie Pendleton (West Texas A&M University) and Dr. John Leslie (Kansas State University) participated in the EEP review at Cedara and Tygerberg, respectively. Dr. Pendleton also conferred with collaborators at Potchefstroom and Gaborone. Dr. Leslie also conferred with collaborators at the Univ. of Pretoria.

Short-term Training

- Twenty students from sorghum beer brewing companies in five SADC countries took the Certificate Course in Opaque Beer Brewing conducted by the University of Pretoria.
- Eduardo Aizequi Lameque Joaquim, Rodrigues Joã Mambonhe, and Flemming Nielsen (all from Mozambique) visited the Zambia sorghum breeding program 2-8 May 2004. A number of sorghum lines that may be useful in Mozambique were identified and will be sent to Mozambique before the next growing season. The Zambia sorghum breeding program will continue to share germplasm, trial results, and expertise with any program in the region.
- The Zambia sorghum-breeding program in cooperation with World Vision International (WVI) conducted a workshop on "Sorghum Seed Production and Managing On-farm Research Trials". There were 17 participants (including three females) in the workshop. The main objective was to assist WVI with their outreach program in seed production and seed availability to small farmers. Advanced pre-released lines from the breeding program will be evaluated by WVI in on-farm trials.

Long-term Training

- Students are in graduate degree programs (either M.S. or Ph.D.) at institutions in the region (University of Zambia, University of the Free State (South Africa), University of Pretoria (South Africa) and in the U.S. (Texas A&M University). The students are supported either fully or partially by INTSORMIL, or work on sorghum and pearl millet research problems of direct benefit to the INTSORMIL program. Students from Mozambique are in USAID Mission (Maputo) training program. The students begin returning to Maputo in August 2004 and will initiate programs as INTSORMIL collaborators.

Seed Increase

- Availability of high quality seed for distribution to farmers continues to hinder adoption of improved varieties and is a major challenge to breeding programs. Local seed companies cite low demand as the reason to not produce seed. The Zambia breeding programs work with INTSORMIL to increase and distribute seed of improved varieties. With INTSORMIL support a Revolving Seed Fund has been established to support the cost of increasing seed. Following harvest the seed is cleaned, packaged, and sold to NGO's with proceeds going back into the Revolving Fund to support future increases. In 2003/04 season NGO's such as WVI, GTZ and Oxfam were involved in seed production of released open pollinated varieties. The following varieties were increased at Golden Valley: Kuyuma (2750 kg available), Sima (850 kg), ZSV-15 (1250 kg), ZSV-35 (1100 kg), and WP-13. Additionally, Zamseed produced seed of a hybrid MMSH-375 on six hectares but the quantity of seed available was not known at the time this report was prepared. For pearl millet three tons of the variety Lubasi was produced with INTSORMIL support.

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 also used to a certain extent as a livestock feed. 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, poor grain quality, lack of improved seed, and poor distribution and 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 and supply. The inconsistent supply of quality grain is frequently cited as a major factor in deciding to use maize as opposed to sorghum. 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, improved environmental adaptation, increased resistance to abiotic (drought tolerance) or biotic (disease and insect) stress, improved end-use traits (for food, feed and forage), and other desirable traits are in development by national programs. Exotic sorghums and pearl millets are continually introduced into the SADC region as sources of needed 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. Research is on-going to improve disease and insect pest management and to improve sorghum and pearl millet processing techniques to improve use in value added foods.

Constraints Addressed by Project Objectives

Pearl Millet Breeding: Develop topcross grain and forage hybrids adapted to low rainfall regimes in Southern Africa with the potential to transform the crop from subsistence to commercial status through commercialization and stimulating industrial development, test prototype cultivars in commercial and industrial ventures, and develop appropriate populations for sustaining the program. Important traits are yield, early maturity, and grain size.

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. Determine disease vulnerability of recently released sorghums and the need for better sources of resistance. Determine mycotoxin production capabilities of new *Fusarium* species, and the presence of *Fusarium* mycotoxins in molded grain. Develop appropriate control measures for economically important diseases.

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.

Entomology: Reduce yield losses by identifying, evaluating, and incorporating sugarcane aphid resistance into adapted sorghum varieties and hybrids. Assess the response of sorghum varieties and segregating populations to other insect pests as appropriate. Develop integrated pest management strategies for sorghum insect pests in Southern Africa.

Sorghum Breeding: Develop high grain yield sorghum varieties and hybrids with improved stress resistance (disease, insect, drought), improved environmental adaptation, and improved end-use quality traits for food, forage and feed for drought prone areas. Maintain pre-basic and basic seeds of all released and pre-released varieties, hybrids and their parents, and assist with seed production and distribution systems at a community level. Develop appropriate agronomic management practices based on the farming system and assist in technology transfer.

Mutuality of Benefits

The collaborative Southern Africa regional program provides reciprocal mutual benefits in breeding, plant pathology, entomology, and food science. The benefits strengthen both the host country and U.S. based programs. In plant breeding a free and unhindered exchange of germplasm occurs. The U.S. based programs have access to germplasm with biotic and abiotic stress resistance sources and well as the opportunity to evaluate germplasm in a diverse set of environments. The host country programs gain access to a wide-array of new technology, germplasm, and gene combinations not present within the country. Much of the research knowledge used in the U.S. for ergot is a direct result of INTSORMIL collaboration with scientists in South Africa. Their expertise assisted the U.S. industry in managing the disease. Collaborating scientists benefit through access to new research technology, germplasm, and reciprocal visits. Entomology research in integrated pest management and host plant resistance uses methodology developed in the U.S. and modified for the pests of Southern Africa. Knowledge gained through the research will benefit the U.S. should the insect pests be introduced into the U.S. The excellent working relationships between the entomologists enable them to exchange research ideas, methodology, and knowledge. The food quality program provides training and expertise at a level not found in the U.S. Students conduct research, supervised by local and U.S. scientists, to understand how to improve the processing of sorghum and pearl millet and to develop new uses for both crops. The information gathered in the program is potentially beneficial wherever sorghum and pearl millet are grown.

Research Progress

The collaborative research program goal is to develop the technology for increased production and use of pearl millet and sorghum. Component projects conduct research specific to the project goals but which has implications to research in other projects. Projects interact to develop new technology and the interaction should increase as additional opportunities and funding become available. The local scientists are encouraged to collaborate across country boundaries.

The Texas A&M University/Texas Agricultural Experiment Station sorghum-breeding program distributes tests and nurseries based on requests from individual collaborators. Multilocation testing establishes base-line data for performance response of introduced germplasm throughout the region. Germplasm suitable for direct use or use as parental lines in a breeding program is identified. Disease pathogen race and insect biotype distribution can be established as well as identification of resistance sources. Regional research is conducted under rain-fed conditions with little if any supplemental irrigation. Thus reporting of results is frequently contingent on timely rainfall sufficient to produce the environment necessary for evaluation.

Pearl Millet Breeding

Zambia

Pearl millet is the third most important traditional cereal food crop after sorghum and finger millet. It is cultivated in low input farming systems and in communities experiencing high poverty levels (more than 80%), endemic malnutrition, and poor agricultural services and delivery systems. Abiotic constraints include poor soil fertility; low soil pH and erratic rainfall while the major biotic constraints are downy mildew, ergot, and smut. The lack of improved seed which affects productivity and production. The breeding strategy involves developing suitable topcross R_4 (cytoplasm) restorer parents from adapted Zambian genetic stocks which can then be crossed with suitable exotic A_4 CMS seed parents to produce hybrids.

The A_4 CMS seed parents 79-2068 A_4, 1163 A_4, 88006 A_4, and 8401 A_4were used in making all possible hybrid combinations with ten diverse potential topcross pollinators (NEC, Lubasi, ZPMBC, ZPMDC-C_2, NLC, Tuso, NLoC, Sepo, ZPMV 92008, and Oksahans-1). In addition, two A_1 CMS seed parents 79-2068 A_1 and 1163 A_1 were also used. The hybrids were evaluated in two trials to assess the combining ability of the parental lines and identify superior hybrid combinations.

In the first hybrid trial for seed parents hybrids based on 1163 A_4 were generally superior (3962 kg/ha^{-1}) to those from 79-2068 A_4 (3588 kg/ha^{-1}), 8401 A_4 (3437 kg/ha^{-1}), and 888006 A_4. In the second hybrid trial parental performance was inconsistent compared to the first trial. Performance of the A_1 CMS system was also inconsistent within and between trials as well as in comparison with the A_4 CMS system. The results generally conform with those from the previous season. For pollen parents in the A_4 CMS-based trial hybrids derived from ZPMDC-C_2 (4638 kg/ha^{-1}) were superior to those derived from Tuso (4414 kg/ha^{-1}) and Sepo (3990 kg/ha^{-1}). In the second trial the best pollinators were NEC (3747 kg/ha^{-1}), ZPMBC (3348 kg/ha^{-1}) and ZPMDC-C_2. There was no consistent superiority for grain yield across pollinators and trials for the A_4 CMS system over the A_1 CMS system. Male parent heterosis for grain yield ranged from -39 to 212%. Ergot was prevalent mainly on late tillers with incidences of up to 60%. A few hybrids showed incidences of smut up to 16%. These preliminary findings highlight the possibility of the existence of superior specific hybrid combinations in both the A_1 and A_4 CMS systems but do not take into consideration the established merits of the A_4 over the A_1 system.

Namibia

The program has three major objectives: develop top-cross hybrids by breeding A_4 restorer versions of the best Namibian varieties for use with selected A_4 seed parents, develop and test prototype hybrids using SMIP A_4 seed parents, and identify the best A_4 F_1 male sterile seed parents. The program is in transition between breeders but working to achieve its research objectives. Mr. S.A. Ipinge has been reassigned as Deputy Director, Ministry of Agriculture, Water and Rural Development. Mr. Simon Awala, previously a technician in the breeding program, completed his B.Sc. degree and is now the pearl millet breeder. Mr. Awala has established collaboration with Dr. Jeff Wilson and will participate in a short-term training assignment with Dr. Wilson.

During the 2003/04 cropping season several crosses were made to develop test varieties. Additionally, test varieties from the 2001/02 cropping season were increased so that all varieties could be entered in multi-location variety trials during the 2004/05 cropping season. The new entries will be tested at three major sites - Omahenene, Okashana, and Mashare to compare grain yield performance and adaptability against the standard checks.

Botswana

A major objective of the program is to identify hybrids with high grain yield potential and adaptation to the areas of Botswana where pearl millet is an important crop. A pearl millet hybrid trial consisting of 25 hybrids obtained from SADC/ICRISAT at Matopos, Zimbabwe was planted and data collected on days to 50% anthesis, plant height, and grain yield. Significant differences were identified for the traits studied. Grain yield ranged from 1600 kg/ha^{-1} to 4440 kg/ha^{-1}. Three hybrids produced over 3,000 kg/ha^{-1} of grain - SDMH 99001 at 4,440 kg/ha^{-1}, SDMH 90005 at 3,381 kg/ha^{-1}, and SDMH 91008 at 3,141 kg/ha^{-1} and were significantly better than the farmer's local check and the experimental entries SDMH 99004, and Okashana-1 at 1,600, 1,600, and 1,627 kg/ha^{-1} respectively. The hybrid SDMH 99001 produced significantly more grain than all but one other entry (SDMH 90005 at 3381 kg/ha^{-1}). The hybrids SDMH 99001 and SDMH 90005 produced significantly more grain that the local farmer's produced the lowest grain yield (kg/ha^{-1}), was the tallest, and was one of the latest entries in the test. Hybrids have the capability of significantly increasing the production of pearl millet grain in Botswana.

Pathology

Research on diseases affecting sorghum and pearl millet is conducted throughout Southern Africa. The pathology program has active research programs in Zambia and South Africa. The primary Botswana collaborator is currently in a Ph.D. program at the University of the Free State, Bloemfontain, South Africa. Field pathology research is supported by Texas A&M University through planting standard replicated nurseries or tests such as the ADIN (All Disease and Insect Nursery), GWT (Grain Weathering Test), and the ARGN (Anthracnose Resistance Germplasm Nursery). The replicated tests are usually planted at more than one location and data compiled to study germplasm environmental response and pathogen distribution. Major activity on fusarium research is conducted in South Africa (Medical Research Council) and through collaboration with Kansas State University.

Zambia

Primary emphasis of the program is to evaluate standard nurseries to determine the disease(s) present and the response of elite germplasm to the disease and the agronomic desirability in the local environment. Four nurseries were planted: the Anthracnose Resistance Germplasm Nursery (ARGN), the All Disease and Insect Nursery (ADIN), the Sugarcane Aphid Resistance Nursery (SCA), and the International Sorghum Virus Nursery (ISVN). Nurseries planted at the Mansa Technical Assessment Site all failed due to abnormally high rainfall. Plant stand at Mt. Kakulu was poor due to excessive rainfall after planting.

The ADIN, planted at Mt. Makulu, was scored for disease and agronomic desirability. Table 1 shows data collect on the ADIN at Mt. Makulu, Zambia and Cedara, South Africa. At Mt. Makulu anthracnose was the only disease present during

Table 1. Disease scores, agronomic information, and plant traits for the ADIN grown at Cedara, South Africa and Mt. Makulu, Zambia, 2003-2004.

Designation/Pedigree	Leaf blight†	Anthracnose†		Ergot‡	Grain mold§	Desirability¶	Grain Color#	Plant Color††	Plant Height
		Cedara	Mt. Makulu	%					cm
92BD1982-4_(PL2120*87EO366)-BD6-	3.2	0.0	2.5	0.0	0.5	3.0	R	T	50-70
98BRON122_(GR127-90M37*GR107-90M18)-LG2	1.5	1.0	1.0	3.0	1.5	2.5	R	T	50-70
B.9715_(B.8201-2*IS9530)-C1-C3	3.0	0.0	1.0	0.0	4.2	3.5	R	R	70-90
BTx635_B.Var,B.Var1,BVG1	0.8	1.0	2.0	6.0	2.2	3.5	W	T	70-90
B35_IS12555 der./SC35-6/Durra	2.2	1.5	3.0	0.5	5.0	4.0	W	R	50-70
LG70_(Tx2862*(Tx2868*PI55607))-LG70	2.0	3.0	3.0	5.5	2.0	4.0	R	R	50-70
96GCPOB172_(88CC445*Tx2862)-HG62-BG2-CG3-CG3	2.5	3.0	3.0	3.5	3.5	3.5	R	T	50-70
TAM428_IS110 der.,IS12610 der.,Zerazera	2.2	1.0	2.5	0.0	3.5	3.5	W	R	50-70
Tx2880_(MR63/(Tx430*MR6)*Tx2766)	3.2	0.0	3.5	13.5	4.2	3.5	R	R	50-70
86EON361_(R5646*SC326-6)	1.5	2.8	1.0	17.0	2.8	2.5	W	T	50-70
R.9528_((SC120*Tx7000)*Tx7000)-10-4-6*(Tx430*77CS1)-1-1-B2	1.0	1.8	2.5	33.5	4.0	3.0	W	T	50-70
9BRON125_(2241*(R5646*SC326-6)*GR107-90M18)-LG94	0.5	0.0	1.0	9.0	3.0	2.5	W	T	50-70
BTx623_(BTx3197*SC170-6)	4.0	0.0	3.5	1.0	3.5	3.5	W	R	90-110
B.LD6(wxy)_(B.BON34*B9502)-LD6wxy	2.0	0.0	3.0	0.0	1.2	4.0	W	T	50-70
B8PR1045_(Tx2783 der.*(BTx623*(BTx625*B35)))	3.0	0.0	1.5	0.0	2.5	2.0	R	R	70-90
B.9955_(IS9530*B8110)-B7	0.0	2.2	1.5	39.5	2.5	3.5	R	R	50-70
98CD187_(87EON366*99EON328)-HF6-ED1	2.0	1.8	5.0	0.0	3.0	4.0	W	T	90-110
SC326-6_IS3758 der./Nigricans	0.0	0.0	1.0	0.0	3.0	2.0	W	R	50-70
Sureno_((SC423*CS3541)*E35-1)-1-2/M62650/VG146	1.8	0.0	1.5	0.0	1.8	3.5	W	T	110-130
LG35_(Tx2862*(Tx2868*PI55607))-LG35	0.8	3.0	3.0	4.0	3.5	3.5	R	T	50-70
SRN39_Striga Res.	3.2	0.0	1.5	0.0	2.8	3.5	W	T	70-90
BTx378_IS413,Redlan	0.0	1.8	1.0	0.0	3.0	4.0	R	R	70-90
95BRON155_(87BH8606-4*GR127-90M48)-HF30-BG1	0.8	0.5	1.5	25.0	1.8	4.0	R	T	50-70
99GWO92_(86EO361*90EON343)-HD12-	2.8	1.0	1.5	0.0	3.2	4.0	R	T	50-70
Tx2911_(SC719-11E*SC630-11E)-1-3/92B1941	0.5	3.0	4.0	21.0	3.0	4.0	R	R	50-70
96GCPOB160_5BRO147/(B.Var*GB102-39-3-1)-LG5-CG3-CG3	1.0	0.0	1.5	0.0	0.5	3.5	R	T	50-70
R.9732_(ADN55*Tx430)-B10	1.0	2.2	2.0	3.5	3.5	4.0	W	T	50-70
RTx2919_R.9603/((SC120*Tx7000)*Tx7000)-10-4-6-1-1-1	0.2	0.0	2.0	10.0	3.0	2.5	R	T	50-70
Tegemeo_Sooty,Stripe Res.	2.8	0.0	3.0	0.0	0.8	3.0	W	T	90-110
96GCPOB143_(86EO361*GR107-36-3)-LG7-BG1-LG1-	1.0	0.2	1.0	10.5	1.2	2.5	R	T	50-70
B.9612_(B4R*B35)-B9	0.5	0.8	3.0	0.0	1.8	4.5	R	R	50-70
B8PR1059_(88B885*GB102B)	3.5	1.0	1.0	28.0	3.0	4.0	R	T	50-70
96CD635_(SRN39*90EON328)-HF4-ED2	2.0	1.0	1.0	31.0	3.2	3.0	W	T	90-110
B.9712_B.MF/RS4490-?64-74-C5	1.8	1.5	1.0	0.0	2.8	4.0	R	R	50-70
RTx2918_R.9317/(((SC120*Tx7000)*Tx7000)*Tx2894)			1.0			4.5			

Table 1. Cont'd - Disease scores, agronomic information, and plant traits for the ADIN grown at Cedara, South Africa and Mt. Makulu, Zambia, 2003-2004.

97BRON179_(89BE5398*GB112-29)-HG52-B1-CG2-CG1-CG4-CGBK-LBK	2.8	0.2	2.5	20.0	1.5	4.0	R	T	50-70
02CA4624_(Macia*Dorado)-HD12	1.5	1.0	1.5	0.0	1.5	2.5	W	T	70-90
Tx2783_(SC110 der.*Capbam)	3.2	1.8	5.0	15.0	1.5	3.8	R	R	50-70
BTx631_(BTx378*SC110-9)*BTx631)-4-3-4	2.0	0.0	1.0	0.0	2.2	3.0	W	T	90-110
SC630-11E(II)_IS1269 der./Caffrorum	0.8	1.5	2.5	0.0	0.8	3.0	R	R	90-110
B8PR1051_(BTx631*GB102)	1.0	0.8	1.0	0.0	4.5	3.2	W	T	50-70
R.8901_((SC120*Tx7000)*Tx7000)-10-4-6-	0.0	0.2	2.0	6.0	2.8	4.0	W	T	50-70
R.9529_(Tx2894*R8504)-B2-B3-	0.8	2.5	3.5	4.0	3.2	3.5	W	T	50-70
96GCPOB124_GR134B-LG56-BG1-L2-BG1-LGBK	0.5	1.2	2.5	0.0	2.2	3.0	R	T	50-70
B.HF14_(B1*BTx635)-HF14-	0.2	2.5	1.0	0.0	4.5	3.0	W	T	50-70
Malisor 84-7_Mali Pop der. Headbug Res.	2.5	0.0	1.0	7.5	1.0	3.0	W	T	70-90
SC414-12E_IS2508 der./CauKaf	2.5	0.0	1.0	52.5	4.2	2.5	W	R	50-70
02CA5053_(86EO361*88BE2668)-LL2	0.8	2.8	1.0	0.0	3.2	2.5	W	T	50-70
MB108B_MB108B-7-23/P. Grande	1.5	1.5	1.0	5.0	4.2	2.8	MIXED	R	70-90
R.9818_((Tx430*Tx2816-1*Tx435)-13*RTx436)-B2	0.0	1.2	1.0	55.0	LATE	4.0	LATE	T	50-70
RTx2917_R.9120/(Tx2894*Tx433)-F2-B13-B1-	1.0	0.5	2.0	58.5	0.8	4.0	R	T	50-70
Tx7078_IS415,Combine 7078	0.5	2.0	1.5	10.0	3.5	4.0	R	R	50-70
B8PR1013_MB120A-BM48	3.0	1.2	2.8	0.0	4.8	3.2	W	R	50-70
GR108-90M24_GR108-90M24/(BioE Tx430der*SC414-12E)	3.0	1.0	1.0	0.0	4.2	2.0	W	R	50-70
00CA4654_(Sureno*SRN39)-BE1-CW5-	2.8	0.0	1.0	12.5	3.5	2.5	R	T	70-90
R.9645_(RTx430*Sureno)-B12	1.2	0.0	1.0	1.5	4.5	3.5	W	T	50-70
90EON328_(Sureno*BDM499)-HD5-CW1	1.5	2.8	1.0	27.5	1.5	3.0	W	T	90-110
Tx436_((SC120*Tx7000)*Tx7000)-10-4-6/R8505	0.2	1.2	1.0	40.0	3.5	4.2	W	T	50-70
Tx430_(Tx2536*SC170-6)	0.0	4.0	1.5	58.5	4.5	4.0	W	R	50-70
B.9701_(BTx631*BTx626)-B11	1.0	0.0	1.5	0.0	2.2	3.5	R	T	50-70

† Rated on a scale of 0 = no disease expression to 5 = leaves killed by disease
‡ Percent of florets infected by ergot
§ Rated on a scale of 0 = no grain mold present to 5 = grain mold on all kernels with significant grain deterioration
¶ Rated on a scale of 1 = most desirable to 5 = least desirable
# W = White, R = Red.
†† T = Tan, R = Red

the growing season and entries were rated for disease severity. Thirty-five entries were rated 2.0 or less (24 at 1.0 and 11 at 1.5) indicating at least a low level of resistance. However, disease pressure in the nursery was low and there were no significant differences between treatments. For agronomic desirability most entries were average at best. Desirability ranged from 2.0 to 4.5 with only 13 entries rated below 3.0

South Africa

Susceptibility to the grain mold complex is the principle constraint to the introduction of white (food) sorghum to the South African market. Emphasis in the local program has thus shifted towards the identification of tan plant, white grain sorghums with an acceptable levels of grain mold resistance which also express resistance to the major diseases i.e. leaf blight, anthracnose, ergot and root rot. The ADIN (All Disease and Insect Nursery), SABN (South African Breeding Nursery), GWT (Grain Weathering Test) and a grain mold evaluation trial of six white grain tan plant U.S. (food) hybrids were planted at Cedara for disease evaluation. Delayed receipt of the nurseries due to shipping error resulted in late planting and relatively poor stands. Nonetheless, disease incidence was severe and a rating could be made in most trials for the primary diseases. A Head Smut Nursery was received but was too late to plant and is being used in a winter greenhouse evaluation to attempt to determine the local race(s) of the pathogen (head smut).

The SABN, ADIN, and GWT were scored for incidence of leaf blight, anthracnose, and ergot. In the ADIN 20 entries had leaf blight ratings less than 1 while 19 and 25 remained anthracnose and ergot free respectively (Table 1). Sixteen entries had grain mold ratings less than 2 of which 8 where white grained varieties. Individual panicle selections from entries in each nursery were made based on disease evaluation and agronomic desirability and will be incorporated into the larger local program. In the SABN 12 entries had leaf blight (mean = 1.6) ratings less than 1 while most were resistant to anthracnose (mean = 0.8) (partial results in Table 2). Twenty-seven entries were free of ergot although most were shorter season varieties that flowered during warmer conditions. The mean ergot severity was 8.3 % with a range of 0 to 51.5 %. Most entries were highly susceptible to grain molds although two entries were rated less than1 and 8 entries were rated less than 2. Disease severity was high in the GWT with mean leaf blight and anthracnose ratings of 1.96 and 0.56 respectively while ergot was severe in a number of entries (Table 3). Grain mold severity was generally high with a mean rating of 2.5 and only four entries were rated less than 2.

The grain mold hybrid evaluation trial was composed of six entries: Tuli, MK8828, Orbit, W902-W, DKS44-41C, and 14186-39104. Most entries were well adapted to local conditions. The hybrid 14186-39104 was susceptible (3.0) to leaf blight while the other entries were rated less than 1.5. All anthracnose ratings were less than 1 except for DKS44-41c which had a mean rating of 1.67. Grain mold severity was generally high. W902-W had a mean grain mold rating of 3.5 while remaining entries had ratings less than or equal to 2.5. Milling and seed quality tests are being conducted to determine the suitability of these hybrids for local markets.

Within the local commercial hybrid trials, most entries were highly susceptible to leaf blight with eight of the 16 entries having leaf blight ratings of 3 or higher while only four had ratings of # 1. Since all entries were red/brown seeded, grain molds were generally less severe although NK283 which makes up a large proportion of local production yielded a rating of 3. No white hybrids are currently on the commercial cultivar list due to susceptibility to grain molds. Ergot was also limited due to continuous screening of new releases for cold tolerance in relation to the production of viable pollen. Only MRBuster (imported) was susceptible to the disease (mean = 32.7 %). Within the local line screening test consisting of 68 entries, mean ratings of 1.1, 0.48 and 1.5 were recorded for leaf blight, anthracnose and grain mold respectively indicating improved levels of resistance within selections. A local seed company has expressed interest in evaluating a number of these for market potential.

Studies into the etiology and epidemiology of grain molds and root rots continued in collaboration with students from the University of the Free State from Eritrea (partly supported by INTSORMIL) and Botswana (fully supported by INTSORMIL) respectively. *Alternaria alternata* remains the primary isolate in grain from field trials at Cedara, Bethlehem and Potchefstroom. In greenhouse trials this pathogen reduced seed mass by 26.2 and 17.2 % in the test hybrids NK283 and PAN8706W respectively. *Fusarium graminearum* was commonly isolated from Cedara samples and reduced seed mass by 21.6 and 16.6 % in the two hybrids respectively while *F. proliferaturm* was most effective in reducing seed mass i.e. 31.6 and 36.1 % respectively. In field trials mean concentrations of fumonisin, zearalenone, aflotoxin and DON were 0.13, 29.7, 2.57, 1.64 and 0.15 ppm/b respectively. Highest concentrations were 0.48, 140.7, 6.1 and 0.26 ppm/b respectively and the potential of toxicity due to grain mold pathogens appears limited. Toxin production using artificial inoculation with pri-

Table 2. Evaluation of selected entries in the SABN for disease resistance at Cedara, South Africa, 2003-04

PEDIGREE	LEAF BLIGHT †	ANTHRACNOSE†	ERGOT‡	GRAIN MOLD§	GRAIN COLOR¶	PLANT COLOR#	PLANT HEIGHT
			%				cm
SURENO	2.0	0.3	7.0	4.3	W	T	90-110
ICSV 1089BF	0.8	1.0	10.0	3.0	W	T	110-130
MACIA	3.5	0.5	10.5	3.5	W	R	50-70
KUYUMA	1.5	0.3	0.0	2.5	W	T	70-90
ZSV 15	2.0	1.0	10.0	2.5	W	T	>150
CE 151-262-A1	1.8	0.0	19.0	3.5	W	T	70-90
TAM 428	1.8	2.5	2.5	3.0	W	T	50-70
86EO361	2.5	0.0	0.0	3.8	W	T	50-70
96CD 635	2.3	0.5	19.5	4.0	W	T	>150
02CA 4254	4.0	0.0	0.0	1.0	W	T	90-110
5EO 509	2.5	0.0	5.5	2.8	R	R	50-70
RCV(EL SALVADOR)	2.5	0.3	0.0	2.8	W	T	110-130
PINO/EM 1(NICARAGUA)	1.5	1.8	6.0	3.5	W	T	110-130
INTA 108/(TORT *PIN1) NICARAGUA	1.8	2.3	0.0	2.3	W	T	110-130
INTA LP-99 (NICARAGUA)	0.8	0.3	0.0	4.0	W	T	70-90
(87EO366 * WSV387)-HD27	2.8	0.5	2.5	2.5	W	T	90-110
(87EO366 * WSV387)-HF3	2.8	0.0	10.0	0.5	W	T	90-110
(87EO366 * WSV387)-HF14	2.8	0.8	11.5	1.3	W	T	90-110
(87EO361 * MACIA)-HD39	0.8	0.0	38.5	3.8	W	T	50-70
(ISCV 1089BF * MACIA)-HF112-CA2-	0.3	2.5	16.0	3.5	W	T	70-90
(ISCV 1089BF * MACIA)-HF2-CA2-AE	1.5	0.8	0.0	1.5	W	T	70-90
(86E0361 * BE2668)-LL2	0.8	0.8	0.0	2.5	W	T	50-70
(87EO366 * TAM 428)-HF2	1.5	2.0	0.0	2.3	W	T	50-70
(87EO366 * 90EO 328)-HD14	2.5	0.5	23.5	2.3	W	T	50-70
(98CD192/EO366*ED328)-HF6*KUYUMA)-BE22	1.8	0.8	0.0	3.3	W	T	130-150

Table 2. Cont'd - Evaluation of selected entries in the SABN for disease resistance at Cedara, South Africa, 2003-04

PEDIGREE	LEAF BLIGHT †	ANTHRACNOSE†	ERGOT‡	GRAIN MOLD§	GRAIN COLOR¶	PLANT COLOR#	PLANT HEIGHT
(90EO328 * CE151)-LA37	1.3	0.0	0.0	0.8	W	T	90-110
(CE151 * MP 531)-LD42	1.3	0.3	2.5	3.5	W	T	90-110
(CE151 * MP 531)-LD47	0.5	1.5	0.0	3.0	W	T	70-90
(MACIA * DORADO)-HD2-CA1	1.3	1.0	0.0	2.3	W	T	90-110
(MACIA * DORADO)-LL2	1.0	0.0	0.0	2.0	W	T	90-110
(MACIA * DORADO)-LL7	1.5	0.0	0.0	2.3	W	T	90-110
(MACIA * DORADO)-HD2----CA3	1.5	0.0	0.0	1.8	W	T	70-90
(MACIA * DORADO)-HD4	0.8	0.5	0.0	2.3	W	T	70-90
(MACIA * TAMU428)-LL7	0.3	2.0	1.5	3.8	W	T	70-90
(MACIA * TAMU428)-LL9	1.0	0.0	0.0	3.0	W	T	70-90
(MACIA * SURENO)-HF19	1.0	0.5	0.0	2.5	W	T	70-90
(MACIA * SURENO)-HF11-BE4	2.5	0.3	17.5	3.0	W	T	50-70
(MACIA * SURENO)-HF11-BE4	1.5	1.0	6.5	3.0	W	T	70-90
(CE151 * MACIA)-LD8	1.5	1.8	0.5	2.8	W	T	50-70
(SC56-14E * 86EO361)-HF1	0.8	1.5	0.0	2.8	W	T	50-70
Mean	1.28	1.30	15.85	1.93			

† Rated on a scale of 0 = no disease expression to 5 = leaves killed by disease
‡ Percent of florets infected by ergot
§ Rated on a scale of 0 = no grain mold present to 5 = grain mold on all kernels with significant grain deterioration
¶ W = White, R = Red
# T = Tan, R = Red

mary isolates is currently being determined. Grain molds significantly reduced milling and malt qualities. The latter was particularly affected and ranged from 17.15 to 38.57 dsu depending on the severity of grain molds and genotype. The past season was the final season for data accumulation for the development of a grain mold risk analysis model based on weather. Indications are that temperature and humidity are the principle variables with infection requiring RH>84% for the period 9-13 days post-anthesis. This model will be applied to predict high and low risk periods based on historic weather data for a specific locality.

The root rot study is directed to the development of an integrated root rot control strategy to optimize the utilization of limited moisture and nutrient reserves, particularly in low input agriculture. Initial emphasis has been on the etiology of root rots, concentrating on *Fusarium spp*. Isolates from 16 *Fusarium* spp. (based on provisional identifications) have been quantified in the field at Bethlehem, Cedara and Potchefstroom, purified and single-spored for the evaluation of pathogenicity and disease expression on a range of host genotypes. *F. solani*, *F. oxysporum* and *F. thapsinum* were the primary isolates. Emphasis will be on the identification of resistance and the components of resistance, extending to epidemiology as influenced by crop production systems and the potential that biocontrol agents may have in root rot control in small-scale production systems.

Mycotoxin

Investigations continued on toxigenic *Fusarium* species and mycotoxins associated with samples of sorghum (7) and pearl millet (7) collected from local markets and village granaries in Mali. *Fusarium* species were isolated from the samples and identified. The sorghum and millet samples were analyzed by high-performance liquid chromatography (HPLC) for fumonisins (FUM), i.e. fumonisin B_1 (FB_1), fumonisin B_2 (FB_2) and fumonisin B_3 (FB_3) and for moniliformin (MON). The presence of FUM in some of these samples was confirmed by liquid chromatography-mass spectrometry (LC-MS).

The identification of the *Fusarium* species isolated from these samples proved to be very difficult. Although staff members of PROMEC have been involved over many years in mycological studies on *Fusarium* species including the description of several new species of *Fusarium* from sorghum and millet, most of the *Fusarium* isolates from Mali could not be placed in any known *Fusarium* species on morphological grounds. Many of these unidentified *Fusarium* isolates probably belong in new species in the *Gibberella fujikuroi* complex and are currently being characterized molecularly by Dr. John Leslie at KSU.

The results of the chemical analyses for FUM (FB_1, FB_2, FB_3) and MON are given in Table 4. All the sorghum and millet samples contained FB_1 at levels ranging from 10-360 and 5-55 ng/g, respectively. None of the sorghum samples contained MON, but 4 of the 7 millet samples contained levels ranging from 65-524 ng/g. In addition to FB_1, 2 of the 7 sorghum samples contained FB_2 and one (sample 16) also contained FB_3. Sample 16 contained by far the highest levels of FB_1, FB_2, FB_3 and total FUM (1025 ng/g). The presence of FUM in Sample 16 and one other sorghum sample was confirmed by LC/MS and this is the first confirmed report of the presence of FUM in sorghum. None of the sorghum samples contained chemically detectable levels of MON (detection limit 30 ng/g).

Table 3. Evaluation of the Grain Weathering Test for disease resistance at Cedara, South Africa, 2003-04.

Pedigree	Leaf blight[†]	Anthracnose[†]	Ergot[‡]	Grain mold[§]	Plant color[¶]	Grain color[#]	Plant Height
			%				cm
97BRON30_(R4317*SC748-5)-C2-	2.3	0.0	8.0	2.5	R	R	50-70
Tx2911_92B1941/(SC719-11E*SC630-LLE)-1-3-	1.0	3.5	4.0	2.0	R	R	50-70
00CA4051_(M84-7*BH8606)-BE4-CWB'50-70-Z2-B2-	3.5	0.0	0.0	1.5	T	R	50-70
02CA4796_(ICSV1089BF*Macia)-HF9-CA1-BE2-CA3-CA2-C	2.0	0.0	34.0	3.0	T	W	70-90
00CA4254_(M84-7*VG153)-LB'50-70-PR7/19178-L4-L2	3.5	0.0	0.0	2.5	T	W	70-90
B.01336_((BTx631*BTx626)-B11*BTxARG1)-B7	1.8	0.0	0.0	2.0	T	R	50-70
SC650-11E(t)_IS2856 der.,Caffr('50-70afir)	0.5	2.0	0.0	2.3	R	R	90-110
Tx430_(Tx2536*SC170-6)	0.5	2.3	22.0	3.5	R	W	50-70
96CA5986_(Sureno*87EO366)-CW3-CW1-CW2-	0.0	1.5	25.0	2.5	T	W	50-70
01BD5689,62_(CE151*LG10-BE5-BE1,4(F7)	1.0	2.5	0.0	2.0	T	R	50-70
99L-GWO50_(5CBR765-2/(?*?)	2.0	1.0	46.0	3.0	T	R	70-90
R6078_(SC170-6-17*MR4-4671)-HL15(TM)	2.3	0.0	0.0	2.0	R	R	50-70
90L19178_(M84-7*VG153)/19178/-LB'50-70-PR7-L4-L2-	3.5	0.0	18.0	3.5	T	W	70-90
96GCPOB124_GR134B-LG56-BG1-L2-BG1-LGB'50-70	2.5	0.0	0.0	2.0	T	R	50-70
Sureno_((SC423*CS3541)*E36-1)-2/M62650/VG146	2.0	0.0	36.0	2.8	T	W	70-90
Tx2536_Y.E.Feterita Deriv.	1.8	0.0	58.0	3.5	R	W	50-70
00CA3936_(M84-7*VG153)-LB'50-70-PR7/19178-L4-L2	3.5	0.0	0.0	4.0	T	W	50-70
00CA4879_(87EO366*(CS3541*SC630))-F4-BE2	1.0	0.0	0.0	2.0	T	R	70-90
94BE6335_(Tx2891*R4317)-BD1-BC2-B'50-70	3.0	0.0	10.0	2.5	T	W	50-70
B.9904_((BTx3197*SC170-6)*SC748-5)	4.0	0.0	0.0	1.8	R	R	50-70
98CA4779/5EO509_(PL2120*BH8606)-BD19	4.0	0.5	0.0	2.5	R	R	50-70
90L19037_(M84-7*VG153)/19037/-L6-LB'50-70-PR2-1-1-	1.5	0.0	0.0	3.0	T	W	50-70
SC279-14E_IS7419C,Guinea/Conspic.	1.0	0.0	0.0	2.0	R	R	50-70
00CA3936_(M84-7*VG153)-LB'50-70-PR7/19178-L4-L2	3.0	0.0	0.0	3.0	T	W	50-70
R4317_(SC170-6-17*MR4-4671)-LEC	3.5	0.0	14.0	2.5	R	R	50-70
B.9818_(B155*BTx635)-CS3	2.3	0.0	0.0	2.5	T	W	50-70
02CA5226_(Macia*Sureno)-HF19-BE5-BD1-BD1-BD1	2.0	0.0	0.0	2.5	T	W	130-150
99CA3019_(VG153*(TAM428*SBIII))-23-BE2-BE2-BE1	2.0	0.0	44.0	3.5	T	W	90-110
90EON343_(Tx2895*(SC170*R4671))-BH7	2.0	0.0	0.0	1.5	T	R	70-90
01BD4966_(Macia*Sureno)-HF19-CCGWO193-1-BE5-BD2	0.5	0.0	0.0	2.5	T	W	90-110
95BRON155_(87BH8606-4*GR127-90M48)-HG30-BG1	1.0	0.0	0.0	2.0	T	R	50-70
ICSV1089BF_ICSV1089BF/ICRISAT	0.0	1.5	0.0	2.5	T	W	110-130
90CC549_(Sureno*VG153)/CC549/-HF42-BD2-CCB'50-70	0.5	0.0	0.0	3.5	T	W	90-110
SC630-11E(II)_IS1269 der.,Caffr('50-70afir)	0.0	2.5	0.0	2.0	R	R	70-90
99GWO92_6CA5466/(EO361*EO343)-HD12	1.5	0.5	0.0	2.5	T	R	70-110
02CA4801_(ICSV1089BF*Macia)-HF11-CA2-BE2-CA1-CA1-	1.0	1.0	0.0	3.0	T	W	90-110
SC170-6-17_IS12661 der,Zerazera,BC1 der.	4.5	0.0	0.0	2.5	R	W	50-70
01BD5546_(87EO366*(M84-7*Sureno)-Tx3-2)-BE7-BE1	2.5	0.0	0.0	3.0	T	W	70-90
VG153_(Wa1-1*IS9327)-1/M62676	3.5	0.0	0.0	2.5	T	W	90-110
SC719-11E_IS7013 der.,Caudatum	1.0	3.0	0.0	2.0	R	R	50-70
Mean	1.37	1.02	16.87	1.68			

† Rated on a scale of 0 = no disease expression to 5 = leaves killed by disease
‡ Percent of florets infected by ergot
§ Rated on a scale of 0 = no grain mold present to 5 = grain mold on all kernels with significant grain deterioration
¶ W = White, R = Red
# T = Tan, R = Red

In addition to FB_1, only one millet sample (Sample 4) contained FB_2 and FB_3 and this sample had the highest level of total FUM (70 ng/g) of the millet samples. The presence of FUM in Sample 4 and two other millet samples was confirmed by LC-MS and this is the first report of the natural occurrence of FUM in pearl millet. Sample 4 also contained the highest level of MON (524 ng/g) of the 4/7 positive millet samples. This is the first report of the natural occurrence of MON in pearl millet. The sorghum sample that contained the highest levels of FUM (Sample 16) and the millet sample that contained the highest levels of FUM as well as MON (Sample 4) were selected for detailed mycological investigations. *Fusarium* species were isolated from these two samples at KSU and at PROMEC, selected strains were cultured on corn patties and analyzed for FUM and MON at PROMEC.

Table 4. Fumonisin and moniliformin levels in sorghum and millet samples from Mali

Sample	Fumonisin (ng/g)[1]				Moniliformin (ng/g)[2]
	FB_1	FB_2	FB_3	Total	
Sorghum					
3	10	ND	ND	10	ND
5	35	5	ND	40[3]	ND
9	10	ND	ND	10	ND
10	20	ND	ND	20	ND
12	15	ND	ND	15	ND
14	25	ND	ND	25	ND
16	360	345	320	1025[3]	ND
Pearl Millet					
2	25	ND	ND	25[3]	65
4	55	10	5	70[3]	524
6	17	ND	ND	17[3]	ND
7	20	ND	ND	20	76
11	5	ND	ND	5	ND
13	15	ND	ND	15	ND
15	15	ND	ND	15	76

[1] ND = Not detected; Detection limit of fumonisins: 5 ng/g
[2] ND = Not detected; Detection limit of moniliformin: 30 ng/g
[3] Fumonisins confirmed by LC-MS

A total of 54 *Fusarium* isolates from sample 16 were obtained from KSU and classified in three morphological groups, i.e., 31 *F. andiyazi*-like (long microconidial chains, pseudochlamydospores), 11 F. *nygamai*-like (short microconidial chains, chlamydospores) and 12 others. Ten *F. andiyazi*-like strains and 5 *F. nygamai*-like strains were analyzed for FUM and MON. None of the isolates produced FB_1, FB_2 or FB_3. Consequently the *Fusarium* species that produced the high levels of FUM in sorghum Sample 16 remains unknown. All 15 *Fusarium* strains from sorghum produced MON at levels ranging from 2214 - 33080 mg/kg. The two highest producers (33080 and 18010 mg/kg) were both classified as *F. andiyazi*-like (MRC 8279 and 8281). The next three highest-producing strains (10280-14010 mg/kg) were classified as *F. nygamai*-like (MRC 8344, 8345, 8346). The identity of these high MON producing strains is unknown at present and it is also not known whether they are conspecific or not. They may belong in one or more new species of *Fusarium* that produce MON in sorghum in Africa.

A total of 27 *Fusarium* isolates that resemble the *G. fujikuroi* complex were isolated from pearl millet sample 4 and classified in three morphological groups i.e., seven *F. andiyazi-like* (long microconidial chains at the margin, shorter in the center of colonies, pseudochlamy-dospores), eight F. *nygamai*-like (short microconidial chains, polyphialides, chlamydospores) and 12 F. *pseudonygamai*-like (short microconidial chains, polyphialides, large, globose chlamydospores).

Five representative strains of each of the three morphological groups were analyzed for FUM and MON and the results are given in Table 5. All 15 strains produced FB_1 at levels ranging from 1 - 3895 mg/kg. The three highest producers of

Table 5. Production of fumonisin and moniliformin by *Fusarium* isolates from pearl millet sample 4 from Mali

Fusarium Species	Strain No MRC[3]	Fumonisin (mg/kg)[1]				Moniliformin (mg/kg)[2]
		FB_1	FB_2	FB_3	Total	
***F. andiyazi*-like**	8192	1	ND	ND	1	17240
	8197	3772	900	155	4827	18
	8198	8	2	ND	10	1997
	8201	3469	909	185	4563	108
	8208	3895	1259	136	5290	98
***F. nygamai*-like**	8193	13	4	ND	17	10080
	8194	3	ND	ND	3	11600
	8202	2	ND	ND	2	12790
	8205	1	ND	ND	1	13210
	8211	1	ND	ND	1	12710
***F. pseudonygamai*-like**	8191	13	ND	ND	13	5886
	8200	2	ND	ND	2	13970
	8204	1	ND	ND	1	6709
	8209	4	ND	ND	4	15470
	8216	1	ND	ND	1	12880

(1) ND = Not detected; Detection limit: 1 mg/kg
(2) ND = Not detected; Detection limit: 1 mg/kg
(3) MRC numbers are accession numbers in the culture collection of the PROMEC Unit, Medical Research Council, Tygerberg, South Africa

FB_1 (3895, 3772 and 3469 mg/kg) were all in the *F. andiyazi*-like group. All three of these strains also produced FB_2 at levels ranging from 900 - 1259 mg/kg and FB_3 from 136-185 mg/kg. These three strains (MRC 8197, 8201 and 8208) were by far the highest FUM producers of the 15 tested and total FUM levels ranged from 4563 to 5290 mg/kg. The identity of these strains is not known but they are most probably not *F. andiyazi* which does not produce FUM. All 15 *Fusarium* strains from millet produced MON at levels ranging from 18-17240 mg/kg. The highest producer (17240 mg/kg) was classified as *F. andiyazi*-like (MRC 8192). Among the remaining eight high producers (>10 000 mg/kg), five were classified as *F. nygamai*-like (10080-13210 mg/kg) and three as *F. pseudonygamai*-like (12880-15470). With one exception (MRC 8193), all of these high MON producing strains were very low FUM producers (1-4 mg/kg). Conversely, the three highest FUM producers (4563-5290 mg/kg) were the lowest MON producers (18-108 mg/kg). The identity of these high MON producing strains is unknown at present and it is also not known whether they are conspecific or not. They may belong in one or more new species of *Fusarium* that produce MON in millet in Africa.

All of the sorghum and pearl millet samples from Mali contained FUM whereas only some millet samples contained MON as well. None of the *Fusarium* strains from sorghum produced FUM, whereas all produced MON, some at very high levels. The findings that *Fusarium* strains isolated from sorghum naturally contaminated with FUM but not MON, produced MON but not FUM in culture cannot be explained at present. *Fusarium* strains from sorghum that produce FUM remain to be found. Some *Fusarium* strains from millet produced high levels of FUM and others produced high levels of MON. Thus both FUM and MON producing *Fusarium* strains have been isolated from millet samples naturally contaminated with both mycotoxins.

Food Quality

The University of Pretoria is the SADC regional center for post-graduate training in Food Science and Technology. Research into the food and nutritional quality of sorghum and millet is focused on cultivar food quality, milling technologies and sorghum and millet food nutritional value. All of the research is conducted by University of Pretoria graduate students under the supervision of Dr. John Taylor and Dr. Lloyd Rooney. One post-doctoral student (from Nigeria), six doctoral students (from Botswana, Ethiopia, Cameroon, Mauritius, Uganda and Zimbabwe) and two masters students (from Namibia and South Africa) are conducting research projects in sorghum and pearl millet food science and technology.

The Ph.D. research of Dr. Senayit Yetneberk (Ethiopia) concerned cultivar quality with a goal of developing a simple system to objectively evaluate the injera making quality of sorghum cultivars. Injera, a fermented flatbread, is the staple food of Ethiopia. The system is to be applied in the Ethiopian sorghum-breeding program and should ultimately result in the cultivation of sorghum cultivars of improved injera making quality. Dr. Yetneberk completed the degree requirements in April 2004, and returned to Ethiopia.

The M.S. research of Mr. Stephen Barrion (Namibia) deals with the rolling technology of pearl millet. His research shows that the traditional Namibian milling process involves a lactic acid steep that does not improve the nutritional quality of the flour in comparison to dry abrasive decortication (dehulling). However, the flour sensory quality is altered by the lactic acid steep in terms of brightness and acidic taste, which the local Namibian consumer prefers.

In February 2004, the University of Pretoria took delivery of a Maximill roller mill provided by INTSORMIL. In March 2004, Mr. Martin Kebakile of the Botswana National Food Technology Research Centre began doctoral studies. The mill is used by Mr. Kebakile to investigate the effect of sorghum cultivar and milling process (roller milling, dehull-hammer mill and pounding) on the physico-chemical and sensory quality of sorghum porridge, the major staple food in Botswana.

Sorghum food nutritional quality is the focus of the PhD research conducted by Mrs. Nomusa Dlamini. Research into the anti-oxidant properties of southern African sorghum foods indicates it is possible through dehulling to substantially reduce the levels of the tannin anti-nutrients in tannin (brown) sorghum while retaining good antioxidant activity. Antioxidants in foods are generally considered to be beneficial to health and protective against a number of diseases including HIV/AIDS. Mrs. Dlamini has been awarded a Fullbright Scholarship and is to continue her research at Texas A&M University under the supervision of Dr. Lloyd Rooney with Dr. Taylor as co-supervisor.

Research, funded primarily by the European Union, on bioplastic films made from sorghum proteins has been initiated. Previous M.S. research by Mrs. Laura da Silva revealed that bioplastic films can be produced from kafirin (the major sorghum protein) extracted from bran, a by-product of sorghum dry milling. This value-added application for sorghum bran has the potential to improve the economics of sorghum milling. M.S. research by Mrs. Janet Taylor showed that glacial acetic acid can be used as an alternative to aqueous-alcohol as a solvent for kafirin protein. This finding is significant since the use of alcohol in manufacturing can pose religious and licensing problems. The Ph.D. research of Mr. Naushad Emmambux showed that the mechanical and oxygen-barrier properties of kafirin films can be improved by cross-linking them using tannins extracted from tannin sorghum. This finding is important since a major motivation for bioplastics is that they are natural. Thus, processes to improve their functional properties must also be "natural".

Entomology

South Africa

The sugarcane aphid (*Melanaphis sacchari*) is an insect pest of sorghum throughout Southern Africa. Research is directed at developing improved varieties with aphid resistance and other acceptable characteristics (maturity, height, grain yield, grain quality, disease resistance) for use in low input, small farmer areas of South Africa and the region. The sugarcane aphid resistance test contains 100 entries. In South Africa, spreader rows of susceptible sorghum were planted two weeks prior to the sugarcane aphid resistance test to ensure presence of aphids. Aphid damage was evaluated when the majority of entries were in the milk stage. Severity of infestation is 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 of 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, while a rating of 3 indicated an intermediate level of resistance. Plants with a rating of 4 or 5 were considered susceptible. Additionally, the percent of plants infested with aphids is estimated as a measure of resistance.

Sugarcane aphid infestation levels at both South Africa locations were low. It was, however, higher at Burgershall than at Potchefstroom. Results from both trials indicated that 69 and 57 %, respectively for Potchefstroom and Burgershall, of the entries rated 1 on a scale of 1 to 5, indicating no to very slight damage. Ratings of 2 were scored for 18 % of the entries at both Potchefstroom and Burgershall. Since aphid infestation levels were low, a high level of damage was possible. One and 9 % of the entries at Potchefstroom and Burgershall respectively, died as a result of aphid infestation. In Botswana the abundance of sugarcane aphids on most of the sorghum lines was generally low. The abundance on 51 of the 100 lines was less than 10% infested plants per plot. Based upon the data collected 21 experimental entries were identified with a damage rating of 1 and fewer than 10% of the plants infested.

In Botswana the test was evaluated for the percent of plants infested by stem borers and termites. Ten lines were identified with fewer than 13.7% infested plants and therefore classified as expressing some level of resistance to stem borers. While the results show that some of the sorghum lines escaped stem borer and sugarcane aphid attack, termites infested all the 100 sorghum lines evaluated. Seven lines were identified with fewer than 9.2% infested plant and were classified as having a level of resistance to termites. From the data collected it was determined that while individual lines may be resistant to one insect (either sugarcane aphid, stem borers, or termites) none were resistant to all three insects. Additional breeding and selection will be necessary to develop improved varieties with resistance to multiple insects.

A late (January 2004) planting date of the sugarcane aphid test at Potchefstroom resulted in the test becoming infected with ergot. The test was therefore rate for severity of ergot as the percentage of ergot infection. It varied between 0 and 90 %, with 30 % of the entries showing less than 5 % infection. Thirteen entries were evaluated for sugarcane as very resistant (damage = 1) and possibly have some level of resistance to ergot (percent ergot infection less than 5%). Entries with less than 5% infection were classified, as possibly expressing some level of resistance to ergot but additional research is necessary.

In Botswana the abundance of sugarcane aphid, stem borer and termite infestation on each of 19 sorghum varieties developed in the SADC region was assessed at the Botswana College of Agriculture (Gaborone, Botswana). The sorghum varieties were: BSH1, ICSH93107, ICHR89028, LARSVYT46-85, Macia, Mahube, Mmabaitse, Marupantsi, Phofu, SDS6013, SDSH89009, SDSH98012, SDSR91014, SDSR91039, Segaolane, SV1, SV2, Tegemeo and Town. The field plots were examined every two weeks to monitor pests and their natural enemies, to determine periods of pest infestation and when the natural enemies such as coccinellid predators and ichneumonid parasites occurred. Abundance of sugarcane aphids, stem borers and termites was assessed by determining the percentage-attacked plants, using counts of total number of plants and numbers of infested plants per plot. Abundance of coccinellid predators was estimated using direct counts of the predators (including larvae, pupae and adults) found on all sorghum plants in each plot. Samples of adult coccinellids found on the sorghum plants were collected and processed for identification by coleopterists. Ichneumonid wasps found in the field were also collected for identification.

Analysis of the data led to the conclusion that the average abundance of sugarcane aphid infested plants and coccinellid predators per plot was not significantly affected by sorghum variety. Overall average abundance was 42.8% infested plants per plot. These results led to the conclusion that the 19 varieties were equally susceptible. The average abundance of coccinellid predators per plot was also not significantly affected by the sorghum variety. The average abundance of predators (including larvae, pupae and adults) was 18.3 per plant while the average number of coccinellid adults was 8.8 per plot. Comparison of the average abundance of sugarcane aphids and their coccinellid predators found during the 2002-2003 and 2003-2004 cropping seasons were similar. The overall abundance of sugarcane aphids was not affected by variety. Although the average abundance of coccinellid predators was not significantly affected by variety the overall average abundance of coccinellid predators found was considerably higher during the 2003-2004 than during the 2002-2003 cropping season. It is interesting to note that the high abundance of coccinellid predators recorded during the 2003-2004 cropping season corresponded with a high abundance of the sugarcane aphid infestation. Only one early season field assessment was possible during the 2003-2004 season. This might explain why the pest and predator numbers recorded were high. It is likely that a later assessment would have recorded a reduction in abundance of sugarcane aphids.

For plants attacked by stem borer data analysis led to the conclusion that the average abundance of stem borer attacked plants was not significantly ($P < 0.05$) affected by sorghum variety. The overall average was 78.3% attacked plants per plot. The results obtained during the 2002-2003 and the 2003-2004 cropping seasons led to the conclusion that the 19 varieties evaluated were equally susceptible to stem borer attack. The percent of sorghum plants with dead hearts was similar in the varieties with an overall average abundance of 17.3%.

Sorghum Breeding

Zambia

Sorghum research in Zambia is conducted on a collaborative basis with INTSORMIL and SMINET. Research goals are determined by the national program with input from the collaborators. The end of the SMIP/SMINET program increases the importance of INTSORMIL as a strategic collaborator. Collaboration between the Zambia sorghum-breeding programs has resulted in the reciprocal exchange of germplasm lines that are used in crosses in Zambia and the United States and evaluation of advanced lines and hybrids in replicated trials. INTSORMIL trials were evaluated at Golden Valley and Mansa, and evaluation of photoperiod sensitive material was done in Mansa. The overall program goal is to develop sorghum for areas that are marginal in the production of maize and frequently experience a food deficit. Government policy is now promoting crop diversification rather than maize dependency only. Increased production and use of sorghum is expected to benefit household food security and increase income for subsistence farming sector while providing commercial entities with increased production of a consistent supply of improved quality grain.

The major objective of the breeding nursery is to generate genetic variability through collections, introductions, and hybridization. Program activities are designed to target both small-scale farmers and commercial end users. A major emphasis of the program is the development of suitable hybrids for food (tan plant, white grain), brewing, feed and forage. This emphasis has been expanded to develop for the high rainfall region late maturity, white grain, tan plant genotypes. The pedigree breeding method is used with crosses made in the main season and F1's grown in an off-season nursery to obtain F2 seed. Promising lines are evaluated in multi-location trials for grain yield, quality traits, and other agronomic traits. Seed of released varieties is maintained and increased with evaluation conducted at Golden Valley and Mansa.

Three major replicated yield trials were grown at the Golden Valley Research Trust. The Sorghum Advanced Variety was composed of 20 entries (15 experimental entries and 5 standard checks). No significant differences were found for grain yield, days to 50% anthesis, or plant height (Table 6). The experimental variety [FRAM x SDS 3845] F6-5 produced the most grain at 7690 kg/ha^{-1}. Other varieties that produced over 7000 kg/ha^{-1} include had high mean yields were ZSV- 13, SDS 4345-2-1-4-3, ZSV – 15, and [ICSV 112 x WSV 187] 15-1-3-2. The White Sorghum Advanced Hybrid Trial contained 16 entries and included hybrids previously selected from preliminary yield trials. No significant differences were observed among the hybrids (Table 7). MMSH 1401 produced the most grain (6582 kg/ha^{-1}) and four additional hybrids MMSH 1391, ZSH 102, MMSH 1257, and MMSH 1038 produced over 6000 kg/ha^{-1} of grain. The brown sorghum advanced hybrid trial had 16 entries. Significant differences were observed among the entries for days to 50% flowering, plant height, and grain yield. The trail mean grain yield was 5746 kg/ha^{-1}. The check MMSH 375 had the highest mean of 7900 kg/ha^{-1} followed by MMSH 1194 with 7670 kg/ha^{-1}. The most promising varieties will be evaluated further at other locations for wider adaptation before on-farm activities are initiated.

To generate interest with the kind of products that can be made from sorghum and to distribute information from the research program that will benefit farmers or other interested participants from industry field days were organized at the Golden Valley Agricultural Research Trust and Mt. Makulu Research Station. Representatives of the program also attended and exhibited at locally and nationally organized agricultural shows. At the shows farmers and other participants were shown some of the promising improved varieties and products. Zambia Breweries (South African Breweries subsidiary) have indicated that their brewing plant in Ndola will exclusively utilize sorghum and a grower's scheme has been devised that will initially target 4,000 farmers to produce grain for the brewery.

Table 6. Grain yield, days to 50% anthesis, and plant height of entries in the Sorghum Advanced Variety Trial I & II, Golden Valley Agricultural Research Trust, 2003-04.

PEDIGREE	GRAIN YIELD	DAYS TO 50% ANTHESIS	PLANT HEIGHT
	kg/ha^{-1}		cm
(FRAM *SDS 3845)F6-5	7696	79	230
ZSV-13	7668	82	222
SDD 4345-2-1-4-3	7477	77	216
ZSV-15	7038	73	203
(ICSV 112 * WSV 187)15-1-3-2	7035	80	222
SARDIN 10-1-1	6904	75	222
(FRAM * SDS 3845)16-3	6821	75	210
Sima	6776	74	228
ICSV 93010-1	6765	79	225
Kuyuma	6715	76	205
(FRAM * SDS 3843)16-2-2	6640	77	227
(ICSV 112 * WSV 387)20-3-4	6615	72	212
SDS 1958-1-5-2	6607	74	203
ZSV-3	6507	75	213
SDS 3047	6487	75	217
90CC 651-655-1073-3	6343	78	238
CZADIN 1237-1	5970	73	197
SDS 4882-1	5807	75	225
SDS 3335-1	5601	74	195
(ICSV 112 * WSV 387)15-1-3	5221	78	197
Mean	6635	76	215

Table 7. Grain Yield, plant height, and days to 50% anthesis of entries in the White Sorghum Advanced Hybrid Trial, Golden Valley Agricultural Research Trust, 2003-04.

DESIGNATION	GRAIN YIELD	DAYS TO 50% ANTHESIS	PLANT HEIGHT
	kg/ha^{-1}		cm
MMSH - 1401	6582	63	220
MMSH - 1391	6557	67	173
ZSH - 102	6499	76	260
MMSH - 1257	6485	76	225
MMSH - 1038	6126	76	190
MMSH - 1338	5935	76	177
MMSH - 1399	5848	68	168
MMSH - 1287	5771	77	317
MMSH - 707	5437	80	237
MMSH - 1363	5289	69	205
MMSH - 1347	5257	69	167
MMSH - 1376	5215	68	158
MMSH - 1389	5020	67	170
MMSH - 1324	4900	66	192
MMSH - 1346	4759	67	155
MMSH - 1382	4325	68	175
Mean	5625	71	199

Botswana

The major objective of the breeding program is to provide small-scale farmer with seed of improved varieties and hybrids. The majority of sorghum production in Botswana is by small-scale farmer that using current technology cannot produce enough grain to satisfy national demand. The need exists to introduce and evaluate advanced improved lines for grain yield, adaptation, stress resistance, and agronomic traits. Based on the data superior lines will be identified for use in a crossing program to produce populations for selection and to elite adapted hybrid parental lines to produce hybrids for evaluation.

In 2003-2004 two INTSORMIL nurseries from Texas A&M University, the Drought Line Test (DLT) and the All Disease and Insect Nursery (ADIN), were evaluated at Maun. Unlike the previous cropping season timely rain was received, and there were no significant disease and insect problems. In the DLT significant differences were identified for the traits studies (grain yield, days to 50% flowering, plant height, panicle exsertion, and agronomic desirability. The test mean grain yield was 3122 kg ha^{-1}. Local checks were Segaolane (a Botswana developed variety with pre-flowering drought tolerance) and Macia (a Mozambique with excellent grain quality). Two entries produced more grain than Segaolane (4630 kg ha^{-1}) - 87EO366*WSV387 (5565 kg ha^{-1}) and CE151*MP531 (4769 kg ha^{-1}). WSV387 was developed in Southern Africa and CE 151 is an introduction from Senegal. Generally, entries with Macia, Dorado, or CE151 as one parent produced more grain than other entries.

The same traits were measured in the ADIN. Significant differences were identified for days to 50% flowering and plant height. The mean for days to 50% anthesis was 16 days later (86 vs 70) than for DLT entries. This was attributed to early season slow plant development. The mean grain yield (3023 kg ha^{-1}) was lower than that of the DLT. The lower ADIN grain yield could be attributed to parentage of the ADIN entries and less drought tolerance (either pre- or post-flowering). One local entry, the sooty stripe resistant local variety Tegemeo, produced 2960 kg ha^{-1} of grain. However, 17 entries produced more grain than Tegemeo.

Selections were made in promising lines in both nurseries. The selections will be evaluated in the next growing season at various locations. In off-season nursery superior R-lines will be crossed with A.Segaolane to produced hybrids for evaluations. Additionally, a test of red seeded entries from both nurseries will be planted to evaluate the entries from the good malting qualities that are needed for the opaque beer industry.

West Africa – Eastern Region (Niger, Nigeria, Burkina Faso)

Bruce Hamaker
Purdue University

Coordinators

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Collaborative Program

Beginning in the 2004-2005 fiscal year, the INTSORMIL program in West Africa will change from two regional programs, representing the eastern and western regions, to one merged six-country program. Thus, this is the last separate reporting of the eastern (and western) regions. The eastern region of West Africa includes a long-standing collaborative research effort in Niger, and, since 2000, the initiation of 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 various production agriculture disciplines, utilization, and economics. Programs in Burkina Faso and Nigeria are positioned with breeding/agronomy and utilization projects to address market-driven issues. Burkina Faso also has plant protection activities. ICRISAT has been an institutional collaborator in the region, as well as, in the past, the regional millet and sorghum networks of ROCEFREMI and ROCARS. The regional networks, however, did not significantly function in this reporting year. It is hoped and expected that a network covering sorghum and millet activities in the region will be revitalized. INTSORMIL looks to become an active partner in such regional network, as it sees the network as vital in realizing a coordinated effort towards regional sorghum and millet research and engagement.

At the programmatic level, a workshop was held in Ouagadougou, Burkina Faso in April 2004 to plan and implement the merger of the two regional programs into one six-country regional INTSORMIL program. A majority of INTSORMIL PIs from the region attended, as well as eight U.S. PIs. Progress reports were given for each of the West Africa country programs comprising Niger, Mali, Senegal, Burkina Faso, Nigeria, and Ghana. Work plans were discussed in terms of the INTSORMIL strategic plan and regional priorities. Two new integrated, regional projects were identified in crop utilization and technology transfer with a goal of developing concept notes/proposals to seek additional funds for these areas of activity.

List of Disciplines and PI Collaborators

Genetic Enhancement – Sorghum and Millet

Sorghum: INRAN, Niger - I. Kapran; KSU - M. Tuinstra, PU – G. Ejeta; IAR, Nigeria - P. Marley; TAM – D. Rosenow

Millet: Lake Chad Research Institute, Nigeria – I. Angarawai; ARS – J. Wilson

Sustainable Plant Protection Systems

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

Plant Pathology: INRAN, Niger – A. Kollo (on leave) INERA, Burkina Faso – A. Neya, H. Traore; TAM – D. Rosenow, C. Magill

Sustainable Crop Production Systems

Agronomy: INRAN, Niger – S. Sirifi, N. Mamane; UNL – S. Mason; INERA, Burkina Faso - J.B. Taonda, P. Siebou

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

Utilization and Marketing

Cereal Processing: INRAN, Niger – K. Saley, M. Moussa; PU – B. Hamaker; University of Maiduguri, Nigeria – I. Nkama; IRSAT, Burkina Faso – B. Bougouma; ITA, Senegal – A. N'Doye

Poultry: INRAN, Niger – S. Issa; KSU – J. Hancock

Marketing: INRAN, Niger - A. Tahirou; Purdue – J. Sanders

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 to generate income at the farmer and entrepreneurial levels.

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 processing businesses. New projects in breeding and poultry nutrition aim to encourage poultry producers to use sorghum and millet for feed.

Institution Building

Expendable supplies for field and office uses were purchased for the programs, as well as laptop computers and software for some project areas. All PI's listed above had regional support funding through INTSORMIL. INTSORMIL regional and ME programs also sponsored the April 2004 planning workshop held in Ouagadougou, Burkina Faso.

Tahirou Abdoulaye, INRAN/Niger, completed post-doctoral studies with Dr. John Sanders at Purdue University and returned to Niger in December 2003

Research Progress

Niger

Sorghum Breeding and Seed Production
I. Kapran, INRAN; M. Tuinstra, KSU ; G. Ejeta, Purdue

Objective

To evaluate various germplasms to identify highly productive and well-adapted, open-pollinated varieties and hybrids to be increased for food and feed uses. Efforts focused on fieldwork as well outreach activities with other partners:

- Breeding nurseries and trials were designed to evaluate germplasm from various origins based on INRAN request for material with acceptable maturity and grain quality, resistance to drought, and/or *Striga*,
- Seed production was organized to provide foundation seed in support of the INRAN seed unit which is in charge of all seed production activity for INRAN,
- Finally the results of this collaborative breeding program were used for outreach to other groups through training of university students or presentations at workshops and seminars.

Collaborative Breeding Nurseries

The project allowed us to identify well-adapted lines that may be released for cultivation and/or used in our hybrid-breeding program. More than 3,000 entries were evaluated in 2003 as given in Table 1 below. Some highlights of the activities include:

<u>Development of new germplasm for drought/sandy soil adaptation</u>. Farming in Niger is practiced essentially on highly drained sandy soils poor in nutrients, the so-called dune soils where farmers intercrop cereals with cereals, cereals with legumes, or more complex schemes of cereals/legumes/cereals. Landraces are well adapted to this environment but have poor yield potential. On the other hand, we have developed through this collaborative effort a number of improved varieties and hybrids, most of which do not have enough adaptation to achieve a larger diffusion and more significant contribution to food security. Therefore we crossed a well adapted sorghum landrace (MDK) to a breeding line (L153-5, itself derived from a cross involving *Striga* resistant SRN39 with landrace ABH) to develop a population for genetic studies of yield/adaptation traits and selection of lines that may be released to farmers or used in the synthesis of widely adapted F1 hybrids. A preliminary characterization work showed that the parents are different for emergence, maturity, height and yield. MDK has an excellent germination, is very late in maturity, but relatively better yielding than the early parent. Progeny average is usually intermediate but the range of distribution is wide for these traits so as to indicate good feasibility of selection.

<u>Development of midge resistant cultivars.</u> After testing midge resistant lines we introduced from TAMU and ICRISAT, we developed a population (MMxICSV88032) which was characterized as part of a university student research (Amadou Mahaman Bassirou: 1999. Comportement agronomique et résistance à la cécidomye des descendances non sélectionnées de sorgho –*Evaluation of the agronomic performance and midge resistance of single seed descent lines*). The best of these lines were further tested in our breeding/entomology nursery (see entomology report) which confirmed their resistance. We selected entry 35 (SSD35) as the most promising for re-

Table 1. Collaborative sorghum breeding nurseries in Niger, 2003

Description	Number of entries	Source	Observation
Single Seed Descent lines (F8)for sandy soil adaptation	995	INRAN	Derived from local cultivar MDK
Single Seed Descent lines (F10) for midge resistance	30	INRAN	Derived from local cutivar MM
Hybrid observation nursery	482	INRAN	Between 60 A lines (PU,TAMU, NE) and 74 R lines (INRAN, PU, TAMU)
New experimental hybrids	396	Purdue	
Tan food grain hybrids	100	Purdue	
Drought tolerant hybrids	66	Purdue	
Advanced hybrid trial	24	INRAN	
Large seeded experimental hybrids	18	Kansas State	
International striga testing	25	Purdue	
Striga introgression lines	300	Purdue	Using landrace El Mota from Niger
Striga introgression F2 population	1	Purdue	Using improved SEPON82 from Niger
High digestibility lines	108	Purdue	
Elite R line observation nursery	86	Kansas State	
MACIA derivatives	351	Kansas State	
BRON nursery	82	TAMU	
IFSAT	40	TAMU	
Selected lines from Lubbock nurseries	139	TAMU	
Total	3243	4	

lease, based on its high resistance to midge, apparent good grain quality, and a maturity and height very close to those of the local parent MM. SSD35 seed was increased in isolation to produce enough quality seed for on farm testing during the 2004 crop season.

Introgression of *Striga* resistance into landrace El Mota (EM). EM is a favorite of farmers in the Maggia valley of Niger for its early maturity associated with rapid grain-fill. Although it may escape *Striga* damage, it is highly susceptible as seen in controlled studies. On the other hand, improved *Striga* resistant cultivars are less accepted in this environment, because of problems of grain deterioration, despite their higher yield potential. A project was started to transfer *Striga* resistance genes from a well-characterized source of resistance to *Striga* (SRN39) to EM through a bioassay-mediated and/or molecular marker assisted introgression. As part of this on going effort, an advanced backcross population made of 103 BC2F3 progeny between EM and SRN39 was evaluated for *Striga* resistance in a *Striga* sick plot at the Konni station during 2002 and 2003. Overall our results show that important genetic variation was present in the parental lines and was largely transmitted to the progeny especially for broad sorghum phenotypes. There is also indication of *Striga* resistance being introgressed in this second-generation backcross population. This suggests that these lines may be the best candidates for the next stage of backcrossing whereby *Striga* resistance will be further incorporated into EM background. This project was initiated with financial support from the Rockefeller Foundation to the Ejeta lab at Purdue University.

Hybrid Program

There is sustained interest in hybrid cultivars in farming communities of Niger following the large number of convincing demonstrations with NAD-1, the first hybrid released. In 2003, we evaluated around 1,000 testcross hybrids largely to evaluate best inbreds for further experimentation. Out of 60 A lines and 74 potential R lines, we have identified the most promising to be used as testers for hybrid combinations in the Sahelian environment of Niger. They include 7 A lines (NE223, P9504, P9511, P9512, P9521, P9526, HF8) and 9 R lines (MR732, ST9007-5-3-1, MACIA, P9401, P9403, N7112R, 97M7642, 97M10522, 91BE7414). In the end, this activity aims at identification of best-adapted, high yielding food grain combinations for commercial cultivation in Niger.

Seed Production Activities

Seed production including hybrid seed was conducted in support of the INRAN seed unit which took off from the INRAN/INTSORMIL hybrid seed project. Nearly six tons of seed of various sorghum cultivars and lines were produced. The seed unit increased foundation seed for varieties MM, IRAT 204, SEPON82 and 90SN7. The last two are direct products of the INTSORMIL collaboration.

NAD-1 and F1-223 hybrids were produced at the Gabagoura station near Niamey. Production environment is at least as important as the genetics of maturity, which explains our agronomic trial to determine the best interaction of soil fertility level with planting density for optimal seed yields.

Another partner, the West and Central Africa Sorghum Research Network (WCASRN) helped with NAD-1 seed production.

In addition to breeding for open pollinated varieties, a strong focus is placed on hybrid breeding. Hybrids synthesized at INRAN or coming from Purdue go through nurseries and the best will reach advanced testing. In the preliminary hybrid trial, a yield average of about two tons per ha was obtained, which was also the yield of checks NAD-1 and Mota Maradi (MM). The best three hybrids yielded, however, over three tons per ha each. The best hybrid was P9526AxST9007-5-3-1 which yielded around 3.6 tons per ha while being early maturing. It is a cross between two tan plant parents belonging to the same maturity group, which will ease seed production and provide improved grain quality for food uses. Such early hybrids have the potential for adaptation over a wide area in Niger.

Sorghum/Millet Quality and Utilization
K. Saley, M. Moussa, I. Kapran, INRAN;
B. Hamaker and A. Aboubacar, Purdue

Primary Objective

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

- Identify and implement a form of contractual agreement between farmers and processors that could help to support a reliable and sustainable supply of quality grains needed to produce high quality sorghum/millet foods.
- Optimize the couscous agglomerator and solar dryer.
- Monitor product stability under different packaging materials and define a shelf life for both couscous and flour.

Findings

A partnership was initiated among sorghum/millet breeders, food technologists, food processors, and grains producers to identify potential grains producers and production sites to create consistent and reliable sources of high quality sorghum and millet grains for food processors. The optimized couscous agglomerator designed by CIRAD was locally reproduced with the collaboration of the national institute of mechanical engineering of Niger and the financial assistance of IFAD Regional project (Sorghum-Millet Initiative). The new equipment is in the process of being tested by a group of private processors under the supervision of INRAN food technologist. The existing solar dryer was optimized and repaired and discussion and planning is going on to construct a large-scale (50 kg/h) couscous steamer (estimated to cost $6000).

Entomology
H. Kadi Kadi and I. Kapran, INRAN;
B. Pendleton, WTAMU

Primary Objective

To determine the sorghum lines or varieties that are resistant to sorghum midge under field conditions.

Specific Objectives

- Identify the sorghum lines with stable resistance against sorghum midge.
- Determine if variation in the flowering of sorghum lines affects sorghum midge incidence and day-to-day variation in midge population abundance.

The sorghum midge is the most encountered insect pest in Niger on sorghum causing damage to the flowering panicles. Caging sorghum midge with sorghum panicles is an important method for avoiding escape, and permits screening for midge resistance under uniform insect pressure. Six lines (99 SSD F9-3, 99 SSD F9-4, 99 SSD F9-24, 99 SSD F-31, 99 SSD F-32 and IRAT 204) had highest damaged spikelets (20-40%). The percentages of grain loss recorded on these lines were 20-30%. Sorghum lines 99 SSD F9-18, 99 SSD F9-21, 99 SSD F9-33, 99 SSD F9-35 and ICSV 745 were identified as resistant to midge. These lines had the lowest grain loss (10-20%), even though some had high damaged spikelets. After three years of screening, we confirm that the lines 99 SSD F9-21, 99 SSD F9-33, 99 SSD F9-35 and ICSV 745 are resistant to sorghum midge.

Agronomic Studies for Producing Hybrid Sorghum Seed
N. Maman, S. Sirifi, I. Kapran, INRAN; S. Mason, UNL

Objectives

- To determine recommendations for microdose fertilizer application in combination with N and P application on pearl millet.
- To find the best combination of plant population and fertilizer rate in hybrid sorghum seed production.

Activities

Results from a three year study on microdose of N and P application showed that use of a combination of microdose with 20 units of P and 30 units of N gave better millet grain yield than seven other treatments (Table 2). Experiments on plant population and fertilizer rate on hybrid sorghum seed production, however, failed due to environmental problems in two years of the study out of three. In one year of the trial, the greatest seed yield was from the combination of plant density of 31,250 plants/ha with 100 kg/ha^{-1} urea application.

Table 2. Mean grain yields from on-station pearl millet trials in 2001, 2002, and 2003 at Kalapaté, Niger. Treatments (8) consisted of check (T1), Microdose (T2), Microdose + 20 P (T3), Microdose + 30 N (T4), Microdose + 40 P (T5), Microdose + 60 N (T6), Microdose + 20 P + 30 N (T7), and Microdose + 40 P + 60 N (T8), on millet genotype (Zatib).

Treatments (T)	2001 yields (kg/ha^{-1})	2002 yields (kg/ha^{-1})	2003 yields (kg/ha^{-1})	Average (kg/ha^{-1})
1	526	250	195	322
2	643	570	391	535
3	765	961	521	749
4	456	1026	399	627
5	944	570	317	610
6	977	449	415	614
7	903	1335	651	963
8	977	1171	627	925
Average	773	791	439	668

Nigeria

Pearl Millet Breeding

Angarawai I. I., W. B. Ndahi,
Z.G.S. Turaki, M. Is, LCRI; J. Wilson, USDA-ARS

Objective

Pearl millet improvement especially regarding hybrid development.

Activities

Improvement of adapted A4 cytoplasm male sterile (B) lines for multi-line resistance to Downy mildew. This project was initiated in October 2000. A4 cytoplasm male sterile (B) were composited from diverse maintainer lines during December 2000-April 2001 and December 2002-April 2003 dry seasons at Lake Chad Research Institute (LCRI) experimental station under irrigation. Seed was harvested and planted during the 2003 main season to screen for stable sterility and fertility restoration. Multi-location evaluation at both on-station and on-farm of A4 cytoplasm male sterile-based pearl millet hybrids from 2001-2002 seasons across millet growing zones of Nigeria, revealed increased yield more than the improved OPVs varieties with the hybrids having yield potential of 4.5-5.0t/ha.

Adapted male sterile (B) lines were used for the development of new male sterile maintainer lines. During December 2000-April 2001 dry season, 65 plant-to-plant crosses were made between SOSAT-C88 (pearl millet variety) and 75A-2/75B-2 (male sterile pairs). Each set of 75A-2 X SOSAT-C88 and 75B-2 X SOSAT-C88 were planted for BC1 in 2001 main season. 17BC1A and 26BC1B obtained were bulked separately as SOSAT-75A-2 and SOSAT-75B-2 pair. During December 2002-April 2003 two diverse A/B pairs were developed; LC0475A-3/LC0375B-3 and LC044A-2/LC034B-2 were composited from six diverse adapted maintainer lines. Each pair was screened for sterility in the 2003 main season. During the December 2003-April 2004 the newly constituted A-lines were each crossed to LCICDMR15. This material will be evaluated for sterility and fertility restoration in 2004 main season.

Genotype, environment and diseases effect on grain quality of pearl millet. This project was initiated in 2002. Forty pearl millet lines made up of West African landraces, and improved cultivars and hybrids, were centrally collected and distributed by Jeff Wilson to collaborating scientists in West Africa. The long-term goal of the research is to develop top-cross hybrids for West Africa that will be acceptable by farmers, local markets, and consumers. As a step toward that goal, selection must be carried out in the target areas to ensure adequate adaptation and disease resistance. Results from this year indicate that line 086R could be exploited as a maintainer on male sterile (A) lines, since its hybrid produced sterile heads. NKOXTCI a medium maturing material can be explored for downy mildew resistance (1%).

Effect of population density and N-Fertilizer application on growth and yield of pearl millet hybrid. This project was initiated in 2002. Although the optimum plant population and nutritional requirement of OPV's have been determined there is a need to establish the requirement of newly developed millet hybrids. A combination of two factors: 4 intra-row spacing of 15, 30, 45 and 60 cm between stands, and 4 levels of N (0, 30, 60 and 90 kgN/ha) were applied as treatment, and planted on 6 row plot of 5m long and 75cm apart. The experiment was conducted at LCRI during the 2003 main season. Data was taken for days to flower, plant height, stalk weight and grain yield. Result showed application of 60 kgN/ha at 45cm intra-row spacing as the optimum for maximum yield since increasing the N rate to 90 kgN/ha at 30cm intra row spacing only lead to luxury consumption. This will be confirmed during 2004 main season experiment.

Seeds of a newly developed hybrid, which document for release is being prepared, were sent to Dr Iro Nkama for nutritional quality evaluation at the University of Maiduguri. Seeds of evaluated millet lines at LCRI were sent to Kaka Saley, INRAN/Niger for grain quality analysis.

Millet Utilization
I. Nkama, M. Badau, A. Jato, U. Maiduguri; I. Angarawai, C. Uga, LCRI; B. Hamaker, Purdue

Objective

To characterize new pearl millet lines and local cultivars for physical, chemical, rheological and sensory properties, and food processing qualities

Grain and Food Quality

Studies on the physical, chemical, and sensory characteristics of the 10 multi-location millet hybrid lines developed by LCRI were continued for the 2003/2004 cropping season. There were variations in 1000 kernel weight (8.1 - 10.2 g), 1000 kernel volume (6.8 - 8.8 ml), density (1.1 - 1.4 g/ml), and grain hardness (36.8 - 52.9 N). Also, the proximate composition varied considerably. Protein ranged from 9.5 – 11.7%, fat 3.7 - 7.4%, and ash 1.5 - 1.9%. The *in vitro* carbohydrate digestibility varied significantly ranging from 29.5% for LCICMH99-39 to 64.1% for LCICMH99-12. LCICMH99-1 and LCICMH99-10 had digestibilities of 62.3% and 61.7%, respectively. The protein, fat, and ash contents of all the hybrids were within the normal range of values reported for pearl millet and also in comparison with the farmers' local. Studies on the acceptability of these hybrids for the preparation of kunun zaki, ogi and couscous showed that all the hybrid lines could be used to produce acceptable kunun zaki, ogi, tuwon tsari and couscous. These hybrids can be considered as good materials for food processing. *However, based on yields and downy mildew resistance LCICMH99-10 was selected as the best hybrid line.*

Studies on the malting characteristics of 10 pearl millet cultivars

The malting characteristics of 10 pearl millet cultivars with negligible tannin content, low mold count, and good germination properties were investigated. During steeping, the pearl millet cultivars Zango and Gwagwa absorbed more water per temperature rise and were more heat sensitive. Peleg's equation was found satisfactory in modeling the water absorption characteristics of these cultivars. GB 8735 had the lowest total malting loss of 21.1% and Zango had the highest of 35.6%. á– and â– amylase activities and diastatic power of samples varied significantly during mating (Table 3). SOSAT–C88, G.1-14.9, Zango, G.1-297.1 and Gwagwa had higher amylase activities. Diastatic power increased with germination period. SOSAT–C88 had the highest diastatic power after 72 hr steeping. Addition of 5% malt from SOSAT-C88, Zango, Ex Borno, ICMV-IS-94206, Gwagwa and GB 8735 to weaning foods prepared from mixtures of pearl millet, cowpea and groundnut (65:20:10) considerably reduced the hot paste viscosities of the weaning foods and improved taste and texture of the weaning foods. Gruels prepared from the weaning foods generally exhibited pseudoplastic behavior.

Germination of the pearl millet cultivars considerably reduced the phytic acid content by 85–90 % in all cultivars. The HCl extractability of calcium, iron, zinc and phosphorous, iodine, copper, and manganese increased progressively with germination up to the 72 hr germination.

Studies on couscous from the pearl millet hybrids lines

In 2002/2003 season the physical and proximate composition of 10 pearl millet hybrids developed by LCRI were investigated. During the 2003/2004 season, the couscous production potentials of these cultivars were evaluated. The proximate composition of the couscous from the 10 hybrids varied significantly. Sensory evaluation of the couscous using 30 panelists showed that any of the hybrids could be considered as a good material for couscous production. The *in vitro* carbohydrate digestibility of the couscous from the hybrids varied significantly for all samples and ranged from 56.5 – 82.5%.

Dissertation and Theses

Mamudu Badau a Ph.D. student is at the final stages of his study on the malting characteristics of pearl millet cultivars and their food application.

In this year, 12 undergraduate students participated in the INTSORMIL project. The main thrust was on couscous and its production from tsari flour. Marketing studies on couscous will be conducted this year. Work is continuing on the protein and carbohydrate digestibilities of the pearl millet hybrids and couscous from them. About 10 sorghum cultivars, both local and improved, are being characterized for their tannin contents and their malting characteristics.

Collaborative Sorghum Breeding Trials
P. Marley, IAR; D. Rosenow, TAMU

Activities

Regional trials were conducted for early, medium, and late maturing sorghum lines. All the countries involved made contributions of elite lines into each of the cycles for distribution to each country for evaluation.

Early maturing variety trial. Fifteen newly developed lines of sorghum were evaluated for yield, plant height, and days to flowering in the 2003 wet season. Three local checks

Table 3. α– and β-amylase activities (unit/mg protein/min) and diastatic power (%) of some pearl millet cultivars as affected by germination time[1,2,3]

Samples	α – amylase activity		β- amylase activity		diastatic power	
	0 hr	72 hr	0hr	72 hr	0 hr	72 hr
SOSAT-C88	6.32	85.0xy	55.0x	80.5v	22.0w	45.4x
ZANGO	6.01	80.2xy	53.0x	78.4vw	20.5w	42.3xy
EX BORNO	6.03	82.0xy	49.4x	66.0vwxy	18.7wx	38.4xy
LCIC-IC-9701	5.54	39.5z	40.3y	57.8y	12.1z	27.0z
ICMV-IS-94206	5.47	36.5z	48.3xy	71.7vwxy	15.3xyz	36.9xyz
ICMV-IS-94208	5.38	36.2z	46.5xy	58.0xy	12.8z	30.1yz
GWAGWA	6.00	80.9xy	42.8y	61.3vwxy	15.1xyz	26.8z
G.1-14.9	6.19	82.1xy	47.9xy	76.0vwx	13.5yz	27.9z
GB 8735	5.57	36.1z	46.6xy	71.0vwx	13.9xyz	29..7yz
G.I-297-1	6.04	81.0xy	48.4xy	77.2vw	17.1wxyz	45.0x
ICSV III(SORGHUM)	6.45	86.4x	32.5z	45.1z	17.1wxz	45.9x

[1]0 hr is time after steeping and before germination; [2]Mean of triplicate determinations
[3]Means in each column not followed by the same letter are significantly different ($p < 0.05$)

were used – ICSV III, Samsorg 16, and KSV 4. Line 98-BE-F5P-74-1 gave the best yield of 1333.4 kg ha^{-1} followed by the check Samsorg 16 with 1200 kg ha^{-1}. Lowest yields came from line 98-BE-F5P-58 and the check variety ICSV III with 533.4 kg/ha^{-1}. Plant height ranged from 120 cm for Seguifa to 272.5 cm for 98-BE-F5P-54-1. The days to 50% flowering ranged from 65.5 for 98-CZ-F5P-83 to 89 for 98-BE-F5DT-128-1. Lines 98-BE-F5P-74-1 and Seguifa were more promising in terms of their yields.

Medium maturing variety trial. The medium maturing trial was made up of twelve (12) entries, which were evaluated for yield, plant height and days to maturity. This trial showed more promise as most of the entries yielded above 1000 kg ha^{-1} The best line yielded 2072 kg ha^{-1} compared to the local Faradawa 2020 kg ha^{-1}. Only three lines did not do well giving yields of less than 1000 kg/ha^{-1} (10-SB-F5DOT-210, 00-SB-F5DOT-427, AND 98-SB-F5D0T-170-1). Lines 12-G1-1—100-SB-F5DT-19 and 00-SB-F4DT-275-282 have been selected for multi-locational trials for their adaptability. Days to 50% flowering ranged from 71 for lines 00-SB-F5DT-427 and E2-B02-108 to 95cm for the local Faradawa.

Burkina Faso

Cropping Systems to Optimize Yield, Water and Nutrient Use Efficiency of Pearl Millet and Grain Sorghum

J.B. Taonda, S. Pale, INERA; S. Mason, UNL
***Collaborators:* B. Albert, I. Ilboudo,**
B. Bougouma, INERA

Objectives

- Conduct multi-year research on microdose, N and P fertilizer application on pearl millet grain yield, nutrient removal, and changes in soil nutrient levels.
- Conduct research on mechanized (i.e., animal traction) Zaï production system for pearl millet, production practices for traditional beer production.
- Collaborate with national extension services and NGO/PVOs in transferring improved pearl millet and grain sorghum agronomy practices.

Activities

Microdose fertilizer study. Three-year central studies were initiated on-station. A randomized complete designed study was used with four replications. Treatments consisted of zero, microdose (cap-full of complete fertilizer in the seed hill at planting), Microdose + 20 kg ha^{-1} P, microdose + 40 kg ha^{-1} P, microdose + 30 kg ha^{-1} N, microdose + 60 kg ha^{-1}, microdose + 20 kg ha^{-1} P + 30 kg ha^{-1} N, and microdose + 40 kg ha^{-1} P + 60 kg ha^{-1} N. In addition, satellite studies were conducted on farms using zero, microdose and microdose + 20 kg ha^{-1} P or 20 kg ha^{-1} P + 40 kg ha^{-1} N treatments. One replication was planted per farm, and in the data analysis farms were considered to be replications. Analysis of variance indicated that grain and stover yields to fertilizer treatments varied by country and year. However, on the average, microdose fertilizer application increased grain and stover yield by 62% increase. Clearly the microdose application is a low cost investment that has a high probability to increase grain yields across the West Africa pearl millet production area. Yield responses were greater for P application than N application, but application of microdose plus 40 kg ha^{-1} P and 60 kg ha^{-1} N was required to maximize yields of grain and stover.

Zaï and other fertilizer treatments on grain. A study conducted at SARIA in 2002 and 2003 compared a no fertilizer check (farmer practice), microdose fertilizer application at planting, Zaï with compost 300 g hill^{-1} compost application, and the recommended fertilizer rate of 75 kg ha^{-1} of 15-15-15 complete fertilizer at planting and 24 kg ha^{-1} N 45 days after planting. Microdose and recommended fertilizer rates increased grain yield by approximately 600 kg ha^{-1} stover yield by approximately 1000 kg ha^{-1} (Table 2). The Zaï plus compost increased grain yield over the control by 1200 kg/ha^{-1}, and stover yield increased by 2000 kg ha^{-1}. The water conservation and nutrient supplying of the Zai plus compost system clearly increases yields greater than the other systems in the study.

Sorghum production practices for *dolo* (traditional beer). Previous research showed that the red grain sorghum varieties - IRAT 9 and ICSV 1001(Framida) - to be superior for *dolo* (traditional beer) production. A study was initiated in 2003 to develop production practice recommendations for grain yield and *dolo* quality. The study is being conducted with a randomized complete block and split plot treatment arrangement. The whole plot includes water management (shallow cultivation control, tied ridges, manual Zai), mechanized (animal traction Zai, and dry soil tillage) and split plots of fertilizer levels (zero, microdose with 4 g 15-15-15 per hill, recommended rate of 75 kg ha-1 15-15-15 plus 50 kg ha^{-1} urea, and microdose plus 20 kg ha^{-1} P and 30 kg ha^{-1} N). Grain yield and quality tests associated with *dolo* production are being collected. In 2003, tied ridges and mechanized Zai resulted in the highest yields for Framida, while tied ridges and dry soil tillage produced the highest yields for IR12. Also, the microdose plus 20 kg ha^{-1} and 30 kg ha^{-1} produced yields that were more than 50% higher than all the other fertilizer treatments.

Sorghum Disease Nursery

A. Neya, INERA; D. Rosenow, C. Magill TAMU

Objective

To identify resistance to multiple diseases in selected breeding lines assembled by NARS in West Africa.

Activities

The West Africa Sorghum Diseases Nursery (WASDON) comprised of 13 sorghum-breeding lines replicated two times in randomised complete block design. The materials were from Mali (3 entries), Nigeria (5 entries) and Burkina Faso (5 entries, including the local check). In order to increase the overall incidence and severity of leaf anthracnose, a mixture of three susceptible sorghum genotypes (i.e., IS 18442, IS 4585, IS 905) was planted prior to test genotypes, alternately every fifth row and as border rows on both sides. The field experiments were conducted at two locations at Farako-Ba (latitude 11° 11' N; longitude 4° 18'; altitude 432 m, and Niangoloko (latitude 10° 16' N; longitude 4° 55' W; altitude 320 m). Scorings were made for leaf anthracnose (*Colletotrichum graminicola*), sooty stripe (*Ramulispora sorghi*), grey leaf spot (*Cercospora sorghi*), zonate spot (*Gloeocercospora sorghi*), stalk red rot (*Colletotrichum graminicola*) and grain mold (complex of fungi) on 10 plants randomly tagged on the row next to the infector row.

Grain yield ranged up to 2506 kg ha^{-1} with a test mean of 1523 kg ha^{-1}. When days to 50 % flowering were considered, the earliest entry was BES-SAMSORG 4 (67 days), and the latest was SAMSORG 17 (109 days). Data show that plants height ranged from 139 – 357 cm with a test mean of 226 cm. Leaf anthracnose severity ranged from 1.6 to 4.5, the entry EPII-2002-19 from Burkina Faso being the most susceptible with a rating of 4.5. Grey leaf spot severity was low, ranging from 1.0 to 1.2. The severity of stalk red rot also was low with a test mean of 1.2. Mean severity of stalk red rot ranged from 0.4 to 2.2 (scale 0-5). Under the condition of Farako-Ba, symptoms of sooty stripe and zonate leaf spot were recorded in a few cases on lower leaves but they were observed on the four upper leaves. Grain mold severity ranged from 1.2 to 3.2 with test mean of 2.3 (scale 1-9). Considering the reaction of the genotypes to all diseases, the following entries exhibited field tolerance to multiple diseases: 02KIF-5T-22 and 99 SB-F-5DT-196 from Mali, SAMSORG 14 and SAMSORG 17 from Nigeria, and Sariaso 01 from Burkina Faso. These entries showed low leaf anthracnose severity (less than 2.0) and low grain mold severity (less than 2). The severities of different diseases were variable and none had multiple disease resistance.

Striga Control

H. Traore, INERA; G. Ejeta, Purdue

This project was new and trials were planted in 2004. They include using: 1) water conservation, cultivar tolerance, fertilizer to control *Striga* in sorghum and millet in farmers' fields in eastern Burkina Faso, and 2) evaluation of sorghum cultivars for *Striga hermonthica* resistance in eastern Burkina Faso.

Sorghum and Millet Utilization

B. Bougouma, L. Ouattara, K. Zida, B. Diawara, IRSAT; B. Hamaker, Purdue

Objectives

- To determine the nutritional and technological qualities of five sorghum varieties and five millet varieties used in Burkina Faso.
- To determine the impact of packaging in polyethylene sachets with thickness of 150 and 200 µm on the shelf life of three market products containing millet.

Activities

Characterization of sorghum and millet varieties for specific end uses. Three local varieties and seven selected varieties introduced recently into the central area of Burkina Faso for their high agronomic potential were characterized on the nutritional level. The varieties Sariaso 11, tan Nazongala, ICSV 1049, and Fibmega had comparably high protein contents of at least 12.3% db. Sarisao 14 had low protein content of 8.0%. Tests of suitability for local dishes and market products must be conducted to identify the suited varieties.

Conservation and packaging tests of millet-based products. The impact of polyethylene packaging thickness on shelf live of three millet-based products was studied. Polyethylene sachets with thickness of 150 and 200 µm were used to package millet rolled flour, millet simple flour and millet weaning food. Quality was evaluated by evolution of fatty acids and water content at room temperature. There was no significant difference in fatty acid contents between samples stored within the two thicknesses of packaging (p = 0.15), as well over times (p = 0.83). Water content also did not change among samples stored in different package thicknesses or over time. The three products kept good characteristics in the four months of storage; also the 150 µm thickness packaging material was found to be adequate and is economically profitable.

A survey is also being conducted on traditional malting and brewing processes in western Burkina Faso, and is a collaboration with the above agronomic study on production of sorghum for *dolo*.

Senegal

Cereal Technology Project (new)
A. N'Doye, ITA; B. Hamaker, Purdue

<u>Characterization of the millet variety "Thialack"</u>. A local landrace millet cultivar "Thialack" has been found to be superior in making composite flour bread ("pan riche") compared to other cultivars. In this study, cv. Thialack is being characterized to understand the basis of its better bread-making quality so that tools can be developed to breed for improved millet varieties. Three millet varieties were tested in preliminary testing – Thialack, Sossat C, and Souna III. Electrophoresis of proteins showed little discernable differences among the three varieties. Starch and simple sugar analyses showed a higher level of total sugars in Thialack (4.3%) compared to Sossat C (3.5%) and Souna III (2.5%); starch analyses showed little differences, although there was a discrepancy in amylose values among three laboratories. Amylose content and starch structural characterization is being done.

Networking

Discussions were ongoing in West Africa for formation of a joint millet and sorghum network in the 2003-2004 year. ROCARS had some minimal activity in the region during this period. INTSORMIL supports the concept of a new network in the region, and looks to play an active role when renewed. Networking occurred with the Millet-Sorghum Initiative coordinated by Global 2000 involving contracting between farmers and processors, and farmer warrantage/contracting conducted by Ouendeba Botorou and John Sanders. World Vision supported seed activities in the Maradi region of Niger. Rockefeller Foundation, through Gebisa Ejeta, is supporting research to introduce *Striga* resistance into adaptable varieties.

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

Darrell T. Rosenow
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Collaborative Program

The initial INTSORMIL collaborative program in this area was established in Mali which now has 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 or other host countries, or to PI conferences or workshops as appropriate, to observe field trials, consult, review progress and plan future activities with host country scientists. Occasionally, host country scientists also travel to the U.S. for research review, planning, and coordination.

The Mali 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. In Ghana, the program includes breeding, entomology, pathology, agronomy, and economics, while in Senegal it includes sorghum and millet breeding, entomology, pathology, and commercialization/transformation/marketing of grain.

In 2000-2001 a new thrust to the program previously centered in Mali began with the initiation of collaborative INTSORMIL research in Ghana and Senegal. An 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 and expanded to include the new collaborative efforts in Ghana. In 2002 a new MOU was signed between INTSORMIL and ITA (Institut de Technologic Alimentaire) in Dakar, Senegal which deals with commercialization of grain in Senegal.

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. 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 interact and /or travel to these new countries. The PI Conference in Ethiopia in November 2002 served as the initial broad based planning conference for collaborative research efforts among Mali, Ghana, and Senegal as well as with the Eastern Region (Niger, Nigeria, and Burkina Faso) scientists. In April 2004, an INTSORMIL West African Regional Conference was held in Ouagadougou, Burkina Faso to finalize the merger of the Western and Eastern West African Regions into one overall West African Regional Program. The new structure became effective July 1, 2004.

Other Collaboration

Previous collaboration involving germplasm exchange, workshops, monitoring tours, and specific research projects with the regional networks ROCARS (WCASRN), and ROCAFREMI essentially ended in 2003. Unfortunately, ROCAFREMI ceased operation prior to the 2002 crop season, and ROCARS funding for the 2003 crop season was greatly reduced, effectively ceasing operation. Collaboration with ICRISAT at Samanko outside Bamako has continued, although on a more limited scale than in the past. There also was cooperation with NGOs such as World Vision, Winrock, AMEDD, FDS, GRADECOM, and other small NGOs in evaluation and seed increase 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 Mali IER research program through the SPARC Project which ended in June 1997. In addition to the Malian Government, the Syngenta Foundation and World Bank support the IER research program.

Sorghum/Millet Constraints Researched

Plant Production Constraints

Grain 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 as well as the head miner.

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. The population increase and increased demand for food has impacted the traditional multi-year land rotation system and contributed to reduced soil fertility and productivity.

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 predominantly subsistence 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. Effective supply chain management systems are needed to assure a consistent supply of good quality identity-preserved grain which is required for increased commercialization and transformation of sorghum and millet into value-enhanced products.

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 along with the development of 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 in the area 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 - Mali

The sorghum-breeding program in IER in Mali is a large and diverse program. The program utilizes 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. Use is made of elite lines from the U.S. and previously developed ICRISAT lines. 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 non-guinea intergrades. Essentially 100% of the breeding effort is directed toward white-seeded, tan-plant genotypes. Breeding for the dry northern areas also involves crosses with local Durras and good yielding Bicolor derivatives 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. 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 more 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 2003 rainy season, 79 new crosses were made at Sotuba, and the F_1s grown during the 2003-04 off-season nursery to produce F_2 seeds.

From the multilocation evaluation of 135 F_2 families in the 2003 rainy season, 366 single-plant selections were made at Samanko, 162 at Cinzana and 158 at Finkolo. These selections will be advanced by the pedigree method. The 866 F_3 progenies evaluated were mostly derived from tan guinea cultivars. The F3 families were grown at Samanko, Cinzana, Finkolo, Bema, and Kite, and selected were 183 single heads at Sotuba, 106 at Cinzana and 223 at Béma, and 48 at Finkolo and Kita. The F_4 and F_5 generations were evaluated according to the maturity group. The early and medium F_4 progenies were evaluated at Sotuba, Kolombada, Béma and Cinzana. Selected were 199 panicles at Kolombada, and 168 at Cinzana, and 246 at Bema. The late F_4 progenies were evaluated at Finkolo and Kita with 61 and 38 panicles selected, respectively, at Kita and Finkolo. In the early F_5s 18 lines at Béma and four at Cinzana were selected. The medium F_5 progenies were evaluated and we selected 43 lines (38 at Sotuba and 28 at Kolombada). A total of 38 lines were selected from late F_5 progenies at Finkolo and Kita. The F_5 selections move to the off-season for seed increase for entry into Group I yield trials the following year.
Yield trials of new breeding lines and improved varieties in 2003 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 Maturity Variety Trials

Three advanced elite early varieties groups (GI, GII and GIII) were evaluated at two locations, Bema and Cinzana. In GI (first year evaluation) at Cinzana and at Bema the analysis showed significant difference among entries for grain yield, plant height and flowering date. At Bema the highest yielding variety was 02-CZ-F5P-100 with 3278 kg/ha^{-1}, while the local check produced 1555 kg/ha^{-1}. At Cinzana the grain yield varied between 3671 and 1224 kg/ha^{-1} with thirteen varieties showed a yield gain of 20 to 27% compared to the local check.

In the GII (two year evaluation) at Cinzana and Bema there are no significant differences among lines for grain yield with the average yield at Cinzana 2354 kg/ha^{-1} compared to 1500 at Bema.

After three years of evaluation in the two locations (GIII), five lines 00-BE-F5P-15 (1766 kg/ha^{-1}), 00-BE-F5P-22 (1963 kg/ha^{-1}), 00-BE-F5P-23 (1773 kg/ha^{-1}), 00-BE-F5P-135 (1986 kg/ha^{-1}) and 00-BE-F5P-245 (1970 kg/ha^{-1}) were retained for grain yield and grain quality and will be in on-farm tests in 2004 (Table 1).

Advanced Medium Variety Trials

In the GI trial at Sotuba, with an average yield of 2688 kg/ha^{-1}, there were no significant differences among entries for grain yield. However, some entries 02-SB-F4DT-298, 02-SB-F4DT-275-282, 02-SB-F5DT-144, 02-SB-F5DT-142, 02-SB-F5DT-94, 02-SB-F5DT-12, 02-SB-F5DT-60, and 02-SB-F5DT-63 showed high grain quality and good plant architecture.

At Kolombada the average grain yield was 1463kg/ha^{-1} with significant differences among entries. The combined analysis of Sotuba and Kolombada indicated a good performance of 02-SB-F5DT-144 and 02-SB-F5DT-169. The local check with a grain yield of 2858 and 2500 kg/ha^{-1}. The variety 02-SB-F5DT-141 was most stable in the two trials with an average grain yield of 2369 kg/ha^{-1}.

In GII at Sotuba, the highest yielding variety 01-SB-F5DT-221 produced 3389 kg/ha $^{-1}$ and showed a yield gain of 16% compared to the check. The average yield was 2089 kg/ha^{-1}. At Kolombada, there were no significant differences among entries for grain yield with an average yield of 1984 kg/ha^{-1}.

In the combined analysis, the varieties 01-SB-F5DT-14 (2639 kg/ha^{-1}), 01-SB-F5DT-21 (2417 kg/ha^{-1}), 01-SB-F5DT-46 (2551 kg/ha^{-1}), 01-SB-F5DT-184 (2070 kg/ha^{-1}), 01-SB-F5DT-216 (2389 kg/ha^{-1}), 01-SB-F5DT-144 (2692 kg/ha^{-1}) and 01-SB-F5DT-221 (2709 kg/ha^{-1}) showed good performance compared to the average yield of 20033 kg/ha^{-1}.

After three years of evaluation at the two locations (GIII), with a mean grain yield of 2134 kg/ha^{-1}. The varieties 00-KO-F5DT-18 and 00-KO-F5DT-30 gave more than 2500 kg/ha^{-1} and performed well in the two localities during the three years of evaluation (Table 1).

Advanced Late Variety Trials

Elite varieties were yield tested agronomically along with Foulatiéba and local check at two locations in North Guinea Zone of Mali in a randomized complete bloc design. Each plot

Table 1. Mean performance data of selected improved breeding varieties from sorghum yield trials, 2001-2003, Mali.

Designation	Pedigree	Days to 50% flowering	Plant height (m)	Grain yield (kg/ha^{-1})
Early GIII - (3 years - 2 locations)				
00-BE-F5P-15*	((M84-7*Nagawhite)*M84-7)	80	1.7	1766
00-CZ-F5P-22*	((M84-7*Nagawhite)*M84-7)	81	1.6	1963
00-CZ-F5P-23*	((M84-7*Nagawhite)*M84-7)	81	1.5	1773
00-BE-F5P-135*	((M84-7*Nagawhite)*CEM326/11-5-1-1)	75	1.7	1986
00-BE-F5P-245-2GR*	(M84-5*(CSM388*Sureno))	80	2.1	1970
Malisor 92-1 (check)		74	1.9	1853
CSM-63 (check)	Improved Local	73	2.4	1478
Local Check	Local Cultivar	73	2.7	1629
(Test Mean)		77	1.85	1664
Medium GIII - (3 years - 2 locations)				
00-KO-F5DT-18*	((M84-7*Nagawhite)*CEM326/11-5-1-1)	92	1.8	2682
00-DO-F5DT-30*	((M84-7*Nagawhite)*CEM326/11-5-1-1)	95	2.0	2575
00-DO-F5DT-386	(CGM-19/9/1-1*(M84-7*CSM-388)	95	2.7	2266
CSM-388 (check)	Improved Local	93	3.6	2270
Local Check		80	3.8	2310
(Test Mean)		89	2.6	2134

*Entries to be advanced to on-farm trials in 2004.

Table 2. New Malian white-seeded, tan-plant sorghum breeding lines recently released and named in Mali.[1/]

Name	Designation	Pedigree	Days to flower
Wassa	97-SB-F5DT-63	(N'Tenimissa*Tiemarfing)	77
Kénikédiè	97-SB-F5DT-64	(N'Tenimissa*Tiemarfing)	78
Darrellken	99-BE-F5P-128-1	(N'Tenimissa*Seguetana CZ)	79
Niéta	97-SB-F5DT-74-2	(N'Tenimissa*Tiemarfing)	83
Zarra-blè	96-CZ-F4P-98	(N'Tenimissa*Tiemarfing)	94
Zarra-djé	96-CZ-F4P-99	(N'Tenimissa*Tiemarfing)	90
Niétichama	97-SB-F5DT-150	(92-SB-F4-14*92-SB-F4-97)	89

[1/]The top six cultivars are all true guinea types, but with tan plant. The last cultivar is an intermediate caudatum-guinea type. Tiemarfing is a Malian local landrace guinea type sorghum.

consisted of four rows, 0.75 m apart and five m long. Cultivars were evaluated for maturity, yield, agronomic desirability and food quality.

In the G1 at Kita significant differences were observed among entries with an average grain yield of 2207 kg/ha^{-1}. Entries 02-F1-F5T-38 (3000 kg/ha^{-1}) Foulatiéba (3611 kg/ha^{-1}), and Zarra (3056 kg/ha^{-1}) performed well. At Finkolo there was no significant difference in grain yield. In GII, no significant differences were observed among varieties. There was no GIII trial in 2003.

On-Farm Trials

Six farmers were selected in each of two locations, Cinzana and Sirakorola where 15 new early maturing breeding varieties were compared to the local of the farm. At both locations, there were no significant differences for grain yield, indicating equal to, but not greater than, the farmers local. In the second year on-farm trials with six farmers at two locations, there was no significant difference among entries for grain yield, but one line, 98-BE-F5P-84, had superior grain quality compared to the local.

For medium maturity varieties, six farmers each at Ouéléssébougou and Bancoumana evaluated nine new varieties compared to the local check. At Ouéléssébougou there were significant differences among entries for grain yield with the line 98-BE-F5DT-82 ranked first with 1400 kg/ha^{-1}, followed by 98-SB-F5DT-52 and 98-SB-F5DT-19-3. The entry 98-SB-F5DT-52 was appreciated by farmers for both forage and grain quality.

For late maturing on-farm trials, four new tan-plant varieties were compared to the local check by six farmers each at two sites, Kita and Kébila. At Kébila, three of the new varieties produced yields equal to the local check, Zarra, Kénikéba, and 98-SB-F4P-98. In an on-farm large adoption trial at Kébila, Zarra yielded 960 kg/ha^{-1} compared to the local with 810 kg/ha^{-1}, and Zarra had superior grain and food quality.

New Developed Cultivars

Six new N'Tenimissa derivative tan-plant IER developed breeding guinea lines and one intermediate caudatum-guinea line have been named and released in Mali, or distributed thru on-farm trials, demonstrations, or NGOs. Their names, pedigrees, previous designations and days to flower are given in Table 2. The guinea cultivars have superior grain quality and less stalk breakage than N'Tenimissa.

Seed Multiplication

Listed below are some improved cultivars and new breeding lines for which seed was increased by the Mali IER sorghum breeding program in 2003 for distribution, NGOs, on-farm trials and demonstrations, and future seed increase.

Varieties	Localities	Area (ha)	Quantity (kg)
CSM-63 E	Béma	1	1000
Malisor-92-1	Béma	1	600
CSM-388	Kolombada	1/2	400
Kinikeba	Sotuba	1/4	100
N'TENIMISSA	Kolombada/Tamala	1/2	600
Wassa	Cinzana/Kafara	3/4	800
Darrelken	Cinzana	1/4	300
Niéta	Tamale	1/2	587
98-BE-F5P-84	Cinzana	1/4	400
98-BE-F5P-84	Kolombada	1/2	700
96-CZ-F4P-98 (Zarra-blé)	Kita/Kebila/Tamale	1 1/2	1800
96-CZ-F4P-99 (Zarra-bjé)	Kita	1/4	100

Hybrid Development

In a cooperative IER/ICRISAT project supported by the Rockefeller Foundation some hybrids involving newly sterilized A-lines (BC4) were planted for observation in 2003. Some tan-plant Guinea0Caudatum intermediate lines of short stature and sterilized by IER (97-SB-F5DT-150, 154, and 160) produced good hybrids but their sterility was poor, resulting in numerous female selfs, thus these lines are probably not useable as females. One female from Burkina Faso, Sariaso9, a purple plant Guinea type cultivar was fine on sterility, but possessed the dominant B1 gene and produced very tall, brown, high tannin hybrids.

The white, tan-plant guinea cultivar, N'Tenimissa, has good sterility as an A-line, and makes good, but very tall, hybrids, and has the recessive b_1 gene. New N'Tenimissa derivative with shorter stature should be good candidates for new B-lines to sterilize N'Tenimissa produced higher yielding hybrids than true guinea A-line such as CSM-219 or Seriaso 9. Two IER breeding guinea type lines produced good hybrids (and have the recessive b_1 gene), 96-CZ-F4P-98 and 02-SB-F4DT-57.

Four IER tan-plant guinea-breeding lines introduced into the U.S. showed a good B-line reaction in Puerto Rico, and are recessive b_1. The BC2 of the A and the B0line were sent to Mali for further sterilization and evaluation in 2004. The four are: 99-CZ-F5-131 (N'Tenimissa*Seguetana CZ); 98-SB-F5DT-17 ((M84-7*N'Tenimissa)*N'Tenimissa); 98-SB-F5DT-52 (N'Tenimissa*CSM-388); and 99-SB-F5DT-169/98-SB-F4DT-164-1 (N'Tenimissa*CSM-388). It appears that the Caudatum derivatives involved in at least part of the hybrid significantly increases heterosis compared to true Guinea hybrids.

In another study, 35 diverse Mali indigenous cultivars from the Mali Sorghum Collection and 30 Guinea-Caudatum derivative exotics from southern Sudan were evaluated as potential breeding germplasm to use in a hybrid-breeding program. They were evaluated in Puerto Rico and Mali for hybrid vigor, B/R fertility reaction, and pressure of the dominant B1 gene (gives test with U.S. Females). Data is presented on page 88 (TAM 222) of the 2003 INTSORMIL annual report. Most Malian cultivars were restorers except for a few Guinea types, especially Margarita ferum types. Essentially all the Guinea-Caudatum cultivars from southern Sudan were strong restorers and had the dominant B1 gene. The B1 gene was absent in most Durra and Durra-Bicolor Malian lines, and some of them showed promising heterosis. Thus, they could be useful in breeding non-guinea cultivars for northern Mali.

Sorghum Breeding - Senegal

At Bambey, two yield trials were grown involving selected lines from previous INTSORMIL observational nurseries. Based on agronomic performance, the genotypes 97-CZ-F5-28; 96-CZ-F5P-12; KSV111; 99-EA-P102 and ISCV 401*S34 were chosen for inclusion in multi location tests in 2004. In another trail involving lines developed in Burkina Faso and received frmo CIRAD three lines were selected, CEF418-/1-3-2; Cirad 439, and Cirad 440 for use in the 2004 field trials at several locations. Highly performing lines were observed for the new INTSORMIL observation Nursery; namely 98-CZ-F5P-83 and Seguifa. From the dwarf guinea population originally obtained for ICRISAT, 6 families were selected with plant height ranging between 168 and 190 cm., and grain yield of 180 to 2350 kg/ha^{-1}.

F_2 segregating populations involved crosses between Sorvato1, a high yielding line with good grain qualities identified from the ROCARS trials and the local varieties CE151-262, CD145-66 and 180-33 were grown. Segregating populations of those same three lines with very earliness sources were also grown with the F2 and BC1F1. The objective is to develop very early materials (about 80 days from planting to maturity) for the northern zones.

At Kolda, two observation nurseries from ICRISAT were grown with eight lines selected from the 25 entries, IS3443, IS22680, ICSV902, ICSV2N, S8135, Sariasso-10, ICSV1063, and ICSV1079. From the dwarf S1.2 guinea population, 139 plants were selected based on agronomic performance.

From the INTSORMIL collaborative West African yield trial, which was comprised of medium maturity lines, it was observed that the highest performing were CSM-388 and SSV 20031, producing 2462 and 2084 kg/ha^{-1} compared to 1421 kg/ha^{-1} for the local check F2-20.

Sorghum Breeding - Ghana

The nation-wide sorghum germplasm collection continued in October-December, 2003 in the whole Upper West Region and six districts in the Northern Region. In all, 467 accessions have been collected so far. Visually, the collections show a wide range of seed size, grain color, and panicle shape. Agro-morphological evaluations at two locations in 2002 and 2003 were carried out on the 2001 and 2002 collections. Maturity and grain yield varied considerably among entries and from year to year. Most accessions appear genetically low yielding, but they do possess good food quality according to the farmers. All accessions will be evaluated in 2004 and the nutritional and functional properties of some of the promising accessions as well as advanced breeding lines will be determined in collaboration with the Ford Research Institute.

One hundred and ten INTSORMIL breeding and germplasm lines were planted for observation, selection, and subsequent use. However, poor stands and excessive midge damage made the plantings useless. New seeds will be replanted in 2004.

Millet Breeding

Mali

The 40-entry Regional Millet variety trial developed cooperatively among West African millet breeders and Dr. Jeff Wilson was evaluated. There was a great range in days to flowering, from 38 to 90 days. Panicle length also varied greatly, from 5 cm to 80 cm. Most of the long panicle varieties were from Niger. The trial was also scored for head miner incidence and downy mildew, the most miner susceptible lines being 99-72, DMR72, PT7328, Tongo Yellow, and Sosat. The varieties 3/4 Souna, 99-72, ICMVIS90311, and IBMV8401 had no downy mildew. There also were significant differences for grain yield, with Indiana 05 and ICMVIS89305 having the highest grain yield with 2000 kg/ha^{-1}.

On a trial involving a hybrid, the hybrid grain yield was not better than the original parents, and was less than other millet varieties (Table 3). During the off-season, crosses were made with eleven male parents onto the male sterile Civarex 9105_{A4} for future hybrid evaluation.

Senegal

A 40-entry yield trial was conducted collaboratively with the University of Georgia. The objective was to evaluate the productivity and the grain quality of 40 genotypes of West Africa and USA origin and to identify parents to be included in the breeding process. The genotypes consisted of open pollinated varieties, hybrids and lines. With a mean yield of 930 kg/ha^{-1}, the best performing were ICMV IS 89305 (2331 kg ha^{-1}), Sosank (2163 kg ha^{-1}). (Table 4) Four entries, 99-72, P1449-2, 3/4 EX Bornu and 99M59043Mw x 68 A4R4, were free of smut while T99B, 01 Miso NCD23-NE, 68A x 086, 3/4 Souna, and Kapelga were highly susceptible to mildew. The SOSANK, SOSAT C88, Taram, Gwagawa and ICMB IS 89305 cultivars will be further evaluated.

On-farm test were conducted with the varieties BGB 8735 and ICTP 8203 in the direr northern zones. They were highly appreciated for their earliness, but have short panicles. Seed multiplication of the new synthetics; ISMI 9301, ISMI 9506 and ISMI 9404 was carried out at Bambey, Simthiou, and Kolda. The quantity of seed obtained (ISMI 9304:45 kg, ISMI 9506:13 kg, ISMI 9404:1.6 kg) will be used in the 2004 on-farm trials.

Table 3. Hybrid Civarex 9105A$_4$ x TrombedieR$_4$ performance evaluation, 2003, Cinzana, Mali.

Varieties	Plant height (cm)	Days to flower	Panicle length (cm)	Number heads harvested	Grain yield (kg/ha^{-1})
Civ 9105A$_4$ x TrombedieR$_4$	232	61	31	90	2470
Civarex 9105	223	40	30	92	3750
Trombedie	254	64	31	70	2470
NKO x TC1	335	75	34	66	3720
TC1	344	71	34	71	3750
Boboni (loca)	357	79	33	66	3720
CV (%)	4.2	19.4	5.8	15.5	8.5
Significance	HS	S	NS	NS	HS

Table 4. Results from the collaborative millet trial, 2003, Bambey, Senegal.

Variety	Grain yield (kg/ha^{-1})	Days to 50% flower	Plant height (cm)	Head length (cm)	Panicle diameter (cm)	Panicle length (cm)	Number plants	Number heads	Head weight (g)	1000 grain (g)
Sadoré local	1039	60	244	55.5	2.3	-5.0	12	56	2685	10.5
Kapelga	266	70	256	29.4	2.1	6.5	14	35	827	10.6
Torinio	755	62	279	40.1	2.4	5.9	14	64	1960	9.8
Zatib	1624	50	239	53.9	2.6	-3.9	14	134	3283	10.2
Zongo	555	63	248	76.7	2.3	-10.4	8	26	1325	8.5
HKP	1661	53	235	56.5	2.1	-0.6	10	69	3211	8.3
CIVT	2128	44	244	58.3	2.3	-2.3	14	77	4093	10.1
SOSAT C88	2028	48	202	28.3	3.1	5.5	14	90	3563	8.4
Taram	1472	55	229	66.7	2.6	-7.0	13	69	3133	8.6
SOSANK	2163	49	188	27.1	3.4	4.9	15	99	4051	7.6
ICMV IS 89305	2331	53	226	51.2	2.3	1.2	13	92	4208	8.4
ICMV IS 90311	1342	53	235	42.5	2.5	0.1	13	76	2709	9.4
Synthetic 1-2000	677	65	245	38.1	3	0.1	13	51	1850	9.5
NKO x TC1	375	60	240	36.3	2.3	4.1	9	34	923	7.7
Guéfoué16	593	67	291	38.7	2.3	6.3	12	70	1801	9.4
Indiana 05	782	64	270	42.6	2.5	1.7	13	77	2407	8.6
NKK	794	63	262	46.0	2.7	3.9	15	78	2371	9.3
Bongo Short Head	952	43	158	8.8	3.6	5.3	12	95	1796	8.2
Manga Nara	987	42	181	20.7	3.0	5.9	12	81	1791	9.3
Arrow	1023	44	215	33.1	2.1	4.1	15	57	1888	8.6
Tongo Yellow	702	45	192	22.9	3.3	9.4	10	75	1310	10
PT 732B	702	52	152	31.5	2.2	1.7	9	88	1588	8.9
P1449-2	865	51	158	28.1	2.3	-1.7	11	51	1685	10.4
3/4 Ex Bornu	687	47	168	42.1	2.7	0.7	12	78	1667	8.8
3/4 HK	601	59	138	40.6	2.3	-1.1	9	58	1446	9.6
3/4 Souna	450	55	106	33.9	2.3	-0.2	10	47	957	9
Gwagawa	2085	49	232	26.2	2.6	7.3	14	112	3748	7.6
LCIC 9702	691	47	140	24.1	2.6	3.7	9	54	1422	9.1
DMR 15	872	58	181	25.1	2.7	-3.6	13	68	1951	9.2
DMR 68	533	58	211	27.4	2.6	-1.1	11	46	1328	7.9
DMR 72	418	64	212	29.2	2.4	-0.3	10	56	924	9.6
GB 8735	1120	39	160	23.9	2.9	4.7	11	111	2186	8.9
99-72	166	53	118	16.3	2.4	2.1	10	45	560	8.3
TG102	851	36	115	26.1	2.7	10.7	14	69	1934	9.6
T99B	497	52	153	3.8	2.1	2.5	9	59	1527	10.2
T454	94	52	101	27.5	2.5	5.8	10	52	320	8.3
IBMV8401Mx 68A4R4w	574	45	126	33.3	2.6	9.5	12	86	1307	8.7
01 Miso NCD2-NE	672	46	97	28.2	1.8	5.5	10	91	1458	10.8
68A x 086R	498	34	112	21.9	1.7	17.1	13	85	989	9.7
99M5904Mw x 68A4R4	466	38	104	24.8	3.8	934	13	88	1148	8

The 40 genotypes in the collaborative yield trial were also tested for reaction to *Striga* in a screen house. *Striga* emergence was very early on GB8735, and IBMV8401M X 68A4R4@ and occurred 38 days after planting while it was late with Sadore local, Zongo, Guefoue, and Tongo yellow (62 days after planting). On four genotypes, emergence was not observed, these being HKP, NKO x TCI, Indiana 05, and NKK. Sosat C88, Arrow, DM$68 and ICMVIS 89305 have shown high susceptibility to *Striga* . The *Striga plants* that emerged on PT732B, Guefoue 16 and T99B died 10 days dater and did not complete their biological cycle.

Striga

Mali

Thirty-three early, thirty-two medium and fifteen late maturing breeding lines selected from the breeding program were evaluated for *Striga* in field trials in 2003 at Sotuba. *Striga* infestation level was low in all three trials and the results showed no significant differences among entries.

A 20-entry collaborative nursery with varieties from Nigeria, Burkina Faso and Mali was planted at Sotuba and Cinzana for *Striga* evaluation. *Striga* infestation was low, with no significant difference among entries on *Striga* counts at 75 and 95 days. Grain yield differences were significant at Sotuba with SSV200123, Sequetana, Komo Farfara, KL3, CEF 322/35-1-2, and EPII-2002-17 producing well with over 2000 kg/ha^{-1}.

Senegal

Field and screen house trials were conducted to evaluate the reaction to *Striga hermonthica* of genotypes from Mali, Nigeria, Burkina Faso and Senegal. The field trials had no *Striga* emergence while in the screen house, pots were infested with *Striga* harvested from a sorghum field. *Striga* emergence was low but Seguetana showed some resistance. *Striga* emergence was significantly delayed in CMDT-38 (111 days after planting) compared to Kamo Farafara (58 days) and Twin secdeel (65 days) both from Nigeria. Improved varieties from Senegal showed high susceptibility.

Ghana

Fourteen lines and cultivars contributed by INTSORMIL, Mali, Nigeria, and Burkina Faso were evaluated in a *Striga* infested field (on-farm) in 2203 at Yendi. *Striga* infestations were higher in 2003 than in 2002. The 14 lines screen showed varied levels of *Striga* infection/resistance (Table 5). In 2003 the lines 97-SB-F5DT-63, 97-SB-F5DT-64, and SRN 39 showed quite a high level of resistance to *Striga* but had very low yields. Conversely, CMDT-45 was quite tolerant to *Striga* as it combined high yield (1156 kg/ha^{-1}) with high *Striga* infection. SAMSORG 14, CMDT-39 appeared to be the most susceptible and N'Tenimissa being moderately susceptible. There didn't appear to be distinct correlations between the *Striga* infestations and their corresponding yields for the two years.

Pathology

Mali

For anthracnose, out of 88 breeding lines screened artificially at Sotuba, 02-SB-F5DT-9, 02-BE-F5P-90, 02-CZ-F5P-96 (02-CSM409C*N'Tenimissa)-2, 02-SB-F4DT-275-282, 02-SB-F5DT-12, 02-SB-F5DT-26, 02-SB-F5DT-93, 02-SB-F5DT-149, 02-SB-F5DT-180, 02-KI-F5T-44 and F2-78 showed a good level of resistance to the disease.

In the West African Disease Observation Nursery (WASDON), SAMSORG14 from Nigeria, OUEDZOURE from Burkina Faso and CSM660, Sakoika02, 00/ISO-CSM335 from ICRISAT/Samanko screened for the third year were considered resistant to anthracnose.

Table 5. Performance of selected sorghum varieties in *Striga* infested field at Yendi, Ghana in 2002 and 2003.

	Grain yield (kg/ha^{-1})		*Striga* count at maturity (No/ha)	
Line	2002	2003	2002	2003
CMDT-38	568	568	7	46
CMDT-39	578	578	8	179
SEGUETANA	472	472	9	54
CMDT-45	711	711	32	163
97-SB-F5DT-63	395	395	28	7
97-SB-F5DT-64	2232	2232	6	40
N'TENIMISSA	474	474	47	86
97-SB-F5DT-65	690	690	2	60
MALISOR-92-1	1011	1011	12	42
MALISOR-8401	627	627	2	66
CD-151-202-A1	341	341	39	58
SRN 39	-	-	-	30
SAMSORG 41	-	-	-	47
SAMSORG 14	-	-	-	225
Grand Mean	736	736	18	79
CV (%)	57	57	24	107
LSD	717	605	7	141

Table 6. Field reaction[1] of sorghum genotypes in WASDON trial, Nyankpala, Ghana, 2003.

Entry	Grey leaf spot[1]	Leaf blight	Long smut[1]	Zonate leaf spot[1]	Shootfly infestation (%)
BES-SAMSORG 4	2.0	6.0	1.0	3.0	85
NR-71168	3.0	1.0	1.0	2.0	19
99-SB-F5DT-154	4.5	1.0	1.0	4.0	47
97-SB-F5DT-154	3.0	1.0	1.0	3.0	19
EP 11 2002-1	2.0	2.0	1.0	2.0	65
TEMOIN DELA ZONE	3.5	2.0	1.0	3.0	29
SAMSORG 14	1.0	1.0	2.2	1.0	27
EP 11 2002-3	2.0	1.0	1.0	3.0	26
SP 11 2002-9	1.0	1.0	1.0	1.0	36
SAMSORG 17	1.0	6.5	2.2	1.0	12
EP 11 2002-19	3.0	2.0	1.0	3.0	22
02-K1-F5T-22	1.0	2.5	1.0	2.0	30
SAMSORG 40	1.0	3.0	1.0	3.0	19
CV (%)	35	51	15	26	54

[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.

Three years results indicated that covered smut incidence can be reduced by dressing sorghum seeds with 20 g of (Diro+Nguo+Nere) powder/kg of seed while grain yield can be increased to 56%. This plant pesticide can replace conventional fungicides such as Apron Stars in the future.

Senegal

From WASDON nursery, it was found that the lines 99-SBF5DT-196, 97-SBF5DT-154, and 02-KIF5-22 were highly resistant to grain mold, while Samsorg 14 and Samsorg 17 were resistant to *Ramulospora*, and EP 11 2002-19 and 02-KIF5T-22 were resistant to anthracnose.

Ghana

The 13 entry WASDON was rated for several diseases in 2003 with several showing good resistance to each of the four diseases (Table 6). The 60 entry ADIN was evaluated at Nyankpala in 2003 for gray leaf spot, leaf blight and zonate leave spot, with leaf blight, infestation being very light. ADIN entries which scored the most resistant to gray and zonate, with either no disease of no more than 5% leaf area infested included: SC414-12E, 86EO361, 90EO328, 96CD635, 96CD677, 92BD1982-4, 99GW092, B.HF14, 95BRON155, 96GCP124, 96GCPOB143, 96GCPOB160, 97BRON179, 91BE7414, BTx2928, RTx2925, RTx2914, RTx2919, RTx2916, BTx2923, Sureno, Tx 436, and BTx631.

The 40 entry collaborative INTSORMIL/ARS 206 regional West Arica pearl millet trial was evaluated for disease and agronomic traits (Table 7). Downey mildew was quite severe, but several entries showed good resistance. Ten entries yielded over 1,000 kg/ha^{-1} which is considerably above the traditional system yields of 200-700 kg/ha^{-1}.

Entomology

Senegal

A trial was conducted at Nioro to evaluate the effect on several species of head bugs of botanical (neem extract) and insecticide (decis) on different varieties. Eight different pest species were observed with *Eurystylus immaculatus, Ceontiades pallidus* and *Spilostethus sp* being dominant, with respectively 66%, 21%, and 6% of the total number of insects observed. The insect populations were reduced by 40% and 52% respectively with the neem and decis treatment compared to the untreated plots. The reductions were 43% and 58% for *Eurystylus immaculatus*. CE151-262, F2-20 and Malisor 84-7 were less infested by *Eurystylus*_with 6, 7, and 7.3 insects/panicle respectively while CE180-33 had the highest infestation with 14.8 insects/head. The amount of grain loss varied between 36.7% and 43.3% for F2-20 and CE 151-262 to 77% for CE245-66. For CE196-7, CD183-333 and Malisor-84-7, the loss was 50-52%.

Ghana

Seventy-five sorghum lines from the local breeding, ICRISAT, and other NARS in West Africa were planted for evaluation for multiple insect resistance (shootfly, head bugs, grain mold, and midge) at Manga. Poor germination and lateness due to photoperiod sensitivity rendered the results unreliable. The study will hopefully be repeated with earlier lines.

Table 7. INTSORMIL ARS 206 Multilocation West Africa Pearl Millet Trial, Ghana, 2003.

Entry	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Panicle diameter (cm)	Downy mildew incidence (%)[1]	Yield (kg/ha^{-1})
Sadore local	64.0	259.0	49.7	1.9	7.3	355
Kapielga (Burkina local)	94.7	251.3	23.0	1.6	40.3	133
Toronio (Mali local)	75.3	289.7	33.0	2.1	22.0	178
Zatib	49.7	202.7	52.3	2.2	0.0	645
Zongo	55.3	260.7	70.7	2.1	0.0	556
HKP (GMS)	50.0	242.7	56.3	2.1	2.7	911
CIVT	50.0	229.0	55.3	2.0	0.0	1156
Sosat C-88	52.0	201.3	22.0	2.8	3.0	1022
Taram	50.3	232.3	70.3	2.2	1.3	600
SoSant	52.0	201.7	26.3	3.0	0.0	600
ICMV IS 89305	53.3	236.0	50.0	2.0	0.0	644
ICMV IS 90311	53.7	207.0	41.3	1.8	0.0	555
Synthetic 1-2000	81.0	236.3	30.0	2.3	8.3	222
NKO x TC1	84.0	233.0	30.7	1.3	13.3	178
Guefoue 16	87.3	206.0	25.7	1.6	5.3	156
Indiana 05	86.7	225.7	32.7	2.2	1.3	142
NKK	79.3	268.0	38.0	2.2	18.0	178
Bongo short head	43.7	164.7	10.7	3.3	32.0	1205
Manga nara	40.7	163.3	17.7	2.7	33.3	1200
Arrow	44.3	200.0	28.3	1.9	13.0	1089
Tongo Yellow	42.3	173.7	31.3	2.7	31.7	1044
PT732B	52.0	103.3	23.0	1.9	51.0	467
P1449-2	53.7	191.0	30.0	1.8	11.3	600
3/4 Ex Bornu	48.0	119.3	40.7	1.6	0.0	533
3/4 HK	56.7	144.7	49.3	2.0	5.3	400
3/4 Souna	53.0	142.0	38.7	1.8	1.7	200
Gwagwa	57.7	238.3	24.3	2.3	0.0	600
LCIC 9702	43.3	148.3	23.7	2.5	30.0	667
DMR 15	56.0	170.7	20.7	2.5	1.3	204
DMR 68	54.3	193.3	27.7	2.2	12.0	356
DMR 72	51.7	212.0	33.0	2.2	2.7	400
GB 8735	39.0	144.0	20.3	2.4	38.3	1245
99-72	50.0	118.3	23.7	2.5	4.0	111
TG102	37.7	90.3	23.7	1.9	66.3	711
T99B	44.7	61.7	39.3	1.5	96.3	222
T454	44.3	53.7	18.3	1.5	91.3	356
IBMV8401Mx68A-4R4w	42.3	117.0	25.0	2.1	29.7	1111
01Miso NCD2-NE	45.7	105.3	35.7	1.7	16.3	822
68A x 086R	37.3	109.7	19.3	1.8	55.0	1045
99M59043Mw x 68A4R4	37.7	96.7	21.0	2.1	75.0	1156
LSD	3.6	32.9	14.0	0.3	11.6	575

[1]Percentage of plants infected by downy mildew at 70 (soft dough stage) days after planting.

In a study on the effect of planting date and host plant resistance on sorghum IPM, three varieties, Malisor 84-7 (head bug resistant), Kobori (local guinea) and Kapaala (ICSV 111-N) were planted on three dates, early-June, late-June, and mid-July. Head bug (*Eurystylus oldi*) populations increased on all three varieties with delayed planting with Malisor 84-7 showing the lowest infestations in the early planting. Grain yield of all three declined with later plantings, with the local being affected the least. Yield reductions in the mid-July planting ranged from 43% to 72%.

Mali

Several entomology trials were conducted in Mali in 2003. Three preliminary head bug (*Eurystylus*) screening nurseries of primarily IER new breeding lines were conducted at Sotuba in 2003. They were evaluated using natural infestation and cages and pollinating bags to cover panicles at their emergence. At the hard dough stage head bug counts were made. At maturity, visual head bug damage ratings and grain mold ratings were made on the grain. The head bug rating scale ranged from 1, where all grain was well developed with only a few feeding punctures visible to 9 where most grain were brown and/or withered and barely visible through the glumes due to feeding damage. The grain mold rating scale was from 1 to 5. Also, in the laboratory, grain was evaluated for hardness, grain weight, and germination. In Nursery No. 8, 113 lines were evaluated for their third year, and forty-six were resistant to both head bugs and grain mold. In Nursery No. 9 with 109 entries (second year), there were 28 with head bug ratings of 1.0. In nursery No. 10 (first year of evaluation), 17 out of 77 were resistant to head bug damage.

Table 8. Damage assessment of sorghum midge, head bug, grain mold, and seed weight of S34 treated with local plant extracts and Dursban, 2003, Mali.

Treatments	Mean midge damage rating	Mean head bug damage rating	Mean grain mold rating	Mean grain weight of central row panicles(g)
T1: unsprayed check	3.63 a	5.06 a	2.66 ab	633.3 bc
T2: neem seed jelly 80 g/liter	3.20 ab	5.40 a	2.86 a	733.3 bc
T3: neem seed jelly 160 g/liter	2.26 bc	5.00 a	2.60 b	766.6 bc
T4: *C. procera* leaves juice 25 kg/301	2.63 abc	5.33 a	2.70 ab	500.0 c
T5: dursban	1.83 cd	3.30 b	2.53 b	966.6 ab
T6: protected panicle	1.00 d	1.00 b	1.00 c	1200 a
C.V. (%)	36.73	14.96	6.77	22.72
Probability	0.048	0.00	0.00	0.005
Significance	S	HS	HS	HS

Means followed by the same letter for damage score or weight within the column are not significantly different at 5% (Duncan range test).

Of two Advanced Trials, one was lost due to flooding. In the other, five breeding lines were evaluated for head bug resistance under artificial screening, with 20 pairs of bugs per caged panicle. The five advanced breeding lines, 99-CA-F5P-136-2, 99-CZ-F5P-131-2, 99-CZ-F5P-97-2, 99-SB-F5DT-170-1, and 99-SB-F5DT-49-2 all showed excellent head bug resistance, equal to Malisor 87-7, based on number of bugs and larvae per panicle, weight of 200 seed, and grain mold and head bug damage ratings. All entries had head bug and grain mold ratings of essentially 1.0, indicating no damage. In all cases, the infested panicles gave similar results to the cage and pollinating bag-protected panicles.

The effectiveness of local plant extracts (neem seed jelly and *Calotropis procera* leaf juice) and Dursban on midge and head bug damage was studied on a head bug susceptible cultivar (S34) under natural infestations. Bug counts were made a week after treatment. At maturity, head bug and midge damage and grain mold ratings were made along with grain weights. There were significant differences among treatments for traits with data presented in Table 8. Protected panicles showed no damage or insect pests and the best grain yield, and in most cases Dursban was not significantly different from protected. Meanwhile, the untreated check had high ratings and was statistically different in most cases from the low neem jelly or the *C. procera* juice treatments. The high rate of neem jelly was consistently superior to the low dose in insect damage and grain mold ratings. Overall, Dursban gave better insect and grain mold control than the local plant extracts.

In another study, the effect of various crop residue management treatments involving sorghum, millet, and maize on control of stem borers was investigated. Treatments were sole sorghum, sorghum + maize, and sorghum + millet, each with two residue management treatments; (1) Residues removed after harvest and (2) Residues left in field and chopped and buried at planting date. Leaves and stems of subsequent crops were checked for stem borers from the seedling stage to maturity. High numbers of borers were found in the sorghum + millet regardless of the residue management scheme used, but with '2' above the highest. *Coniesta ignifusalis* was the dominant species. Millet was more susceptible to *Coniesta* than either sorghum or maize. Removal of residue after harvest reduced stem borer population in all treatments.

In on-farm trials in the Segou region, four seed treatments were evaluated in three farmer fields in each of three villages (Cinzana, Boussin, Banankoro) on mono-crop millet and on intercropped millet/cowpea. The four treatments were: (1) untreated seed (check) on mono millet; (2) mono millet with seed treated with Apron Star, (3) millet/cowpea - seed treated with neem extract, and (4) millet/cowpea-seed treated with insecticide Dursban. Data was taken on downy mildew, *Striga,* millet head miner, and millet stem borer incidence and grain yield (Table 9). For downy mildew, all three treatments equally reduced (about 50%) downy mildew incidence significantly over the untreated check at Cinzana and Banankoro. *Striga* infestation varied among locations, but with no significant differences among treatments at all locations. For the millet head miner, differences occurred only at Bonankoro where both the mono-crop treatments had a much higher incidence over the intercropping millet/cowpea treatments, with 37.5%, 22.5%, and 7.5%, and 5% for treatments 1 though 4, respectively. For the millet stem borer, treatments were significantly different only at Banankoro, with intercrop + Dursban with the lowest incidence followed by mono millet + Apron. Grain yield showed differences at all locations with mono millet giving the highest yield, however, cowpea grain in addition to millet in intercropping compensates for the reduced millet yields.

Food Technology

Mali

Grain from improved breeding lines from the sorghum breeding IER program Medium Maturity GIII and Early Matu-

Table 9. Data on IPM strategies to reduce pest damage on pearl millet at three villages, Mali, 2003.

	D. Mildew incidence %	*Striga* number	MHM incidence %	MSB incidence %	Millet yield kg/ha^{-1}	Cowpea yield kg/ha^{-1}
Cinzana						
T1	24.3	3.7	2.7	8.7	1533ab	0
T2	10.7	2	2	5.7	1739a	0
T3	10.0	2.7	1.7	6.7	1241b	458
T4	11.3	1.0	2	4.7	1303b	499
Significance	*	NS	NS	NS	*	**
Banankoro						
T1	9.5	6	37.5	11	1442ab	0
T2	4.5	5	22.5	6	1657a	0
T3	5.0	5	7.5	7.5	594c	92
T4	4.5	5	5.0	3.5	842c	68
Significance	*	NS	**	*	*	*
Boussin						
T1	6.7	11	10	5	750ab	0
T2	4.7	11.3	10	8.3	818a	0
T3	2.3	10.7	8.3	6.7	484c	375
T4	2.0	10.7	10	6.7	411c	344
Significance	NS	NS	NS	NS	**	**

MHM = Millet Head Miner: MSB = Millet Stem Borer

rity GIII were evaluated for physical-chemical properties and food traits. Several entries in each trial had similar decortication yield, flotation, and vitrosity to the local Guinea checks. All the lines evaluated showed good tô consistency and acceptable tô color. Data on selected entries with the best grain quality traits from both trials are presented in Table 10.

In diversification of sorghum end-use activities, 15 women each from three villages (Kafara, Dafara, and Marako) were trained on processing techniques of diverse sorghum based products including producing quality flour. Products processed included biscuits, cakes, dégué, and drinks. Techniques of preservation and safety issues were also addressed.

Agronomy

Mali - Sorghum

A rotation/previous crop experiment was planned for four years and included in rotation three legumes, three cereals, and six fertility treatments. The proposed scheme is presented below:

Year 1	Year 2	Year 3	Year 4
Cowpea (C)	Sorghum	C	S
Peanut (P)	Sorghum	P	S
Dolichos (D)	Sorghum	D	S
Maize (M)	Sorghum	M	S
Millet (Mlt)	Sorghum	Mlt	S
Sorghum (S)	Sorghum	S	S

Fertilizer inputs included a check treatment (F1) with no fertilizer, a natural rock phosphate treatment with 200 kg ha^{-1} (F2), alternating with variable rates of N (0, 20, 40, and 60 kg ha^{-1} for F2, F3, F4, and F5 respectively) and manure at 1000 kg ha^{-1} every other year F6. Rock phosphate was applied years one and three to previous crops, while N fertilizer and manure were applied years two and four on sorghum. Three genotypes were used at each fertilizer level: CSM 388, Zarra, and N'Tenimissa (V1, V2, V3). A split-split-plot was used as experimental design, with previous crops (PC) as main plots, fertilizer (K) levels as sub-plots, and varieties (V) as sub-sub-plots. Data were collected during the 2003 rainy season.

In evaluation previous crop effects, none of the interactions observed (PC*F PC*V FC*V PC*F*V) were significant for grain, stover, or biomass yields. The previous crops effect upon sorghum was significant for stover only with dolichos, cowpea, with cowpea the best previous crop. Fertilizer effect and varieties effects were highly significant for grain, stover, and biomass. In evaluation of the main effect only of previous crops, legumes were better previous crops than cereals in this study. Peanut was the best, followed by dolichos and then cowpea with respectively 625, 519, and 450 kg/ha^{-1} of grain sorghum.

Rock phosphate applied biannually at 200 kg/ha^{-1} significantly affected sorghum grain, stover and biomass yields, with respectively 21, 27 and 23% of increase compared to the check treatment (Table 11). Manure applied biannually at 1000 kg/ha^{-1} in combination with rock phosphate did not influence sorghum grain, stover, and biomass yields. Increasing N rate from 0 to 60 hg/ha did improve grain, stover, and biomass yields,

Table 10. Physical-chemical characteristics of grain from selected lines from the Advanced Medium Maturity GIII Trial and Advanced Early Maturity GIII Trial, Mali, 2003.

Variety designation	Decortication yield (%)	1000 Grain weight (g)	Vitrosity [1/] rating	Flotation %	Tô [2/] stability rating	Tô [2/] color rating
Medium Maturity GIII						
00-SB-F5DT-123	77.7	21.0	1.0	2.7	1	1
00-SB-F5DT-133	78.7	20.7	1.0	2.0	1	1
00-SB-F5DT-356	76.0	19.0	1.7	2.0	1	1
00-SB-F5DT-366	81.0	18.0	1.3	0.0	1	1
00-SB-F5DT-427	79.3	16.0	1.7	2.0	1	1
00-SB-F5DT-382	76.3	19.7	1.0	1.3	1	1
00-SB-F5DT-386	78.7	19.3	1.0	4.0	1	1
CSM 388 (check)	85.0	20.3	1.0	2.7	1	1
Local check	81.0	23.0	1.0	2.0	1	1
Early Maturity GIII						
00-BE-F5P-1	71.0	18.7	1.3	8.7	1.5	1
00-BE-F5P-25	72.7	17.0	2.0	6.0	1	1
00-BE-F5P-29	75.3	21.0	2.0	4.7	1.5	1
00-BE-F5P-38	72.0	21.0	2.0	12.0	1	1
00-CZ-F5P-61-2DT	72.7	15.0	2.0	14.7	1	1
00-BE-F5P-93	77.0	20.0	2.0	8.7	2	1
00-BE-F5P-245-2	76.0	20.0	2.0	23.3	1	1
Malisor 92-1	71.0	29.7	2.0	18.0	1	1
CSM-63	87.0	23.0	1.7	3.3	1	1
Local check	70.0	23.0	2.0	8.0	1	1

[1/]Rating 1 = hardest to 3 = soft
[2/]Rating 1 = best to 3 = poor

Table 11. Fertilizer effects on sorghum yield components at Sotuba, Mali, 2003.

Fertilizer treatments		Grain yield (kg/ha^{-1})		Stover yield (kg/ha^{-1})		Total biomass (kg/ha^{-1})	
F1	No fertilizer	967	c	3836	d	5255	d
F2	200 kg/ha of PNT	1172	b	4876	c	6477	c
F3	200 kg/ha of PNT + 20 N	1284	b	5682	bc	7517	bc
F4	200 kg/ha of PNT + 40 N	1484	a	6417	ab	8451	a
F5	200 kg/ha of PNT + 60 N	1521	a	6781	a	8850	ab
F6	F2 + 1000 kg/ha manure	1187	b	5179	c	6887	c
Mean		70		5466		7245	
Significance		**		**		**	

PNT stands for tricalcic rock phosphate.
Split-split-plot in RCBD with PC as main plot, fertilizer as sub-plot and varieties as sub-sub-plots.
Means with the same letters are not different at P = 5%.

with yield increase following a significant linear curve. The significant effect of rock phosphate on grain, stover, and biomass yields indicates a serious lack of available P in the soil, over all crops systems involved in this study.

Yield differences observed between CSM 388 (a local variety) (1542 kg/ha^{-1}), Zarra (new tan plant guinea (1184 kg ha^{-1}), and 97-SB-F5DT-154 (short, intermediate type) (1086 kg/ha^{-1}) were significant for grain, stover, and biomass. CSM 399 was higher than only F5-DT-SB-154 for the three parameters. Zarra was intermediate in all these parameters, but not significantly different from either CSM399 or -154. The lower level of yield in 97-SB-DT-F5-154 compared to CSM388 may be due to it needing a higher population to catch solar radiation.

Mali-Acid Soil-Sorghum

A field screening experiment in plot F9, an acid soil plot (millet soil) on Cinzana Station, was designed to identify tolerant or susceptible sorghum genotypes to acid soils. These genotypes will be used for subsequent experiments on understanding mechanisms of sorghum tolerance to acid soil conditions and developing technology packages needed for sustainable sorghum production in acid soils of West Africa.

Several (13) exotic sorghum genotypes, promising breeding lines, local cultivars, and improved varieties were tested for tolerance. Severe flooding of the experiment during August seemed to bias the performance of the genotypes. Only the local check and Malisor 92-1 were able to develop to physiological maturity 53 and 31%, respectively, of their germinated planting hills. All other entries had no healthy plants at maturity, whereas some had shown promise in previous years with about 50% of hills producing healthy plants. Improved local sorghum genotypes from the breeding program (Programme Sorgho of I.E.R.) failed to confirm their past performance under the waterlogged conditions of the 2003 rainy season.

Mali-Millet

Low soil fertility is one of the most important factors limiting millet yield in Sahelian countries. Millet grain yields were over 1200 kg/ha^{-1} except for the control treatment (Table 12). All the treatments produced more grain (P<05) and more straw (P<0.01) than the control. This indicates that the soil used had a low soil fertility level. The application of 50 kg/ha^{-1} complementary P alone resulted in greater millet grain production compared to the application of complementary N alone. The application of complementary P and N did no significantly increase pearl millet yield. This was probably due to the low clay content of the soil and the subsequent low CEC where excess nutrients were probably lost by lixiviation.

The efficacy of chemical fertilizers on crop production is obvious and doesn't need any more demonstration. However, the inadequacies between the price of chemical fertilizers and that of rain fed crops like millet and sorghum doesn't favor the application of recommended rates of mineral fertilizers (41-46-0) N-P-K on these crops. Considering the small amount of chemical fertilizer needed in micro-dose fertilization (about 30 kg/ha^{-1}) applied at the rate of two grams per hill at planting, it becomes important to evaluate the performance of this alternative way to improve millet production in the Sahelian zones of Mali. To evaluate the performance of micro-dose with and without complementary fertilizer application on millet grain and stover production, a trial was conducted on a leached sandy soil at the Cinzana Agricultural Research Station. The two grams of DAP (Di-Ammonium Phosphate) fertilizer were applied at planting per hill. Complementary N and P were applied after plant emergence. The 2003 rainy season was characterized by a relatively good rainfall quantities and distribution.

Plant height did not differ among treatments that received mineral fertilizer, but were taller than the ones that did not receive fertilizer application. The application of micro-dose alone was sufficient to significantly increase pearl millet height compared to the control. This indicates that on sandy soils were pearl millet is mostly grown, small amounts of fertilizer as little as two grams per hill are sufficient to significantly increase crop productivity in the Sahel. Plant population at harvest did not significantly differ among treatments. However, there was strong tendency for treatments that received mineral fertilizer application to produce more tillers than the control. The number of panicles produced was significantly lower for the control and the micro-dose than the other treatments that received mineral fertilizer application. This is largely due to the differences in effective tiller production.

In low fertility sandy soils of Mali, adding a small amount (micro-dose) of chemical fertilizers on millet at planting increased millet yield. Adding complementary P and N to micro-dose sometimes, but not always, gave higher yield compared to micro-dose alone.

Ghana-Sorghum

In a study at the Wa Station, the effectiveness of phosphorus application rates and timing (current on succeeding crop) on a sorghum/cowpea rotation was studied. Most data was reported in the 2003 INTSORMIL Annual Report in Table 14. The application of P direct to the sorghum crop was significantly better than applying P only to the cowpea, and as good as applying to both crops. Sorghum grain yields showed an increase, but not statistically significant, beyond the 30 kg P/ha level. Cowpea yields and components were not significantly affected by application methods or amounts of P fertilizer, but there was a trend toward lower yield when P was applied only to preceding sorghum. In this study, fertilizer P resulted in significant yield increases on a savanna soil very low in plant-available P. Cowpea response to frequency of P application was negligible; therefore, P application (not more than 60 kg P/ha) to sorghum in a two-yr sorghum-cowpea rotation on such a soil seems to be adequate. Moreover, net returns for sorghum were greater than those for cowpea. The succeeding cowpea could benefit from the residual fertilizer.

In another agronomy trial at Wa the previous crop (sorghum, groundnut, cowpea, soybean) effects on sorghum response to four N rates (0, 40, 80, 120) was studied. Again, some data were presented in the previous annual report. The previous crop had no significant effect on grain yield or other yield components, except for stover yield which was lowest in sorghum after sorghum (Table 13). However, sorghum following groundnut tended to have the highest yields. Previous crop and rates of N did not interact significantly. Averaging over previous crops, grain and stover production were significantly increased by N application of 40 kg/ha^{-1} of N with no further increase at higher N rates. With no added fertilizer, sorghum following legumes produced greater yields than sorghum following itself.

Another trial at Wa studied the effects of plant density (50, 75, 100, and 125% of recommended density of 66,600 plants/ha) and within row spacing in sole and intercrop (sole sorghum and cowpea and soybean intercrops) methods were studied on

Table 12. Effects of micro-doses of chemical fertilizers on the development and grain production of millet, Cinzana, Mali.

Treatments	Plant height (cm)	Plant population harvest/ha	Number panicles/ ha	Panicle weight kg/ha^{-1}	Grain weight kg/ha^{-1}	Straw weight kg/ha^{-1}
T1	255	40972	40833	1354	917	1736
T2	293	44444	40000	1924	1361	2639
T3	288	47361	43056	1847	1299	2639
T4	297	51806	46806	2278	1632	3368
T5	283	46944	46667	1951	1347	2500
T6	276	51528	45000	1757	1215	2778
T7	287	50972	43333	1972	1313	3056
T8	288	52778	49861	2000	1347	3263
Significance	HS	NS	S	S	S	HS
LSD	16.67	9313	422	422	338	9313
CV (%)	4.0	13.1	15	15	18	13

T1: Control (no fertilizer added)
T2: 2 grams of DAP
T3: 2 grams DAP + 20 kg/ha^{-1} of TSP
T4: 2 grams DAP+40 kg/ha^{-1} TSP
T5: 2 grams DAP + 30 kg/ha^{-1} Urea
T6: 2 grams DAP + 60 kg/ha^{-1} Urea
T7: 2 grams DAP + 20 kg/ha^{-1} of TSP + 30 kg/ha^{-1} Urea
T8: 2 grams DAP + 40 kg/ha^{-1} TSP + 60 kg/ha^{-1} Urea
NS: Non Significant at 5% level
HS: Significant at 1% level.
S: Significant at 5% level

Table 13. Sorghum grain yield and yield components as affected by previous crops and fertilizer N, Wa, Ghana, 2002.

Previous crop	Days to 50% flowering	Stover yield at maturity (kg/ha^{-1})	100-seed weight (g)	Kernels m^{-2}	Grain yield (kg/ha^{-1})
Cowpea	68	3033	2.08	8147	1954
Groundnut	68	3192	2.14	8710	2151
Soybean	68	3313	2.06	7131	1721
Sorghum	70	2563	2.19	6515	1627
LSD (0.05)	NS	391	NS	NS	NS
N rate (kg/ha^{-1})					
0	71	2597	2.27	4673	1240
40	68	3058	2.03	7969	1883
80	68	3150	2.03	8874	2129
120	67	3297	2.13	8987	2200
N linear	**	**	NS	**	**
N quadratic	**	Ns	*	**	*
CV (%)	1.8	15.3	12.7	18.6	22.5

*, **, and NS = significant at 1 and 5% probability levels and not significant, respectively.

new sorghum varieties. Sole sorghum planted at one plant/hill produced greater grain yields even when the recommended plant population of 66,600 plants/ha was either reduced to 50,000 or increased to 80,000 plants/ha. With one plant/hill, sorghum planted at 80,000 plants/ha whether sole or intercropped with either legume crop as well as sole sorghum planted at the recommended density or 50,000 plants/ha produced similar yields. At the recommended density, intercropping sorghum with either legume reduced grain yields. Having 1 plant/hill produced greater grain yields than leaving two plants/hill, irrespective of the plant population density. Consequently, it may be better to sow three-four seeds of sorghum per hill and later thin to one seedling/hill in order to achieve the respective optimum plant population density. Grain yield was drastically reduced when planting was done at 33,300 plants/ha. When sorghum was intercropped with cowpea, lower grain yields were produced compared with sorghum planted sole or intercropped with soybean.

Another trial studied the effect of fertilizer (four levels of N (0, 40, 80, 120 kg/ha^{-1}), two levels each of P_20_5 (0 and 40 kg/ ha^{-1}) and K_2O (0 and 40 kg/ha^{-1}) on a new sorghum cultivar Kapaala. The sources of N, P, and K were Urea, triple super phosphate (TSP), and muriate of potash (KCI). For one season only, there were no significant interactions among the rates of N, P, and K. Potassium (K) had no significant effect on grain yield or components. N and P increased grain yield, and when averaged across P and K rates, yield related to N rates in a quadratic manner. Grain yield was not increased significantly beyond the 80 kg N/ha rate. The addition of 40 kg P_2O_5/ha increased grain yield by 16.5% over no P.

Economic Analysis - Ghana Agronomy

When sorghum is grown in rotation with cowpea, the optimal, considering both crops, is a P rate of 60 kg/ha^{-1} to sorghum directly with cowpea benefiting from the residual. If P is applied annually to sorghum, the optimum level is 30 kg P/ha. Direct application of P to cowpea at any level is not cost effective considering only cowpea.

Partial budget analysis on the effect of proceeding crop on response of sorghum to N application shows that maximum net benefits are obtained with 40 kg N/ha when cowpea or soybean precedes sorghum. With groundnut preceding, maximum benefits are with 80 kg N/ha. When sorghum follows sorghum, 120 kg N/ha is the best.

In analysis of the effect of residue removal, net returns decline with increasing rate of residue removal. Maximum net benefit was obtained with no residue removal plus fertilizer applications.

Economics/Marketing

The acceptance of white-seeded, tan-plant improved Guinea type sorghum cultivars, developed in the IER/ INTSORMIL collaborative breeding program in Mali, by both farmers and in the marketplace has been excellent. The interest of farmers in three villages (Marako, Dafara, and Kafara) involved in the flawed 2002 contract with a local grain/market entrepreneur to produce identity preserved grain of N'Tenimissa was very encouraging following visits there in October, 2003. All farmers visited were interested in another such venture, providing it was not with the grain trader that defaulted on the 2002 contact production. This agreed with comments made by Ouendeba Botorou who visited all the five areas of Mali where the 2002 contracts were made.

To emphasize this observation, the following statement is a quote from the project TAM 226 2004 annual report of Dr. L.W. Rooney: "New more efficient higher yielding white tan varieties are near release from the IER breeding program in Mali. The photosensitive types escape significant weathering/ molding that adversely affects earlier insensitive white tan sorghums and led to their failure. These photosensitive value-enhanced sorghums provide improved grain quality for identity-preserved (IP) marketing of sorghums. The grain produced excellent food products because it was not discolored by insects and molds. Farmers were very excited with these white tan plant sorghum varieties because they liked the agronomics and grain yields. They were pleased with the grain quality for their own food consumption and appreciated the opportunity to sell the grain at a potential premium. This was especially significant in view of the fact that some of them had a bad experience the previous year with a grain trader who defaulted on a promised premium price. The principle of supply chain management from seed to food products had been demonstrated; however, a great deal of work to obtain wide-spread participation is required".

Even though the grain trader defaulted on the 2002 contract, the farmers were able to sell the grain at a premium of 15-20 CFA/kg, while some sold in bulk quantities at the market price to other grain traders for resale in Bamako. An emerging organization among farmers in the three villages is a very promising and necessary step in establishing a functioning supply chain management from seed to food.

The other encouraging aspect was that these three villages were very involved in growing on-farm trials and larger scale demonstrations of new sorghum breeding cultivars from IER and liked the new cultivars for their own food use.

Institution Building

The collaborative host country programs in Mali, Senegal, and Ghana were each supplied a computer along with 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 will be Regional sub-coordinator effective July 2004.

Dr. Ndiaga Cisse (Purdue) - Currently Sorghum Breeder, ISRA, and Co-Country INTSORMIL Coordinator, Senegal.

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

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

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

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

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

Dr. Samuel Saaka Buah (M.S. - Nebraska) - Currently agronomist and Co-Country INTSORMIL Coordinator, SARI, Ghana.

Dr. Sidi Bekaye Coulibaly (Nebraska and Texas Tech/Texas A&M) - Previously sorghum physiology/agronomy and sorghum breeding and INTSORMIL Coordinator. Currently Sorghum Breeder, Cinzana, IER, Mali.

Students currently in training include Niaba Témé (Mali) who successfully completed his B.S. and M.S. at Texas Tech University and is currently a Ph.D. student at Texas Tech University. Karim Troaré, former Mali millet and sorghum breeder with a M.S. from Nebraksa is now a Ph.D. student at Texas A&M University. Mr. Tiecoura Traore (Mali) has initiated a M.S. program in sorghum entomology at West Texas A&M University. Mr. Seriba Katile has initiated a Ph.D. program in pathology/biotechnology at Texas A&M University.

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

Dr. Aboubacar Touré, Malian sorghum breeder, is serving as acting Coordinator of the West and Central Africa Sorghum Research Network, WCASRN (ROCARS).

U.S. scientists traveling to the region in October 2003 included Dr. Bonnie Pendleton (Mali and Ghana), Dr. Bruce Hamaker (Senegal and Mali), Dr. Darrell Rosenow (Senegal and Mali), Dr. Lloyd Rooney (Mali), and Dr. Mitch Tuinstra (Mali). Other travel included Drs. L. Rooney and B. Hamaker (Senegal - January, 2004), Drs. John Sanders and Ouendeba Botorou (Mali - January, 2004), and Dr. Tom Crawford (Mali-October, 2003).

Mali and Senegal hosted the INTSORMIL External Evaluation Panel in October 2003 and also provided for EEP interaction with the above-mentioned scientists in Mali and Senegal. Drs. Ibrahim Atokple and Samuel Buah from Ghana traveled to Bamako, Mali to meet with the EEP in evaluating research activities in Ghana.

A major INTSORMIL West Africa Regional meeting was held in Ouagadougou, Burkina Faso, April 18-21, 2004 with host country scientists form Mali, Ghana, Senegal, Niger, Nigeria, and Burkina Faso, and collaborating U.S. INTSORMIL scientists. The purpose of the meeting was to discuss and formalize the proposed restructuring of the INTSORMIL collaborative programs in the six West African countries into one overall regional program and establish a working administrative structure to the program. The meeting also provided the forum to develop and strengthen collaborative ties and collaborative research between host country and U.S. scientists, among host-country researchers in the region, and among disciplines. U.S. scientists participating included: Drs. Darrell Rosenow, Bruce Hamaker, Bonnie Pendleton, Mitch Tuinstra, Steve Mason, Jeff Wilson, Joe Hancock, and Clint Magill, as well as Dr. John Yohe, INTSORMIL Program Director. Scientists from Mali participating included Drs. Aboubacar Touré, Bourema Dembele, Mamourou Diourte, Mamadou Doumbia, and Niamoye Diarisso, as well as Mrs. Fatim Cisse, Mr. Moutaga Kayentao, Mr. Abdoul W. Toure, and Mr. Moussa Sanogo. Senegalese scientists attending included Drs. Ndiaga Cisse, Demba Farba M'Baye, Ababacar N'doye, and Mr. Amadou Fotana. Attending scientists from Ghana included Drs. Ibrahim Atokple, Samuel Saaka Buah, Steven Nutsugah, and Paul Tanzubil.

Networking

A useful research and technology transfer mechanism was lost with the demise of the West African regional sorghum and millet networks, WCASRN (ROCARS) and ROCAFREMI. The direction and scientist losses in ICRISAT has reduced, but not eliminated, collaborative efforts with ICRISAT in both sorghum and millet. Technologies developed in Mali on sorghum are transferable to most countries in West Africa particularly in areas where head bugs, drought, and grain mold are common and grain quality is a high priority trait. Exchange of elite new breeding germplasm with useful traits is ongoing among scientists in the region. The improved white-seeded, tan-plant Guinea types (N'Tenimissa and its derivatives) developed in Mali hold potential in other Guinea-type sorghum growing areas of West Africa. The increased use of NGOs, farm organizations, and extension in on-farm trials, seed increase and distribution is a positive in the region. The new regional approach for the West African INTSORMIL programs should contribute to movement of technologies throughout the region, and foster increased collaboration among scientists from different countries.

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 Touré, and other key Malian IER scientists. Dr. Buah already had previously initiated a collaborative program in agronomy with Dr. Maranville. The discussions were all fruitful and positive with three initial areas of collaboration among Malian, Ghana, Senegal, and U.S. scientists agreed upon: 1) sorghum breeding with one aspect being 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. Touré 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 Dr. Gebisa Ejeta evaluated at several sites. The lines will be assembled in Mali and distributed by Dr. A. Touré. Also, Dr. Ejeta will evaluate 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 of 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 has continued his collaborative activities in Ghana based on previously developed work plans with Dr. Maranville.

In 2002, a new INTSORMIL initiative in Senegal began with the ITA (Institute de Technologic Alimentaire) to work on commercialization and supply chain management of grain in Senegal. An established system in Senegal involving an Austria NGO (EWA) on pearl millet is being looked at as a model for development in other countries of West Africa.

West Africa Regional Program

In 2003, the INTSORMIL Technical Committee and Board of Directors mandated that the West Africa-Western Region (Mali, Senegal, Ghana) and Eastern Region (Niger, Burkina Faso, and Nigeria) be merged into one overall regional program. This led to many discussions on the logistics of such a merging and a possible administrative structure of such as program. To discuss this merger with host country PIs and to provide a forum for strengthening collaboration between U.S. and host country scientists as well as among host country PIs, a large meeting was held in April in Ouagadougou, Burkina Faso with all the key scientists from the six West African countries and U.S. present. The meeting was productive an initial structure of one overall U.S. coordinator (Bruce Hamaker) and two sub-regional host country coordinators (Aboubacar Touré - Mali, Ghana, Senegal) (Issoufou Kapran - Niger, Burkina Faso, Nigeria) named. Essentially, currently funded scientists and projects would be maintained through the end of the grant period ending in June 2006. Two new multi-country and disciplinary thrusts (possibly resulting in future projects) were identified (and coordinators named) for project and proposal development to seek outside funding. The two areas were utilization and technology transfer. Another area, biotechnology, was identified as a third area for possible project development.

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

- Six new N'Tenimissa derivative tan-plant, guinea type improved breeding lines developed by IER, plus one intermediate caudatum-guinea line have been named and released in Mali thru 2003. They were distributed thru on-farm trials and demonstration or thru NGO's and are being well accepted by farmers. The guinea cultivars have superior grain quality and less stalk breakage than N'Tenimissa.
- From on-farm trials, the Guinea-type cultivar 97-SB-F5-DT-63 (N'Tenimissa*Tiemarfing) has been selected, seed saved, and grown by local farmers and has been released and named "Wassa" which mean 'satisfaction' in Bambara. Farmers like it over N'Tenimissa because of its whiter, higher quality grain.
- Two other new breeding lines, true Guinea cultivars (N'Tenimissa*Tiemarfing) were widely tested and given the names Zarra and Keninkedie, and will be increased for use in value-added products. All three of these new cultivars have superior grain quality and less stem breakage then N'Tenimissa.
- 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 Deli-Ken by the private company, GAM, in Bamako.
- A local entrepreneur in Mali successfully produced , in 2001, 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 (Sorgho Phar) in Bamako markets, with a demand so strong he was having trouble keeping the product on the shelf. In 2002, his contracted production for 200 tons was derailed due to financial and other problems in his company unrelated to the N'Tenimissa effort.
- 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 the 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 spring 2000 with seed increased and characterization completed. The remaining two-thirds was grown in a St. Croix quarantine grow out 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*) in a non-Guinea type sorghum, 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.
- Sorghum selfing bags work equally well with cages in head bug evaluations and are much more cost and labor efficient.
- Natural infestation appears superior to infested cages for head bug screening.

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

- Micro-dose fertilizer application increases the grain and stover yield of millet on sandy soils. Its effect on sorghum and on heavier soils is highly variable.
- 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 kg/ha^{-1} N.
- The joint INTSORMIL/Soil Management CRSP 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 unstainability and productivity of pearl millet cropping systems.
- New IER developed sorghum cultivars show moderate levels of acid soil tolerance.

Weed Science

- Wassa and some other improved breeding lines have been identified to have a high level of field *Striga* resistance.
- 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, and CMDT 39.
- Several new Guinea breeding line/cultivars such as Wassa show good *Striga* tolerance.

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 yields, 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 enterprise 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.
- Deli-ken, a cookie using 20% N'Tenimissa flour and 80% wheat flour has been developed by private enterprise 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

- The principle of supply chain management from seed to commercial food products has been demonstrated in Mali, utilizing new sorghum cultivars with improved grains/food quality traits.
- 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 11 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. A portion of the grain was also sold directly in local Bamako markets, and sold well at a premium price.
- 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.