Host Country Program Enhancement

INTSORMIL

Central America (El Salvador, Honduras, Nicaragua)

William Rooney
Texas A&M University

Regional Coordinators

Ing. Rene Clara-Valencia (Central America Regional Host Coordinator), Plant Breeder CENTA (retired), Apdo. Postal 885, San Salvador, El Salvador

Dr. William L. Rooney (Central America Regional Coordinator), 2474 TAMU, Dept. of Soil & Crop Sciences, Texas A&M University, College Station, Texas 77843-2474

Country Coordinators

Ing Rafael Obando Solis, Agronomist, CNIA/INTA, Apdo. 1247, Managua, Nicaragua (Nicaraguan Country Coordinator)

Ing. Hector Sierra, Agronomist, DICTA, Choluteca, Honduras (Honduras Country Coordinator)

Collaborating Scientists

Ing. Humberto Salvador Zeledón, Plant Breeding/Agronomy, CENTA, San Andres, El Salvador
Dr. Máximo Antonio Hernández, Entomologist, CENTA, San Andres, El Salvador
Mario Ernesto Parada Jaco, Entomologist, CENTA, San Andres, El Salvador
Ing. Vilma Calderón, Food Scientist, CENTA, San Andres, El Salvador
Ing. Reina Flor de Serrano, Plant Pathologist, CENTA, San Andres, El Salvador
Alfredo Alarcón, Agronomy, CENTA, San Andres, El Salvador
Edgard Ascencio, Agronomy, CENTA, San Andres, El Salvador
Margarita Alvarado, Food Scientist, CENTA, San Andres, El Salvador
Rodolfo Valdivia, Agronomist, INTA/CNIA, Managua, Nicaragua
Pascual López, Agronomist, INTA/CNIA, Managua, Nicaragua
Ing. Nury Gutiérrez, Plant Breeding/Agronomy, INTA/CNIA, Managua, Nicaragua
Ms. Eliette Palacio, Food Scientist, INTA/CNIA, Managua, Nicaragua
Dr. Lloyd W. Rooney, Dept. of Soil & Crop Sciences, Texas A&M University, College Station, Texas 77843-2474
Dr. Joe D. Hancock, Dept. of Agronomy, Kansas State University, Manhattan, Kansas 66506

Collaborative Program (Regional Program Description)

The regional programs of the INTSORMIL program are designed to support national research program efforts to develop dynamic, competent institutional research programs which contribute to productivity, economic growth, natural resource conservation and improved nutrition of people in the region. By accessing available expertise and infrastructure in the region, support from INTSORMIL is designed to facilitate and promote interaction between national programs, NGOs, international research centers, private sector and scientists from the U.S. land grant universities to achieve the goals of improving producitivity, profitability, economic growth and food security for producers and consumers as well. Historically, the Central American Regional Program has been a robust and active program. Given the new INTSORMIL program, the Central American program is in the process of reorganization including but not limited to development of new program priorities and project development.

Institutions

Active INTSORMIL collaboration in Central America is occurring primarily among the following institutions: Centro Nacional de Technologla de Agropecuaria y Forestal (CENTA), El Salvador; Instituto Nicaraguense de Tecnologia Agropecuaria (INTA), Nicaragua; Universidad Nacional Agraria (UNA), Managua, Nicaragua; Kansas State University, and Texas A&M University. In addition, INTSORMIL has a current MOU with the Universidad Nacional Autónoma de Nicaragua (UNAN), Leon, Nicaragua, and maintains ties with the Escuela Agricola Panamericana (EAP), Honduras based upon past collaboration. INTSORMIL maintains a Memorandum of Understanding with the Dirección de Ciencia y TecnologIa Agropecuaria (DICTA) in Honduras, and program activities continue on a limited basis. Historically, INTSORMIL has developed linkages with the regional seed companies Cristiani Burkart and Productores de Semillas (PROSEMILLAS), allowing activities in Guatemala, primarily for testing of hybrids/varieties and coordinating support of the sorghum industry in Central America. Given consolidation in the seed industries, these collaborations are, as always, subject to change.

Organization and Management

Since 1999, INTSORMIL program emphasis in Central America has been based in El Salvador and Nicaragua. Scientists from collaborating institutions in El Salvador and Nicaragua have met to discuss and develop country-based research plans for the next year with projects proposed in plant breeding, utilization, plant protection (entomology and plant pathology) and agronomy, and grain quality/utilization.

Financial Inputs

Primary financial support for the program is from the INTSORMIL Central America Regional Program budget, which totaled $40,000 in 2007-2008 which is a significant reduction in budget compared earlier years (which averaged ~$120,000). This drop has obviously had an effect on the scope and depth of the Central American program. These funds were allocated to individual projects within both the Nicaraguan and El Salvadoran research programs. In addition, these funds are used for short-term training, equipment purchases and administrative travel.

Discuss how jointly developed collaborative research plans of work are planned and organized.

Sorghum/Millet Constraints Researched

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 Clara Valencia continues to coordinate the regional grain sorghum yield trials conducted by the PCCMCA. In addition, 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 2004. Until 2007, regional scientists have collaboration with the CIRAD-CIAT project on participatory plant breeding for sorghum (and upland rice) (this program was discontinued in 2007).

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 totalled 225,000 ha^{-1}, the average grain yield was 1.5 Mg ha^{-1} (FAO, 2004). More recently, statistics in El Salvador document an average yield of > 2.0 Mg ha^{-1} and given that production area has remained static, the overall sorghum production has increased due to the increased yield. While some of this increase may be due to favorable weather, other reasons include the adoption of 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 photopenod 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), with recent studies documenting improved N use efficiency and N fertilizer response of cultivars spurring interest in increased use of fertilizer. (Figure 1)

The rapid increase in the cost and availability of wheat for bread recently emphasized the critical need to develop 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. Given current wheat prices, the lack of milling equipment (and the knowledge to use it) for production of grain sorghum flour limits adoption of the use of grain sorghum flour for baked products. Right now, there is a significant economic opportunity reason to utilize sorghum flour in bread products. A critical component of the INTSORMIL program involves the use of that technology to capitalize on this opportunity. Finally, the growth of the animal feeding industry provides a real opportunity for the development and use of sorghum as both a forage and dual purpose crop.

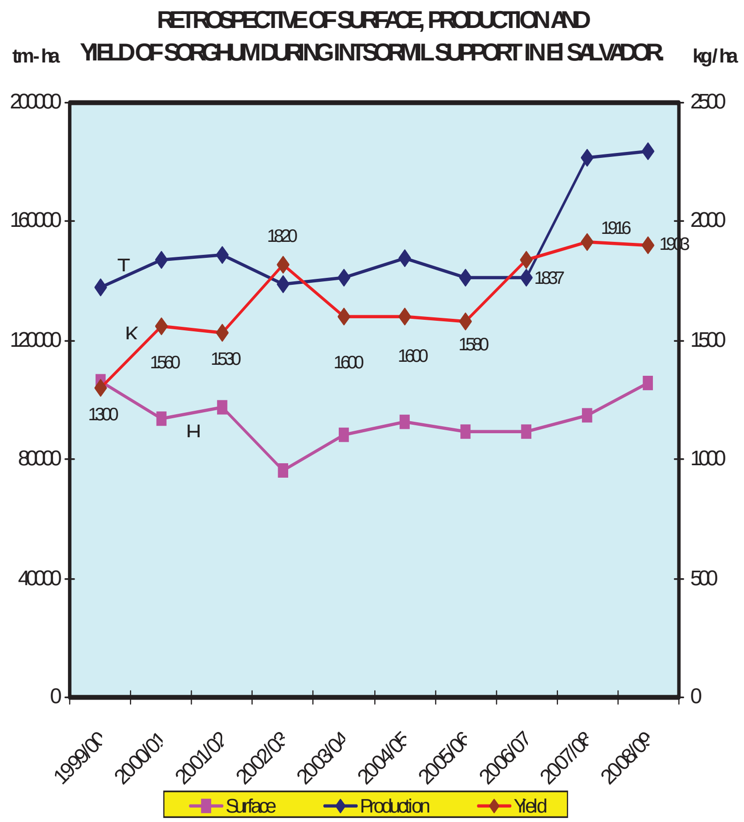
Research Projects and Results

Given the limited funding available for research in the region, scientists in each country were asked to submit proposal that focused on important aspects of the INTSORMIL mission specific to Central America. The areas of emphasis were plant breeding, agronomy, plant pathology, entomology, economics, quality and extension. Within each country proposals were evaluated and funding provided on a merit basis. Projects were implemented in the fall of 2007 and completed by the summer of 2008.

Plant Breeding

Most of the sorghum improvement program is localized in the CENTA program in El Salvador. At this location, selection, evaluation and the production of hybrid sorghum seed have been emphasized. Segregating populations of both Macio Criollos breeding material and photoperiod insensitive sorghum (both forage and grain types) have been grown in San Andres, El Salvador

Figure 1.



and selections were made at this site. Of special emphasis is the development of dual purpose sorghums with high forage yield and grain yield. In these populations, both the bmr and tannin trait are segregating; while all combinations are being selected, the types that are both brown midrib (bmr) and possess tannins are or primary interest. The target market for this material is the forage industry and they desired brown midrib for increased forage quality; the presence of tannins in the grain minimized the loss of grain to birds. All of these selections will be advanced for further evaluation next year.

In hybrid testing, the PCCMCA was coordinated by Rene Clara. A total of 12 locations were planted and grown throughout Central America. In El Salvador and Nicaragua, INTSORMIL collaborators conducted these PCCMCA trials. In 2007, the trial had 17 entries with approximately ½ of these entries coming from private industry and the remainder from INTSORMIL supported breeding activities. In these trials, the hybrid ESHG3 produced the highest yields in both 2005 and 2006. It was designated for commercial seed production studies that have been completed in the recent year.

Seed Production optimization for ESHG3 was evaluated in both El Salvador and Nicaragua. To determine optimum seed production the trial were designed as randomized blocks in a 3x2 factorial; the female:male ratios evaluated were: 3:1 and 4:1 (ICSA613 female: male 86EO361), and three planting dates 0x0 (simultaneous planting), 5x0 (female planted 5 days after the male), and 0x5 (male planted 5 days after the female). In both Nicaragua and El Salvador, differences in planting date did not affect seed yield, indicating that these parents have a good nick. Significant differences were detected for the ratio of female to male row numbers. Higher seed yields were produced in the R = 3:1 ratio (Table 1).

Agronomy

Testing of Line of PS Sorghum 99ZAM 911-3 Y 99ZAM 686-2 in association with maize in El Salvador

Evaluation of two improved Macio-type photoperiod sensitive sorghums (varieties 99ZAM686-2 and 99ZAM911-3) was conducted in on farm trials. Production practices were typical maize/sorghum production (sorghum is planted 25 days after maize). Producers were selected from cooperating producers in different regions of the country where sorghum is grown (Chalatenango, San Miguel, Sonsonete, Ahuachapan). The area for each experimental variety was 500 m2, and each trial included the two experimental and a local check. The experiment was replicated across locations.

The results from 20 locations indicated that 99ZAM911-3 and 99ZAM686-2 yielded nearly the same and both exceeded the local check by an average of 12%. When considered in net revenue (from grain), the use of the improved Macios would net the producers 13% more than the traditional Macio. If the sales of seed are included, the increase of net revenue could be as high as 76%. The maize/sorghum system using these improved varieties even exceeds efficiency of land use on pure cultures of either maize or sorghum. The return on investment was calculated with the sales prices of grain in January, when prices are low and similar for

Table 1. Datos obtenidos en el ensayo de producción de semilla del sorgo híbrido para grano, ESHG-3. Santa Cruz Porrillo, El Salvador 2007.

Planting Ratio (Relaciones de siembra)	Planting Time	Height Cms.	Days to Flowering	Seed Set %	Seed Yield kg/ha^{-1}
3:1	5x0	125	61	27	1025.7
	0x0	132	63	42.5	1571.2
	0x5	131	64	32	1038.8
4:1	5x0	128	57	24	691.32
	0x0	131	57	34	898.72
	0x5	133	57	24	640.88
Mean		128.7	59.71	30.18	968.78
Source					
Planting Ratio		*	ns	ns	**
Planting Date		*	ns	ns	ns
Ratio x Date		ns	ns	ns	ns
C.V. (%)		1.81	6.61	29.62	21.01

both sorghum and maize. If these were sold in months with higher prices, there would be a greater return.

Producers were surveyed regarding the varieties while on a tour of tests. A total of 50 surveys were returned. Producers responded that the height of the new varieties was acceptable (they were slightly lower, and this would facilitate harvest). From a forage perspective, producers preferred ZAM 911-3 to ZAM 686-2 as it had more leaf area early. The grain panicle of ZAM 911-3 was preferred over local checks and ZAM 686-2 as it was easier to thresh. Finally, the most important trait was grain color and flour color. Most all producers preferred ZAM 911-3 because of the white color of the grain and the white flour that the grain produces. From most all perspectives, ZAM 911-3 was the preferred variety from this test.

Testing of the Photoperiod Sensitive Sorghum 99ZAM676-1 in monoculture and in association with Maize

This test was designed to measure the performance of the photoperiod sensitive sorghum 99ZAM 676-1 in monoculture and maize/sorghum association in on farm trial. Cooperators were selected by extension agencies in areas where sorghum is grown (Chalatenango, Cabañas, San Miguel, Sonsonete, Ahuachapan, la Union). Experimental plots were 1000m2 , divided into 500m2 for 99ZAM 676-1 and 500 m2 with the local Creole variety. Seed of the improved variety was provided to the producer. Agronomic management was that typical for the producer. Grain and biomass yields were measured at typical harvest time by random sub-sampling of three spots in the larger plot.

The results obtained indicated that 99ZAM 676-1, exceeded the performance of local varieties for grain by an average of 877 kg/ha and biomass yield by an average of 1787 kg/ha. In addition, ZAM 676-1 was slightly shorter and easier to harvest than some local varieties. Economic analysis indicates that 99ZAM 676-1 has the best return and also the most cost-effective because for every dollar invested, it generates .67 cents greater return than the local variety. This would increase if the grain is sold later in the season when prices are high.

Difusión de variedades mejoradas de millón para el sistema asocio con maíz, en las zonas secas de Las Segovias, Matagalpa y Chinandega.

In Nicaragua, approximately 25,000 hectares of photoperiod sensitive sorghum are planted annually. These varieties typically have white grain and endosperm, they are tall and have an average yield of 1,500 kg/ha. Most of this crop is planted in association with maize and on small hillside farms. The sorghum is planted as security for rural families to feed themselves in areas where the yield of maize and beans are reduced by drought. To encourage production of improved Macios, three blocks of photoperiod sensitive sorghums (varieties EIME 119, ES 790 and 85 SCP 805) were grown to produce 25 quintals EIME 119, 28 quintals of ES - 790 and 37 qq 85 SCP 805, for a total of 90 quintals of seed.

In May 2008 this seed was distributed to 900 producers (individual and cooperative) in the departments of Esteli, Madriz, Chinandega and Matagalpa. The producers will use this seed to plant between 13,000 to 43,000 manzanas in in association with maize. In addition, local extension will assist producers in using this seed effectively to produce the next crop, partition a quantity to use as seed and market the remaining as either seed or grain.

The effect of planting density and fertilization on forage yield sorghum forage variety INTA

Four population densities of the Forage Variety INTA were evaluated (266,000, 332,500, 399,000 and 465,500 plants per hect-

Table 2. Agronomic and compositional data for INTA Forrajero in Nicaragua in 2007.

Nombre	Days to Harvest	Height (cm)	Leaf/Stalk Ratio	Crude Protein %	Crude Fiber %
INTA FORRAJERO	58	214	0.38	11.07	21.19

are). Each population was tested at four nitrogen levels (0, 65, 130 and 195 kg/ha).

No interactions were detected between population density and N level. There was no statistical difference in biomass yield based on population density. Nitrogen was a significant effect and with the best yields produced both the 130 and 195 kg/ha N rates. Because there was no statistical difference between these rates, use of the lower N rate was more cost effective, producing 55.6 and 21.8 Mg/ha fresh and dry weight, respectively (Table 2).

Grain Utilization – Food Use

In 2007-2008, the cost of wheat flour quadrupled in El Salvador. Bakers across the country requested government solutions to the problem that consisted of subsidies, tax elimination, credits, etc. This situation provides an outstanding opportunity to promote and stimulate the use of sorghum flour as a substitute for part of the wheat flour in baked products. At the current price of wheat flour, sorghum is approximately ½ the cost. In response to this situation, in March CENTA, through the Food Technology lab published two newspaper articles and appeared on three different news broadcasts describing the use of sorghum as a flour substitute for wheat (http://www.centa.gob.sv/Videos.aspx ; http://www.laprensagrafica.com/departamentos/1004993.asp ; http://www.laprensagrafica.com/economia /1004098.asp)

This promotion piqued the interest of many people from the food and bakery industries, and additional information and training was requested from CENTA's food lab. In the past year, CENTA food scientists have conducted four training sessions and educated approximately 100 participants. These demonstrations had two objectives: 1) to produce sorghum flour using a small mill (Omega VI) donated by INTSORMIL and 2) to demonstrate the utilization of sorghum flour as a substitute of wheat in different products.

As a result of trainings, big bakeries like Santa Eduviges, Pan Rey, and Monico located in San Salvador and surrounding areas, and many small and medium bakeries and productive groups from rural areas begin conducting trials with sorghum flour and actually they are using it to produce many of their products. "Pan Rey" a medium bakery located in Apopa, San Salvador, is producing its own flour, but is limited in their production by the limited supply of high quality sorghum grain. CENTA, through the INTSORMIL program is assisting them by identifying which hybrids they should buy. This has helped, but consistent supplies of good quality grain are difficult to find. They are using sorghum flour in a diversity of their products they are currently conducting trials right now with French bread formulation using 20% and 25% of sorghum flour. Consumer acceptance of their baked products with sorghum is good.

Another bottleneck to utilization of sorghum is milling capacity. Two Omega VI mills were purchased by INTSORMIL and our currently being used in El Salvador to produce sorghum flour. A small producer (Kris Duville) and CENTA's food lab are now providing this flour in a small scale. The Omega VI mill has a capacity of 2 pounds per minute. To get good particle size (flour pass through a mesh of 80) the flour must pass through the Omega VI at least four times but this is less than seven (what was required in a nixtamal mill). These mills, located in strategic points, will likely be more effective to supply sorghum flour than a large milling company in a single location, primarily because of transportation costs and logistics. There are efforts underway to increase and place these mills in appropriate locations.

La Colina a food processor specializing in Central American Ethnic Foods also requested training related to sorghum and flour production. A meeting with CENTA's cereal program personnel and the food lab personnel was conducted; CENTA is producing 3 hectares of food quality sorghum to be harvested in November, 2008; they will use the grain for flour production. GUMARSAL Company is going to mill all the sorghum produced and the flour is going to be used at La Colina's bakery to elaborate a diversity of sweet breads, cookies and healthy products to export to the USA. This company actually is exporting a diversity of products like frozen fruits, processed vegetables, chutneys, tamales, semitas and other Salvadorian ethnic foods. Last week CENTA's food lab provided La Colina with 200 pounds of fine flour to start conducting trials. CENTA's technicians will be involved in the trials. In addition to these examples, there are numerous other opportunities to use sorghum as a wheat substitute. CENTA is exploring and acting on these opportunities as appropriate. INTSORMIL is supporting this effort as well.

Technology Transfer

Seed production of released varieties of sorghum (Sorghum bicolor L. Moench)

This project is conducted to increase seed of improved varieties of sorghum INTA RCV and INTA SR-16, INTA-Forrajero and release the seed to market as commercial varieties.

On April 29 two varieties (INTA RCV and INTA SR-16) were released by INTA. For each variety, phenotypic descriptors and seed (40 qq INTA RCV and 30 qq of INTA SR-16) were produced. This seed will be distributed to the Pacific zone of Nicaragua where the use of the grain is primarily for animal feeding. Each producer will be provided with approximately 20 lb of seed. The distribution should provide seed to approximately 3500 farmers to plant about 65,000 manzanas. This distribution should allow producers across the región to learn the new varieties.

Production and Transfer of Improved Sorghums to Small Producers in El Salvador

The objective of the Project is to improve the productivity and profitability of small producers in NE El Salvador. During the first year seed was produced for eight varieties (85SCP805, 790, 226, Soberano, RCV, CENTA S-2, CENTA S-3 and Jocoro). Extension training to use these varieties was in the New Conception area. Seed of these varieties was provided to establish 321 plots and 227 varieties insensitive sorghums, making a total 548 plots, using 10 pounds per plot. Yield and productivity was measured and summarize for 211 plots. Seed was also provided to small producers specifically to produce additional seed for sale. A total of 260.50 quintals of sorghum seeds were produced for use in extension agencies that have areas of influence in the northeastern part of the departments of Chalatenango, Cabanas, Cuscatlan, Morazán, San Miguel and Union.

Networking

Several INTSORMIL collaborators attended and made presentations at the 53rd annual PCCMCA meetings held in Costa Rica in April 2008. INTSORMIL regional fund supported the travel of Vilma Calderon to the meeting to make a presentation. In addition, Salvador Zeledon won first place for his presentation at the meetings. Regional Coordinators Rene Clara and William Rooney traveled throughout Nicaragua, Honduras and El Salvador during harvest season to review programs and project activities. Ing. Nury Gutierrez of INTA traveled from Nicaragua to El Salvador to learn sorghum hybridization techniques from INTSORMIL supported CENTA staff. Drs. Joe Hancock and Lloyd Rooney traveled to the region to review and participate in collaborative research project related to animal feeding and food uses of sorghum. An agreement between CARE and INTSORMIL was formalized in the spring of 2008 to cooperate on the development and extension of sorghum into El Salvador for a period of two years.

Several releases of sorghum varieties were completed in 2007-2008. In El Salvador, CENTA released a series of sorghum forage varieties, highlighted by President Tony Saca, formally releasing the material at a field day at a dairy farm in El Salvador. INTSORMIL was recognized for their support in the development of this material. In Nicaragua in April 2008, INTA formally released INTA-RCV, INTA-SR16 and INTA Forrajero. In their release, the support of INTSORMIL in these releases was formally recognized.

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

Gebisa Ejeta
Purdue University

Coordinators

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

Ethiopia:
Taye Tadesse, Senayit Yetneberk & Tewodros Mesfin, Melkassa Research Station, EIAR
Ketema Belete, Alemaya University
Gebreyesus Brhane, Axum University, Faculty of Agriculture and Rural Development

Uganda:
Robert Olupot, Serere Research Station, NARO
Kaiizi Kayuki, NARO

Tanzania:
Elias Letayo, Hombola Research Station,
Robert Olupot, Serere Research Station,
M. Bbwaga, Dept of Crop Research
Dr Joseph J. Mpagalile, Dept. of Food Science & Technology, Sokoine University of Agriculture (SUA)
Emmanuel R. Mbiha and Fredy Kilima, Sokoine University of Agriculture (SUA),

Kenya:
Clement Kamau, Machakos Research Station, KARI
Christopher Mburu, Kakamega Research Station, KARI

U.S.:
Dr. J. Mark Erbaugh, Ohio State University, 113 Ag. Admin Building, 2120 Fyffe Road, Columbus OH 43210
Dr. Donald Larson, Ohio State University, CMPS/3064 Smith Lab, 174 Eighteenth Ave., Columbus, OH 43210
Dr. John Leslie, Dept. of Plant Pathology, Kansas State Univ 4002 Throckmorton Plant Sciences Ctr, Manhattan, KS 66502-5502
Dr. Bonnie Pendleton, Div. of Agriculture, West Texas A&M University, Canyon, TX 79016
Dr. David Jackson, University of Nebraska, 256 Food Science, University of Nebraska, Lincoln, NE 68583-0919
Dr. Jeff Wilson, USDA-ARS, Crop Genetics and Breeding Research Unit, P.O. Box 748, Tifton, GA 31793-0948
Dr. Charles Wortmann, University of Nebraska, 154 Keim Hall, Lincoln, NE 68583-0915

The Horn of Africa Regional Program now encompasses four countries of the Horn of Africa Region: Tanzania, Uganda, Kenya and Ethiopia. Scientists from the four countries and U.S. Collaborators met and participated in a planning workshop to discuss collaborative research for the Horn of Africa Region in September, 2008. The original Sorghum/Millet CRSP Grant program was closed after 27 years and the new Sorghum and Millet and Other Grains CRSP was initiated on September 29, 2006. As the Horn of Africa Regional Program goes forward, the planning workshop participants determined that we need take what has been accomplished and then develop a strategy to build on the strengths of the past. Declining human capacity is the biggest detriment to progress at the present time. This is due to lack of financial support and the cost of advanced training in the US.

Institution Building and Networking

Examples of INTSORMIL trained scientists who have returned home include Dr Senayit Yetneberk of the Ethiopian Agricultural Research Organization (EIAR) who received Ph.D. training in Food Science at the University of Pretoria under the supervision of Prof. John Taylor and Prof. Lloyd Rooney of Texas A&M University. Dr. Yetneberk has now fully implemented a system for evaluating the injera making quality of new sorghum lines, a system that she developed during her Ph.D. studies. This quality evaluation system is proving invaluable as the cost of teff, the grain preferred for injera making, has increased dramatically in the past year, making it unaffordable to many Ethiopians. Hence, people are increasingly utilizing sorghum to make injera.

Dr. Tebkew Damte Belete, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia received Ph.D. training in Entomology at West Texas A&M University under the supervision of Prof Bonnie Pendleton and returned home in December 2007.

Capacity building support

- Support for M.S. degree training at Ohio State University (OSU tuition cost share) in AED Economics for one student from Tanzania starting in 2008. Ph.D. support for one faculty member from Sokoine University (SUA) in the SUA Ph.D. program
- Supported two M.S. students in agricultural economics at SUA

During this year Dr. Gebisa Ejeta has continued collaboration with EIAR scientists in conducting research on sorghum resistance to *Striga* in Ethiopia. Experimental sorghum hybrids with *Striga* resistance that have high yield potential have been identified, and can be utilized for catalyzing a seed business activity once their *Striga* resistance is confirmed in field tests in Africa.

Charles Wortmann and collaborators in Ethiopia, Uganda, and Tanzania working in the area of crop, soil and water management to optimize grain yield and quality for value-added markets met most of their research objectives including: enhancing information bases for tied-ridging in Ethiopia, skip-row planting in Ethiopia, fertilizer use in Ethiopia and Uganda, reviving research activities in Tanzania and enhancement of technology dissemination in Uganda. They did not address some sorghum grain utilization activities in the region but opted to focus resources on technology dissemination in expectation that increased regional demand for grain will lead to increased demand for production technology. Although, one graduate student was partly supported by the project, this level of training proved to be less degree training than intended.

The research led by Mark Erbaugh and Don Larson (OSU) is on target in terms of the activities planned and those accomplished in the past year. The technology adoption analyses have been completed and the papers written and revised and will be sent to journals for review and publication in the near future. The sorghum-based clear beer studies are well underway and the farm household surveys in the high potential areas have been completed. Data entry and cleaning have been completed. A procedure has been established to collect monthly price data for sorghum and millet for the years 2008 to 2011 to permit analysis of monthly price variability and opportunities to store grain on-farms to sell at higher farm prices in the post-harvest period.

A Tanzanian student (Joseph Mgaya) has started his M.S. studies at OSU. During this year, market development in support of sorghum and millet farmers in Tanzania was promoted. Results of smallholder technology adoption studies in sorghum areas showed that,

- Adoption rates of improved technology (improved seed varieties, manure/fertilizer, and tillage practices) are generally low in the study areas
- Sorghum yields are typically low in Tanzania, 338 kg/ha, but are substantially higher for adopters than non-adopters
- Adopters are generally better off economically compared to non-adopters of improved technologies
- Some demographics (education, sex, marital status), farm size, wealth (as measured by the dwelling index, off-farm income) were important factors explaining adoption
- Accessibility to all-weather roads was also an important factor affecting adoption
- Perception about the existence of production and marketing problems are important factors explaining adoption

Preliminary results of sorghum-based clear beer value chain studies show that,

- Lack of input availability for smallholder producers
- Low producer/farm prices at harvest time that increase substantially in the post harvest period
- Poor roads cause higher transport costs for smallholders
- Investors perceive high business risks in sorghum processing because of supply & market demand uncertainty
- Government policy interference, e.g. domestic food security versus export potential
- Contract enforcement challenges for larger scale producers and processors
- Value chain sustainability requires trust and profit opportunities for all members

Dr. David Jackson in year 2 of the project with Sokoine University in Tanzania initiated a point of strategic renewal and refocus. Support efforts based on clientele from the former INTSORMIL project were nearing their completion, as only 5-10 small business groups were actively receiving extensive one-on-one assistance. Therefore, new groups were identified (and surveyed) to receive initial workshop training and services in Year 3. The identification and survey process was designed to ensure that services were provided to those groups most likely to achieve success. In addition, specific planning for year 3 farmer workshops and a regional conference were initiated. The farmer workshops are poised to start in January 2009. In addition, to help achieving program sustainability and improveing human capital, two students were successfully recruited into degree programs in Food Science and Technology at the University of Nebraska.

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

Gary C. Peterson
Texas A&M University

Coordinators

Dr. Gary C. Peterson, Sorghum Breeding, Texas ArgiLife Research & Extension Center, 1102 E FM 1294, Lubbock, TX 79403-6603

Dr. Medson Chisi, Sorghum Breeding, Ministry of Agriculture and Cooperatives, Zambia Agricultural Research Institute, Golden Valley Research Station, Fringila, Zambia

Collaborators

Botswana

Dr. David Munthali, Entomology, Botswana College of Agriculture, Private Bag 0027, Gaborone, Botswana

Mozambique

Mr. Fernando Chitio, Entomology, National Agrarian Research Institute, Posto Agronömico de Nampula Via Corrane, Nampula,

Mr. Ricardo Maria, Agronomy, National Agrarian Research Institute, Caixa Postal 3658, Maputo, Mozambique

Mr. Joaquim Mutaliano, Sorghum Breeding, National Agrarian Research Institute, P.O. Box 43, National Road No. 8, Namialo/ Nampula, Mozambique

South Africa

Dr. Neal McLaren, Plant Path, Dept. of Plant Sciences, Univ. of the Free State, P.O. Box 339, Bloemfontein 9300 South Africa

Dr. Hannalene du Plessis, Entomology, ARC-GCI, Private Bag X1251, Potchefstroom 2520, South Africa

Dr. John Taylor, Food Science, Dept. of Food Science, University of Pretoria, Pretoria 0002, South Africa

Zambia

Dr. Medson Chisi, Sorghum Breeding, Ministry of Agriculture and Cooperatives, Zambia Agricultural Research Institute, Golden Valley Research Station, Fringila, Zambia

Ms. Priscilla Hamukwala, Dept. of Agr Economics and Extension Education, School of Agriculture, Lusaka, Zambia

Dr. Mimoonga Bernard Moonga, Head, Dept. of Food Science and Technology, School of Agricultural Science, University of Zambia, P.O. Box 32379, Lusaka, Zambia

Mr. F.P. Muuka, Pearl Millet Breeding, Ministry of Agriculture, Kaoma Research Station, P.O. Box 940084, Kaoma, Zambia

Dr. Gelson Tembo, Ag. Economics, Dept. of Ag Economics and Extension Education, School of Agriculture, Lusaka, Zambia

U.S.

Dr. J. Mark Erbaugh, International Programs in Agriculture, Ohio State University, 113 Ag. Admin. Building, 2120 Fyffe Road, Columbus OH 43210

Dr. Donald Larson, Ag. Econ, Ohio State University, CMPS/3064 Smith Lab, 174 Eighteenth Ave., Columbus, OH 43210

Dr. John Leslie, Plant Pathology, Dept. of Plant Pathology, Kansas State University 4002 Throckmorton Plant Sciences Cen ter, Manhattan, KS 66502-5502

Dr. Bonnie Pendleton, Entomology, Div. of Agriculture, West Texas A&M University, Canyon, TX 79016

Dr. Lloyd Rooney, Food Science, Dept. of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843

Dr. William Rooney, Sorghum Breeding, Dept. of Soil/Crop Sciences, Texas A&M University, College Station, TX 77843

Dr. Jeff Wilson, Pearl Millet Breeding, USDA-Agricultural Research Service, Crop Genetics and Breeding Research Unit, P.O. Box 748, Tifton, GA 31793-0948

Dr. Charles Wortmann, Agronomy, Dept. of Agronomy/Horticulture, Univ. of Nebraska, 154 Keim Hall, Lincoln, NE 68583-0915

Regional Program Description

The Southern Africa program is composed of 14 investigators in 12 individual research projects representing 8 agencies from 4 countries. There an additional 8 U.S. principal investigators that collaborate with the regional investigators. The regional planning meeting held to develop a plan to guide activities from 30 September 2007 to 29 September 2011 developed the problem statement: Food security and incomes of sorghum and millet farmers in southern Africa remain low and productivity is constrained by a lack of appropriate technologies and farmer linkages with input and output markets. Enhanced collaboration among stakeholders will facilitate technology transfer, adoption, and improved productivity. Market incentives will drive technology adoption and productivity improvements.

Agencies represented include the Botswana College of Agriculture; the Mozambique National Agrarian Research Institute; in South Africa the University of the Free State, the ARC-GCI, the University of Pretoria, and the Medical Research Council, and in Zambia the Zambia Agricultural Research Institute and the University of Zambia. The investigators represent disciplines including:

agronomy (1), breeding (3), socio-economics (2), entomology (3), food science (1), and pathology (1). Regional investigators were selected with the expectation each has expertise that will allow the regional program to achieve the goal of improving sorghum and millet for the regions farmers and end-users.

Work plans are developed by each regional investigator using a format similar to the format for U.S. investigators. Each investigator is expected to specify where activities fall within the regional plan and to provide performance indicators and outputs. Progress listed in the individual annual reports will be used to evaluation progress and performance. Each collaborating investigator brings to INTSORMIL their own collaborators including Future Harvest Centers, NGOs, and other governmental or private organizations. Each also has other grant funds - other donors, grants and commodity organizations - that provide reciprocal leveraging of resources for each organization. Technical backstopping (as needed) and logistical, material and additional operational support is provided by the U.S. collaborators.

The goal of the collaborative program is to develop and transfer 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 will increase as additional opportunities and funding become available. The local scientists are encouraged to collaborate across country boundaries.

Sorghum/Millet Constraints

Sorghum and pearl millet are major food crops in the Southern Africa region. Sorghum is also used to make opaque beer and as a livestock feed. Sorghum is the major cereal in Botswana and parts of Zambia and Mozambique while pearl millet is the major cereal in Namibia and parts of Mozambique, Zambia, and Zimbabwe. In many areas the stalks are used as forage for animal feed, to build fences and traditional storage facilities, and the juice of sweet sorghum as a source of sugar. In some areas sorghum and pearl millet are considered as food security crops, especially in regions where rainfall is a limiting factor for maize and rice production.

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. Policy constraints frequently place sorghum and pearl millet at a disadvantage relative to other commodities. Improved crop genetics combined with 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. To increase end-use beyond the farm gate market channels should be improved as sorghum grain with the required quality to meet commercial requirements frequently has 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. A major constraint to increased farmer production and productivity is the lack of adequate seed systems to distribute improved varieties. The adoption rate of improved varieties is largely unknown due to inadequacies of the seed system. Consequently farmers continue to use their local varieties which have low productivity potentials. Availability of a consistent supply of improved quality sorghum and pearl millet for processing into value added urban products is a major constraint limiting utilization. Food companies will use but cannot consistently acquire sufficient quantities of high quality sorghums for processing. A system of identity preservation for production, marketing, and processing is urgently needed.

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. Reduced stored grain loss, with some estimates of a 30 - 50% loss annually, will increase the availability of high quality grain. Exotic sorghums and pearl millets are continually introduced into the 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 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.

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 for processing into value added urban products is a major factor limiting utilization and development of commercial sorghum markets. Food companies will use but cannot consistently acquire sufficient quantities of high quality sorghums for processing. For example, Zambia Breweries= requirements of sorghum to produce Eagle larger is 40 B 60 tons per month, which cannot be met. A strong need exists for developing a system of identity preservation for production, marketing, and processing.

Institution Building and Networking

Networking

Workshops and Meetings

In November 2007 and September 2008 workshops were held in Pretoria, South Africa and Gothenburg, Sweden on the Science and Technology of Traditional Grains (sorghum and millets and pseudocereals). Each workshop was attended by some 40 delegates. The aim of the workshops was to increase the utilization of traditional grains. The workshops were organized by the University of Pretoria, the Swedish Food and Biotechnology Institute (SIK) and the International Foundation for Science (IFS), with the support of IFS. The workshops involved networking scientists from developing countries and established scientists working on traditional grains. The first workshop focused establishment of mentoring pairs between scientists and development of research project proposals. The second concentrated interaction with industry in Europe using traditional grains and practical learning of gluten-free baking technology.

A workshop for food processing entrepreneurs in southern Africa on Alternative Cereal Processing Technologies will take place in Botswana in November 2008. The workshop is being hosted by the Botswana National Food Technology Research Centre in collaboration with INTSORMIL and Cereal Science and Technology-Southern Africa.

In Mozambique demonstration plots and field days were carried out at Namialo, Namapa, Ocua and Katapua in Nampula and Cabo Delgado Provinces.

Participation by INTSORMIL collaborators in South Africa in meetings and activities of the Sorghum Forum (March 2008) and Sorghum Trust (October 2008) provide the opportunity to interact with commercial producers and discuss technology develop that is applicable to all sizes of farms.

Nearly 500 people attended a pearl millet field field day (Zambia) including representatives from the farming community, farmers= unions, seed companies, schools, NGOs, Ministry of Agriculture staff, Provincial and District Administrators and the public media.

Improved pearl milletvarieties were exhibited at District, Provincial and National shows

Crop production guides were made available to Extension staff in 7 districts.

Research Investigator Exchanges

Dr. Lloyd Rooney (Texas A&M University) - November 2007. Visited South Africa for participation in the Traditional Grains Workshop and meeting with graduate students.

Dr. Medson Chisi (Zambia) visited the national program in Mozambique and evaluated sorghum and millet trials at several locations. Several germplasm lines were sent to Mozambique at their request.

Dr. John Yohe (INTSORMIL Program Director) and Dr. Gary Peterson (Texas AgriLife Research and INTSORMIL Regional Coordinator) - April/May 2008. Evaluation visits to Mozambique, South Africa (Bloemfontein, Potchefstroom and Pretoria), Botswana, and Zambia. Met with INTSORMIL collaborators and relevant administrators to review the current status of collaborative activity and plan future research and technology transfer activity.

Dr. Mark Erbaugh (Ohio State University) and Dr. Don Larson (Ohio State University) visited the Zambian sorghum breeding program at Golden Valley

Several scientists from Botswana and Namibia visited the Zambian sorghum breeding program at Golden Valley

In Mozambique, the national sorghum program received visits from Dr. Carlos Dominguez (ICRISAT-Mozambique), Dr. Mary Mgonja (ICRISAT-Kenya sorghum breeder) and Dr. Jane Ininda (AGRA Program Officer - Crop Improvement)

Research Information Exchanges

Texas A&M University is working with the University of Pretoria to evaluate the brewing potential of the high protein digestibility lines developed in the Texas AgriLife Research sorghum program. Samples of lines that have been found to be promising in terms of improved yeast fermentation nutrition have been supplied to University of Pretoria for small-scale pilot-brewing trials.

Germplasm Conservation and Distribution

The Zambian national sorghum program continued its work with the Food Diversification Project (FoDis) supported by JICA, Care International and Harvest Help in technology transfer as well as seed production and distribution. 2.5 tons of Kuyuma and 2.0 tons of Sima were produced at Nanga. This seed will be distributed in Rufunsa, Luangwa and Sinazongwe district. The program has, with the support of INTSORMIL, continued to increase seed of released varieties such as WP-13, Kuyuma, Sima and ZSV-15 when necessary.

The Zambian national pearl millet program produced 360 kg of Dola and 600 kg of Lubasi foundation seed. The production is adequate to plant 200 ha and produce 200,000 kg commercial certified or quality declared seed in 2008/09.

The Market Access Trade Enabling Policy (MATEP) would like 1,200 MT while Golden Valley Agricultural Research Trust (GART) is interested in funding commercial pearl millet production of Dola and forage types for Strengthening HIV/AIDSs and Food Security Mitigation Mechanisms.

The Mozambique national sorghum program planted seed increases at three locations to produce improved sorghum seed for distribution. In Namapa, 3.0 tons of Macia were produced. The seed will be supplied to farmers and the private sector through District extension services at a cost of $1.45/kg, equivalent to 35 meticals/kg. In Nampula, approximately 4.0 tons of foundation seed of Macia and Sima were produced. Part of the seed will be sold to assist farmer associations through the IKURU national NG). In Manica, 5 ha of Macia and 4.5 ha of pearl millet were planted but production data are not yet available.

Spreading Research Results

In addition to workshops information distribution is also increasingly being achieved through posting of technical publications on the INTSORMIL website. During this past year the University of Pretoria has produced documents on: Developments in sorghum lager and stout sorghum brewing, Five Simple Methods for the Determination of Sorghum Grain End-Use Quality, Guide to Floor Malting of Sorghum and Millets and several posters about sorghum and millet science and technology.

Information is also spread through direct work with organisations and commercial companies. During the past year Prof . John Taylor spent two weeks in Ghana working with UNIDO on its project on Industrial Development of Sorghum Malt and Its Utilization in the Food Industry in West Africa. He also worked with two commercial companies malting and brewing with sorghum in Africa.

Examples of INTSORMIL Trained Scientists Who Have Returned Home

Dr Senayit Yetneberk of the Ethiopian Agricultural Research Organization (EARO) received Ph.D. training in Food Science at the University of Pretoria under the supervision of Prof John Taylor and Prof Lloyd Rooney of Texas A&M University and returned home in 2004. Dr. Yetneberk has now fully implemented the system for evaluating the injera making quality of new sorghum lines that she developed during her Ph.D. studies. This quality evaluation system is proving invaluable as the cost of teff, the grain preferred for injera making, has increased dramatically in the past year, making it unaffordable to many Ethiopians. Hence, people are increasingly utilizing sorghum to make injera.

Human Resource Development Strategy

For degree programs, the primary mechanism is to upgrade the research and sorghum and millet science skills of university lecturers and scientists in research institutes in sub-Saharan Africa. During the past year, there were nine such graduate students studying Food Science at the University of Pretoria.

For non-degree (short-term) programs, the University of Pretoria has a short course in sorghum malting technology and a certificate course in opaque beer brewing. The strategy is now to formalize this training. Discussions are ongoing with the Institute of Brewing and Distilling (IBD) to have a Sorghum elective in the IBD=s General Certificate in Brewing. Such an elective would help raise the human resources skills and status of the sorghum brewing industry, as well as to promote sorghum brewing in new regions.

Rebecca Lubinda, a faculty member in the Department of Agricultural Economics and Extension Education at UNZA, has decided to begin Ph.D. studies in agricultural economics this spring or next fall through the RUFORUM program located at Bunda College in Malawi. Her studies will be supported on a cost share basis between the OSU INTSORMIL/Zambia project and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM).

INTSORMIL supported students, and students affiliated with INTSORMIL collaborators, at the University of the Free State receive training in interdisciplinary research including plant pathology and breeding.

Research Accomplishments

Entomology

Mozambique

Twenty-five sweet sorghum varieties from ICRISAT (also evaluated in the sorghum breeding program) were screened for resistance to shoot fly and stem borer. A differential response to both pests was observed. For shoot fly, varieties with a low severity of attack and some level of resistance include ICSV 700 (1.0), ICSB654 (1.3), ICSB324 (1.3), and SPV1411 (1.7). Varieties with a high severity of attack and susceptibility include IESB91104DL (4.3), SPV422 (4.3), Ent#64 DTN (3.3) and E 36-1 (3.3). For stem borer, varieties with a low severity of attack and some level of resistance include S35 (1.0), ICSB654 (1.0) and ICSB324 (1.3). Varieties with a high severity of attack and susceptibility include SPV411 (3.0), IESB91104DL (2.7) and IESB940218DL (2.7). Two varieties - ICSB654 and ICSB324 - appeared to have resistance to both insect pests.

The Texas A&M University All Disease and Insect Nursery (ADIN) was evaluated for resistance to stem borer. Entries TAM428 (1.00), Sureno (1.50), Tx2911 (1.50), Tx2952 (1.50), and Tx2950 (1.75) had a low severity of attack and were classified as resistant to stem borer. Entries Tx2955 (3.25),6GCPOBS143 (3.25), Tx2959 (3.25), and B9955 (3.5) exhibited a high severity of attack and were classified as susceptible to stem borer.

Botswana and South Africa

Primary collaborative research is on developing varieties resistant to the sugarcane aphid (*Melanaphis sacchari* [Zehntner]). Two trials were provided to collaborators at the ARC-Grain Crops Institute (Potchefstroom) and the Botswana College of Agriculture (BCA-Sebele). The first trial was composed of 50 entries which had not been previously evaluated for resistance to sugarcane aphid. At Potchefstroom the three replication trial was evaluated in a seedling stage greenhouse trial with artificial inoculation. Seedlings were inoculated 10 days after emergence and plants rated for aphid abundance and plant damage 21 days after infestation. Plants were rated on a scale of 1 (highly resistant) to 6 (highly susceptible). TAM428, the resistant check, was rated as a 1 for plant damage and aphid abundance while Segaolane, the susceptible check, was rated as a 5.7 for plant damage and 4.3 for aphid abundance. Analysis of the Potchefstroom data indicated that for plant damage on the experimental entries 18% (7) of the entries rated 1, 34% (13) rated 2, 2% (1) rated 3, 29% (11) rated 4, 16% (6) rated 5 (Table 1). None of the entries rated a 6 for plant damage. For aphid abundance 32% (12) of the entries rated 1 and highly resistant, 50% (19) rated 2 and highly resistant, 16% (6) rated 3 and resistant, and24% (1) rated 4 and slightly resistant. None of the entries rated as susceptible based on aphid abundance. In the field trial 26% (10) rated 1, 55% (21) rated 2, 18% (7) rated 3. In the field none of the entries were rated completely susceptible. In the field 20% (10) of the entries rated under 2.3 (resistant to highly resistant) and under 2.3 based on greenhouse ratings. At Sebele there were few aphid present at most entries were scored as a 1. At the BCA plots were also scored for percent of plants infested with shoot fly (*Atherigona soccata* [Rondani]) and sorghum stem borer (*Chilo partellus* [Swinhoe]). For shoot fly the percent of infested plants ranged from 0 to 33 and for stem borer from 0 to 59. Several experimental entries with excellent sugarcane aphid resistance also had no shoot fly or sorghum stem borers identified.

The second trial was a twenty-five entry three replication trial composed of 22 entries previously identified with a high level of resistance to sugarcane aphid and 3 local checks. The purpose of the trial was to identify entries with excellent adaptation and grain yield to the local production system. All experimental entries were rated as 1 or 2 for greenhouse damage and only two entries rated higher than a one for sugarcane aphid abundance (Table 2). The test average was 3.2 tons/ha with the local hybrid check producing 3.83 tons/ha, Tegemeo 2.78 tons/ha, and Macia 2.70 tons/ha. Five entries produced more grain than the hybrid check with yield ranging from 3.94 to 4.40 tons/ha. Only two entries produced significantly less grain than the local hybrid check, PAN 8420. Five entries produced more grain than PAN 8420 although the differences were not significant. Fifteen experimental entries produced more grain than the local check cultivars, Tegemeo and Macia although a significant difference was identified for only one experimental entry. Several entries were selected for on-farm trials during the next growing season at three locations to identify entries suitable for small-scale farmer market.

Food Quality

Research is being undertaken to promote sorghum and millets within the health food niche market. Research by INTSORMIL supported M.Sc. student Constance Chiremba and by Ph.D. Student Muthulisi Siwela under the supervision of Prof. John Taylor and Dr. Gyebi Duodu of the University of Pretoria has shown that good quality cookies with high antioxidant activity can be produced from 100% sorghum and from finger millet blended with wheat. Similarly, work by Ph.D. graduate Nomusa Dlamini under the supervision of Prof Lloyd Rooney of Texas A&M University and John Taylor has shown that traditional African sorghum porridges and modern extrusion cooked ready-to-eat products from sorghum also have excellent antioxidant activity. Arising from this work, the largest sorghum food manufacturer in South Africa has now approached the University of Pretoria to determine the antioxidant activity of their sorghum raw materials and products.

Research conducted by Ph.D. graduate Martin Kebakile under the supervision of John Taylor, Dr. Riette de Kock (University of Pretoria) and Lloyd Rooney has shown that milling sorghum using the South African developed simple roller mill is much more efficient than the currently commonly used technology of dehulling, followed by hammer milling. As a result of this research, a major international brewing company is now evaluating this roller milling technology for milling its maize and sorghum adjuncts.

Market Development

The adoption of improved technologies among smallholder growers of maize, millet and sorghum was studied using a household survey of smallholder farmers in a sorghum and millet growing district (Siavonga area) to identify factors that influence adoption of improved technologies (improved seed, deep tillage, and manure/fertilizer) in the production of maize, millet and sorghum. Progress toward indicators such as income growth, yield increases, and production increases will be measured against this baseline information. In addition to confirming that adopters are generally better off compared to non-adopters of improved technologies, the results indicate that some demographics (education, sex, marital status), farm size, wealth (as measured by the dwelling index, off-farm income), accessibility, and perception about the existence of production and marketing problems are important in explaining adoption in at least some of the crops. Besides the need to recognize the inherent heterogeneity among crops, broad-based investment in education, and marketing infrastructure and institutions could improve technology uptake.

A survey of sorghum and millet farmers in a high potential area was conducted in two blocks of Luanshya district north of Lusaka. Luanshya is a high potential sorghum producing area that also has market access advantages because of its close proximity (60 kilometers) to the Zambian Breweries Ndola facility that brews Eagle lager. Luanshya was selected after the researchers visited the Mumbwa area (the original high potential area selected) only to discover that very little sorghum is now grown there. Maize is the major crop now grown in the Mumbwa area. The change to maize is due in part to large government subsidies (60%) on maize seed and fertilizer prices. In the Luanshya survey, 170 households were visited, of which 164 were complete interviews. Data entry and cleaning has been completed.

The sorghum based clear beer supply chain analysis resulted in a progress report that identified the value chain players, from farmers to retailers of the clear beer. Interviews were conducted with various representatives of firms that form part of the chain on their activities and experiences in the chain. The producer of Eagle lager, Zambian Breweries, was the first organization to be visited and was the primary source of information on the other chain players. Interviews were also conducted with CHC commodities, the sole supplier of sorghum to Zambian Breweries, and two of the official distributors of Eagle lager, R.S. Distributors and Nenima Trading. Various retailers within Lusaka were also visited. For this year the main activity was the examination of the clear beer supply chain with interviews with retailers, wholesalers, brewers, warehouses, transporters, local buyers, farmers, and others. Information was required on supply chain players= operations, information flows, promotion flows, ownership flows, product flows, payment flows, constraints and the means for smallholders to sell in commercial markets. Estimates of future demand for the clear beer were also required to assess the growth potential of this market. The current analysis of the clear beer supply chain has concentrated on collecting more information that was not available last year and estimating the future demand for Eagle lager.

An interview at CHC commodities, a grain trading company, provided useful information on the flow of information on the quantities, quality and prices of sorghum required for production of clear beer as well as the ownership of the sorghum as it moves from the farmers= fields to Northern breweries. Further interviews are being conducted to collect actual prices of sorghum this year (including how they are determined) and how payments are made. Further interviews were also conducted with R.S Distributors on its operations and flow of clear beer from the brewers to the retailers. The main activity that remains to be done is the estimation of future demand for Eagle lager. Future demand estimates will be based on sales/production forecasts based on trends in sales and production of the beer since its introduction in 2005. Data will be obtained from Zambian Breweries in Lusaka.

Pearl Millet Breeding (Zambia)

Although several seed companies operate in Zambia only 18% of the 523 released plant varieties are marketed. Only one pearl variety is >commercially= marketed but accurate information on seed demand/supply chain is not well documented. Demand for improved seed is increasing domestically and in neighboring countries, especially following the release of the improved bristled and bird-tolerant variety Dola. Thirty-eight exotic seed parents (i.e. 19 A1, A4, and A5 CMS and corresponding maintainer lines) as well as 51 other B-lines were evaluated, characterized and stored. An attempt was made to produce seed of 190 experimental cms based hybrids from 19 A-lines and 10 potential pollinators.

Through collaboration with the Food Science Department of the University of Zambia, some food quality traits were determined on 30 pearl millet varieties.

Five variety trials were conducted to evaluate the performance of experimental varieties versus released standard varieties. A32 entry trial composed of 13 released SADC varieties, 11 Zambian experimental varieties, 1 elite and 7 exotic varieties was planted at three dates to evaluate for grain yield. Statistically significant differences were obtained for grain yield in the November plantings. At the early planting date, Sepo, ZPMV20601, ZPMV 22601, ZPMV 22501, Tuso, ZPMV 20402 and Dola were best while ZPMV 22601, Sepo and ZPMV 20601 were superior in planting two weeks later. There was a 6% yield advantage with early planting, and late maturing varieties out-yield early maturing varieties when planted early and vice versa.

Twenty-two elite varieties were evaluated with 10 released ones that included the sorghum variety Kuyuma. Statistically significant differences were obtained for grain yield with ZPMV 20402 and ZPMV 21401 being equal to the check Lubasi. Other promising varieties were Taram, ZPMV 27401 and ZPMV 21402. Kuyuma produced less grain yield than 28 of the 31 pearl millet varieties tested.

Additional activities in the pearl millet breeding program included the regeneration of 23 Zambian or exotic varieties. Research was also conducted to pursue the development of both top-cross and population hybrids using cytoplasmic genetic male sterility (CMS) in top-cross hybrids and inter-varietal crosses in population hybrids. Nineteen pairs of A/B-lines of the Aa, A4 and A5 CMS system were evaluated. Results led to the conclusion that the lines could still be segregating and require additional inbreeding and selecting. Fifty-one potential B-lines from ICRISAT were evaluated for traits including flowering, maturity, height, size and shape of spikes, absence or presence of bristles, color of grain, tillering, lodging tolerance, threshing percent and grain yield. Based on the data collected 30 were selected for further evaluation and future use. Restorer hybrid parents were characterized and evaluated for potential use in Zambia. From several hybrid BC3 and BC4 inbred progenies, 18 diverse potential restorer hybrid parents were formed.

Sorghum Breeding

Zambia

Several varieties and management practices have been developed by the program. However technology adoption has been modest due to a number of reasons, primarily lack of seed availability. A study done several years ago on sorghum farmers on the availability of sorghum seed reported that forty-five percent cited lack of seed as a major reason for non-adoption, while 36 percent reported lack of information as a constraint. According to the same survey results, 40 percent of the adopters depended on NGOs for seed as compared to only 15 percent who depended on purchased seed from different sources, including Zambia Seed Company. Issues of seed production and distribution have continued to be a major hindrance to increased production of sorghum in Zambia and are largely due to government policy that is restricting access to publically released varieties by private seed companies.

Three of the major focus of the breeding program in Zambia are to ensure food security under the crop diversification policy by developing varieties and hybrids that are of acceptable quality to end users, to elevate sorghum from a subsistence crop to a commercial cash generating crop, and to increase technology transfer. Participatory approaches are used to achieve this goal. This has been achieved through establishing markets and value chain management. The increased production and use of sorghum is expected to provide household food security and increased income for subsistence farming sector. Seed of popular varieties was increased at Nanga and will be distributed in Rufunsa, Luangwa and Sinazongwe. The program in collaboration with various NGOs is involved in the promotion of improved varieties and management practices to farmers. In Siavonga during the 2007/2008 season 130 small holder farmers grew about 200 hectares of sorghum. Most importantly the farmers= average grain yield was 2.5 tons per hectare as opposed to their average of 0.5 tons per hectare. Most of the sorghum growers have moved from thatched huts to iron sheets, a measure of affluence in these communities.

Collaborative research with INTSORMIL has involved the exchange of germplasm and evaluation of trials with specific traits. A number of parental lines have been evaluated for combining ability and other desirable agronomic traits. This research has resulted in the development of sorghum varieties suitable for food, brewing, feed and forage. Varieties and hybrids including ZSV-15, WP-13, MMSH-625 and MMSH-1365 have been released to farmers with a fair amount of success in terms of acceptance. Collaborative activities in technology transfer continue in Kazungula and Siavonga under a sorghum commercialization project involving Care International (Zambia) and Harvest Help designed to promote sorghum production and consumption. With increased production of sorghum, it is expected that incomes and profitability of farmers will increase resulting in food security.

The 2007/2008 growing season was characterized by heavy rains at the beginning of the season and early cessation of the rains in early March. Multi-location trials were abandoned and where they were conducted the coefficients of variations were unacceptably high. However, the breeding nursery and some trials performed well. Field days conducted at GART and Masaiti in Ndola proved successful and the attendance by farmers was good. At GART significant differences were observed among the entries evaluated in the sorghum advanced variety trial and the preliminary hybrid trial. A number of lines were identified for additional evaluation in multi-location and on farm trials. ZSV-15-4. [Framida x SDS 3845]F6-5, ELT1-16 and derivatives of WP-13 are some of the lines selected for further evaluation. New hybrids ZSH-206, 208 and 205 had high yields and good agronomic scores at GART.

Mozambique

Land-race varieties collected in the Central Sorghum Plateau-Gorongosa/Sofala Province (22 varieties) and the Northern Sorghum Plateau-Cabo Delgado Province (19 varieties) was evaluated for agronomic characteristics (including days to flowering, plant height, panicle exsertion), insect resistance (borers, midge, aphids) and disease resistance (downy mildew and head smut). Both collections were resistant to downy mildew and head smut (scored as 1 on a 1 = resistant to 5 = susceptible scale). Level of resistance to aphids (scored between 1 and 2) and midge (scored between 1 and 2) was generally excellent. Most entries exhibited a moderate level of susceptibility to borers. In collaboration with the University of the Free State (South Africa), the varieties will be grown in the next growing season for its characterization using DNA-finger print to determine genetic diversity, grain quality and nutritional value (in collaboration with the University of Pretoria-Department of Food Science).

Ten improved varieties from the Zambian national sorghum breeding program were evaluated for performance in Mozambique. Results indicated that all of the varieties performed well under local conditions. The varieties all scored a 1 (1 = resistant to 5 = susceptible) for downy mildew and head smut reaction. All varieties sustained little damage due to midge (all scored 1) and aphids (8 scored at 1 and 2 scored at 2). The varieties were moderately susceptible to damage by borers, usually scoring at 2 or3.

Twenty-five (25) sweet sorghum varieties developed by ICRISAT-Kenya were evaluated at 6 locations (Manica, Chokwe, Namialo, Montepuez, Oacua and Katapua) under rain-fed conditions. Brix percent (test mean = 11.9) ranged from 7.9 ICSB 324 to 14.5 for Ent #64DTN and S 35. The water limited environment resulted in reduced stalk yield and grain weight (test mean of 543.0 kg/ha).

Four sorghum trials from the Texas A&M University sorghum program were evaluated for agronomic traits, insect and disease resistance, and grain yield. The trials were the All Disease and Insect Nursery (ADIN), Drought Line Test (DLT), Grain Weathering Test (GWT) and Midge Line Test (MLT). Each test contains standards checks for the relevant trait(s) and resistant lines in an improved genetic background. Grain yield in the ADIN averaged 1.08 kg/ha (CV=14.7), 1.27 kg/ha (CV=13.05) in the DLT, and 1.61 (CV=12.67) in the MLT. Based upon the data collected for grain yield, agronomic traits, grain quality, and tolerance/resistance to drought, sorghum midge 9 lines were selected for pre-release increase and testing. Designation/pedigree of the lines are:

- 03CM15067 (((((Tx2880*(Tx2880*(Tx2864*(Tx436*(Tx 2864*PI550607)))))-PR3-SM6-CM3-CM1-CM2-CABK-CABK-CGBK
- 03CM15012 (85OG4300-5*Tx2782)-SM5-CM2-SM2-SM1-CABK-CMBK-CMBK
- 02CM1104 (((((Tx2880*(Tx2880*(Tx2864*(Tx2864*P I550610)))))-PR3-SM6-CM3-CM2-CG3-BGBK-CABK
- Sureño
- 01CS20538 (90LI9178 - (M84-7*VG153)-LBK-PR7-L4-L2
- 02CS30445 (99CA3019 - (VG153*(TAM428*SBIII))-23-B32-BE2-BE1)
- B409 (B1*(B7904*(SC748*SC630)))-HF17B
- 02CS5067 (B1*BTx635)-HF8
- 01CS19225 (B35*B9501)-HD9

During the 2008-2009 growing season in Mozambique and Texas multiple location data will be gathered on each line and selected local checks (such as Macia and Kuyuma). A release proposal will be developed and submitted to the Texas AgriLife Research Plant Release Committee. Intellectual property rights to the lines for use as varieties in Mozambique will be transferred to IIAM.

Plant Pathology

Root efficiency remains a critical component of low input agriculture and is essential in ensuring that limited soil moisture and nutrients are used optimally so as to ensure sustainable crop production. A Ph.D. thesis was completed and included aspect on pathogenisis, resistance, seed treatments and the role of edaphic factors on disease severity. An M.Sc. study has been initiated to continue aspects studied during the Ph.D. study. A new collection of root pathogens was initiated that covered a wider production area than the previous study and included forage, grain and wild sorghums. These are being used to define pathogen aggressiveness and the stability of resistance using different pathogen spectra. In an initial study, 60 isolates, provisionally classified as Fusarium oxysporum, root efficiencies, based on visible root rot and root volume, were reduced by 15-38 %. Additional isolates of other genera are currently being evaluated. Isolates will be used in line screening, winter greenhouse trials to determine isolate x genotype interactions and lines will also be used to determine histological and physiological relationships within the host x pathogen response. Isolates used in the evaluations will be sequenced to confirm the identity of the pathogens. Trials were planted at Cedara including lines obtained from the Texas A&M program for the evaluation of resistance to root rots in B and R populations. Root rot severities ranged from 8.3 to 72.1 % based on visible discoloration and most lines were susceptible to root rots. Only one of 323 lines yielded root rot severities <10 % while 268 line yielded severities >30 %. There was a tendency for more resistant lines to produce smaller root volumes, which ranged from 4.4 to 128.3 ml. Of the 7 lines that produced root volumes in excess of 100 ml, only two old lines ie. A 3739 and ICSV-LM 90364 yielded root rot severities <20 %.

On-going trials were planted in Greytown, Klerkdorp, Cedara and Bethlehem (all in South Africa) to evaluate new releases for cold tolerance and ergot susceptibility. These trials are aimed at preventing susceptible cultivars from entering the market and a re-occurrence of 1980=s epidemics. Data were analyed using the regression methodology developed to quantify ergot susceptibility x weather interactions (McLAREN, N.W. (1992) Quantifying resistance of sorghum genotypes to the sugary disease pathogen (*Claviceps africana*). Plant Disease 76: 986-988). Of the 72 potential releases, 31 were identified as high ergot risk cultivars and will not be marketed.

Sorghum nurseries received from the Texas A&M sorghum program were evaluated for sources of resistance and adaptability to the major foliar diseases at Cedara (KwaZulu-Natal Province). Most lines were white, tan genotypes although some red grained lines were also included. Foliar disease severities in these trials were relatively low due to nurseries being received late. Particular emphasis was placed on grain molds which remain a major concern to processors, both due to the effect on grain quality (milling and discolorations) and the potential health hazard due to mycotoxins. Grain molds were evaluated in trials at Cedara and Potchefstroom (North-West Province). Selections were made to serve both commercial and small scale production. Most lines were however rejected based on extreme susceptibility to grain molds. In the ADIN nursery four lines (Tegemeo, Macia, Sureño and BTx635) were selected to be included in a small farmer evaluation trial in collaboration with INTSORMIL during 2008/09 (Table 3). Similarly, in the Sugarcane Aphid Trial (Table 1) and SCA Yield Trial (Table 2), a number of entries were identified for the small farmer program. Selected lines will be evaluated on-farm during 2008/09 to determine adaptability to low input conditions.

Agronomy

Several trails were conducted on nutrient management in Mozambique. 1) Trials to verify and fine-tune promising practices and to strengthen technology dissemination were conducted on-station and on-farm in northern Mozambique in collaboration with Zonal Research Centers in Nampula and Manica and with CLUSA. 2) Various treatments to evaluate the effect of green manure in rotation with sorghum were evaluated. The treatments include sorghum fertilized with standard fertilizer (Urea + NPK), sorghum fertilized with urea, cowpea, sorghum without soil amendment, and sole crotalaria. 3) The effect of different foliar application rates of monthly fertilized is being evaluated. 4) To understand current sorghum, millet and other small grain production systems as well as farmer=s soil nutrient management practices for restoration soil fertility of sorghum and millet a questionnaire was developed for farmer interviews. Data from all of the studies is currently being analyzed.

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Table 1. Sugarcane aphid damage, shoot fly and stem borer infested plants, plant color and grain color, disease resistance ratings in the 2008 Sugarcane Aphid Test, Potchefstroom and Cedara, South Africa and Sebele, Botswana.

Source	Designation/Pedigree	Plant Color †	Grain Color ‡	Potchefstroom Seedling Damage§	Potchefstroom Adult Damage¶	Sebele Adult Damage ¶	Sebele Shootfly Infested Plants	Sebele Stemborer Infested Plans	Leaf Blight #	Rust #	Zonate #	Anthracnose #	Grain Mold† †	Grain Mold† †
							%	%					Cedara	Potch
5	TAM428	P	W	1.0	1.0	1.0	4.9	0.0	2.8	0.3	0.0	0.7	3.5	2.2
6	WM#177	P	W	1.0	1.0	1.0	3.7	17.8	2.2	2.2	0.0	0.7	3.5	2.3
8	Ent62/SADC	T	W	1.0	1.0	1.0	0.0	0.0	0.2	0.0	0.0	0.8	1.8	3.5
13	(9MLT176/(MR112B-92M2*Tx2880)*Segaolane)-CG1-LG1-CA1	T	W	1.0	1.0	1.0	0.0	0.0	1.8	0.0	0.0	0.0	3.8	2.7
18	(Sureno*Tegemeo)-BE3-CA1-CCBK-CABK	T	W	1.0	3.0	1.0	0.0	16.7	2.2	0.3	0.0	0.0	4.5	3.8
20	(Dorado*Tegemeo)-HW13-CA1-CC2-LGBK	T	W	1.0	1.3	1.0	0.0	0.0	1.5	0.0	0.0	0.3	3.3	3.5
21	(Dorado*Tegemeo)-HW10-CA1-CC2-CABK	T	W	1.0	2.3	1.0	22.2	16.7	0.5	0.0	0.0	0.2	3.0	3.2
22	(M50009/VG15*TAM428)-HW1-CA1-LGBK-LGBK	T	W	1.0	2.3	1.0	21.4	4.8	1.2	0.2	0.0	0.5	3.7	3.2
25	(Tegemeo*WM#322)-CA2-CC2-CABK	T	W	1.0	2.0	1.0	0.0	0.0	1.5	0.2	0.8	1.3	4.2	3.7
20	(Dorado*Tegemeo)-HW10-CA1-LGBK-CABK	T	W	1.0	3.3	1.1	6.7	12.0	1.2	0.0	0.0	0.3	3.3	3.5
1	Kuyuma	T	W	2.3	1.7	1.1	8.3	9.3	0.2	2.2	0.0	0.8	3.2	3.5
3	Macia	T	W	2.3	2.0	1.2	12.3	18.9	1.7	0.8	0.0	0.8	2.7	2.0
9	SDSL89426	T	W	2.3	1.3	1.0	8.3	17.9	0.8	0.2	2.2	0.0	3.7	3.2
16	(9MLT176/(MR112B-92M2*Tx2880)*A964)-LG8-CABK-LGBK-LGBK	T	W	2.3	2.3	1.0	0.0	25.0	1.5	0.7	0.0	0.0	3.8	2.2
17	(LG35*WM#322)-BE40-LG1-CA1-LGBK-CABK	T	R	2.3	2.0	1.0	5.5	12.2	1.2	0.0	0.0	0.0	2.5	2.7
24	(Dorado*Tegemeo)-HG15-CA1-LGBK-CABK	T	W	2.3	2.0	1.0	0.0	11.1	1.8	0.2	0.0	0.0	4.5	3.3
41	(5BRON151/(7EO366*GR107B-90M16)*Tegemeo)-HG1-LGBK-CABK	T	R	2.3	2.0	1.0	0.0	21.7	1.5	0.0	0.0	0.2	1.7	2.2
43	(6BRON168/6OB172/(88CC445*Tx2862)*Tegemeo)-HG5-CC2-LGBK	T	R	2.3	3.3	1.8	15.9	11.4	2.3	0.2	0.0	0.7	3.5	3.2
44	(Tx2883*Tegemeo)-HG17-CC2_LGBK	P	W	2.3	1.3	1.0	8.3	17.9	1.8	0.0	0.0	0.8	3.8	2.3
47	(Tegemeo*ICSR-939)-CA6-CC1	T	W	2.3	3.3	1.8	15.9	11.4	2.2	0.2	0.0	0.0	3.8	3.2
11	A964	T	W	2.7	3.0	1.0	12.2	16.7	0.2	0.2	0.0	0.2	3.7	2.8
19	(Dorado*Tegemeo)-HW4-CA1-CCBK-CABK	T	W	2.7	2.0	1.9	16.7	4.8	2.0	0.3	0.0	0.0	3.5	3.0
26	(A964*P850029)-BE9-CA1-LGBK	T	W	2.7	3.3	1.1	21.4	4.8	0.3	1.0	0.0	0.0	3.5	3.3
27	(A964*P850029)-HW6-CA1-CC1-LGBK	T	W	2.7	1.3	1.0	0.0	20.0	0.8	0.2	0.0	0.7	4.2	4.0
31	(Kuyuma*LG35)-CA6-CC2-CABK	T	W	2.7	3.0	1.3	11.1	11.1	0.2	0.0	0.0	0.0	2.3	3.0
38	(Tegemeo*ICSB12)-CA12-CC1-LGBK	T	W	2.7	3.3	2.2	11.1	22.2	1.0	0.2	0.0	0.2	3.2	3.5
42	(5BRON151/(7EO366*GR107B-90M16)*Tegemeo)-HG7-CC2-CABK	T	W	2.7	2.3	1.0	0.0	0.0	1.7	0.0	0.0	1.2	2.0	2.8
37	(Tegemeo*ICSB12)-CA2-CC1-CABK	T	W	3.3	1.3	1.0	33.3	0.0	2.3	0.2	0.0	0.0	3.3	3.5
10	EPSON2-40/E#15/SADC	T	W	3.7	1.7	1.0	4.8	25.0	0.2	1.8	0.0	1.3	3.2	2.3
7	SRN39	T	LY	4.0	2.0	1.0	0.0	59.2	0.0	2.2	0.0	0.0	3.5	2.3
15	(9MLT176/(MR112B-92M2*Tx2880)*A964)-LG8-CABK-LGBK-CA	T	W	4.0	2.3	1.0	0.0	0.0	1.5	0.0	0.0	1.2	3.5	3.3
29	(Tegemeo*5BRON139)-HW15-CA1-LD2-CABK	T	R	4.0	2.7	1.0	0.0	11.1	2.2	0.0	0.0	0.2	2.8	3.3
30	(R.88B928*Tegemeo)-HW1-CA1-LGBK-CABK	T	W	4.0	1.7	1.2	11.1	11.1	2.3	0.3	0.0	0.0	3.7	3.3
32	(Kuyuma*LG35)-CA10-LGBK-CABK	T	R	4.0	2.3	1.3	13.3	0.0	2.2	0.2	0.0	0.2	2.5	3.7
33	(Kuyuma*LG35)-CA12-CC1-LGBK	T	W	4.0	2.7	1.0	0.0	0.0	1.5	0.0	0.0	0.3	3.7	2.2
36	(Tegemeo*ICSR-939)-CA7-CC1-CABK	T	W	4.0	2.3	1.0	0.0	22.2	2.8	0.2	0.0	0.0	3.5	3.5
46	(Tegemeo*ICSR-939)-CA5-CC2	T	W	4.0	3.0	1.0	3.3	8.3	2.7	0.8	0.0	0.2	3.2	3.5
48	(Tegemeo*ICSR-939)-CA7-CC1	T	W	4.0	1.7	1.1	0.0	32.2	1.8	0.5	0.0	0.3	3.7	3.0
50	(Tegemeo*ICSR-939)-HG2-CC1	T	W	4.0	1.7	2.0	0.0	15.1	1.8	0.7	0.0	0.0	3.5	2.5

Table 1. (cont'd) **Sugarcane aphid damage, shoot fly and stem borer infested plants, plant color and grain color, disease resistance ratings in the 2008 Sugarcane Aphid Test, Potchefstroom and Cedara, South Africa and Sebele, Botswana.**

Source	Designation/Pedigree	Plant Color†	Grain Color‡	Potchefstroom Seedling Damage§	Potchefstroom Adult Damage¶	Sebele Adult Damage¶	Sebele Shootfly Infested Plants	Sebele Stemborer Infested Plans	Leaf Blight#	Rust#	Zonate#	Anthracnose#	Grain Mold††	Grain Mold††
							%	%					Cedara	Potch
23	(Dorado*Tegemeo)-HW15-CA1-CC2-LG1	T	W	4.3	2.0	1.0	8.3	6.7	1.5	0.0	0.0	0.2	4.3	2.3
28	(CE151*Sureno)-HW3-CA1-LG1-CABK	T	W	4.3	1.0	1.0	0.0	44.4	0.7	0.0	0.0	0.0	3.2	3.3
4	Tegemeo	T	W	5.0	3.0	1.1	0.0	23.4	2.5	0.0	0.0	0.5	3.3	2.2
45	(Tegemeo*ICSR-939)-CA3-CC2	T	W	5.0	2.0	1.0	11.1	9.7	2.3	0.0	0.0	0.0	3.8	3.2
49	(Tegemeo*ICSR-939)-CA10-CC1	T	W	5.0	1.7	1.0	5.6	44.4	0.8	0.2	0.0	1.3	3.8	3.2
14	(9MLT176/(MR112B-92M2*Tx2880)*A964)-CA3-CABK-CCBK-CA	T	W	5.3	2.7	1.0	33.3	13.3	1.2	0.2	0.0	0.2	2.8	2.7
40	(5BRON139/(6EO361*GR107-)*Kuyuma)-HG7-LG2-CA BK	T	R	5.3	2.7	1.0	8.3	26.8	0.8	0.3	0.0	0.7	2.5	2.8
12	Segaolane	P	W	5.7	4.0	2.5	25.0	12.4	1.5	0.2	0.0	0.2	3.2	3.0
34	(Kuyuma*5BRON155)-CA5-CC1-CABK	T	R	5.7	1.7	1.3	15.0	0.0	0.7	0.0	0.0	0.7	2.8	3.2
39	(5BRON139/(6EO361*GR107-)*Kuyuma)-HG3-LD2-CA BK	T	W	5.7	2.7	1.1	22.2	0.0	0.3	0.2	0.0	0.5	3.8	1.8
2	CE151	T	W			1.0	13.9	13.3	1.8	0.2	0.0	0.3	3.7	3.7
	MEAN			3.0	2.1	1.2	9.3	13.6	1.5	0.3	0.1	0.4	3.4	3.0
	LSD.05			2.7	1.1				0.4	0.28	0.33	0.25	0.47	0.74

†P = purple plant color, T = tan plant color.
‡R = red grain color, W = white grain color.
§ Scored on a scale of 1 = 0-10% leaf necrosis, 2 = 11-25%, 3 = 26-50%, 4 = 51-70%, 5 = 71-90%, 6 = 91-100% leaf necrosis.
¶ Scored on a scale of 1 = 0=10% leaf tissue covered by aphids, 2 = 11-25%, 3 = 26 - 50%, 4 = 51-70%, 5 = 71-90%, 6 = 91-100% leaf tissue covered by aphids.
# Scored on a scale of 0 = no disease symptoms up to 5 = heavy infestation and near total leaf death.
†† Score on a scale of 0 = no grain mold up to 5 = heavy infestation and blackened grain.

Table 2. Grain yield (tons/ha), sugarcane aphid damage, selected agronomic characteristics and disease evaluation in the 2008 Sugarcane Aphid Yield tests at Potchefstroom and Cedara, South Africa, and Corpus Christi, Texas.

PEDIGREE	Plant Color	Grain Color	Potchefstroom Seedling Damage†	Potchefstroom SCA Abundance‡	Potchefstroom Adult Plant Damage†	Potchefstroom Grain Yield	Corpus Christi Height	Corpus Christi Exsertion	Corpus Christi Midge Damage Rating§	Corpus Christi Grain Weathering¶	Leaf Blight#	Sooty Stripe#	Anthracnose#	Grain Mold††	Grain Mold††
						tons/ha	cm	cm						Cedara	Potch
(SV1*Sima/IS23250)-LG15-CG1-BG2-(03)BGBK-LGK	T	W	1	1	1	4.40	65	1	9	3.5	0.8	1.7	0.5	1.8	3.5
(Macia*GR128-92M12)-HM20-CA2-CG1	T	W	1	1	1	4.02	50	4	4	3.5	0.3	0.8	1.2	1.7	3.5
(SDSL89426*6OB124/GR134B-LG56)-lg5-cg1-(03)BG2-BG1	T	W	1	1	1	3.98	50	0	9	3.5	0.5	0.7	2.2	2.7	3.5
(A964*FGYQ336)-LG4-LG2-(03)BG1-BG3-LBK	T	W	1	1	1	3.95	38	0	6	3.5	0.2	0.3	2.3	3.5	3.5
(SV1*Sima/IS23250)-LG15-CG1-BG2-(03)BGBK-LBK	T	W	1	1	1	3.94	65	2	7	3.5	0.5	2.0	0.3	2.2	3.5
PAN84201	P	R	1	1	1	3.83					2.2	1.0	0.0	2.5	3.5
(6OB128/(Tx2862*6EO361)*CE151)-LG4-CG1-(03)BGBK-CCBK-LBK	T	W	1	1	1	3.80			9	3.5	0.2	0.8	1.7	1.8	3.5
(CE151*TAM4280)-LG15-LG1-BG1-	T	W	1	1	1	3.76	62	4	9	3.5	2.2	1.5	1.5	2.2	3.5
(Macia*TAM428)-LL9	T	W	1	1	1	3.53	42	0	2	3.5	1.0	1.3	1.5	1.8	3.5
(6BRON171/(7EO366*Tx2783)*CE151)-LG5-CG2-(03)BG1-BG2-LBK	T	LY	1	1	1	3.50	42	2	7	3.5	0.0	1.7	2.2	3.0	3.5
(Segaolane*WM#322)-CG1-(03)BGBK-CCBK-LBK	RP	W	1	1	1	3.46	50	2	1	3.5	1.5	2.8	1.8	3.2	3.5
(5BRON131/(80C2241*GR108-90M30)*SDSL9426)-LG6-LG1-BG1-BG2-LBK	T	R	1	2	1	3.38	47	4	2	2.5	0.3	1.5	1.2	3.7	2.5
(Segaolane*WM#322)-LG2-LG2-(03)BG1-LG1-LBK	RP	W	1	1	1	3.36	55	3	3	3.5	1.7	1.0	0.0	3.5	3.5
(Macia*TAM428)-LL2	T	W	1	1	1	3.35	43	1	7	2.5	2.3	0.3	2.0	1.8	2.5
(6BRON161/((7EO366*Tx2783)-HG54*CE151)-LG1-(03)BGBK-CCBK-LBK	P	W	1	1	1	3.09	40	0	1	2.5	1.3	1.2	2.8	3.8	2.5
(6BRON161/(7EO366*Tx2783)*CE151)-LG5-CG2-(03)BG1-BG2-LBK	T	LY	1	1	1	2.79	40	2	7	3.0	0.3	1.7	2.7	3.2	3.0
Tegemeo	T	W	6	3	2	2.78	48	1	3	3.5	1.8	1.2	1.5	3.2	3.5
Macia	T	W	6	3	3	2.70	50	2	6	3.5	0.2	0.3	2.3	3.5	3.5
(6OB128/(Tx2862*6EO361)*CE151)-LG16-CG1-LGBK-LG2-LBK	T	R	1	1	1	2.69	41	1	9	3.5	0.3	2.2	2.2	1.8	3.5
(SDSL89426*6OB124/GR134B-)-LG5-(03)CCBK-CCBK-LBK	RP	WB	1	1	1	2.63	45	4	2	3.5	1.8	1.3	2.7	2.2	3.5
(6BRON161/(7EO366*Tx2783)-HG54-	T	W	1	1	1	2.61	47	2	9	3.5	0.2	1.3	2.0	1.8	3.5
(6OB128/(Tx2862*6EO361)*CE151)-LG19-(03)CCBK-CCBK-LBK	T	W	1	1	1	2.60	26	0	6	3.5	1.8	1.5	1.8	3.2	3.5
(6BRON126/((87BH8606-14*GR107-90M46)-HG10)*CE151)-CG1-(03)BGBK-CCBK-LBK	T	W	1	1	1	2.31	43	3	3	3.5	1.0	2.2	2.0	2.8	3.5
(EPSON2-40/E#15-SADC*TAM428)-LG3-BG1-BG1-LBK	T	W	1	1	1	2.07	38	1	5	3.5	0.2	2.3	0.2	3.5	3.5
(CE151*TAM428)-LG1-(03)BGBK-CCBK-LBK	RP	W	1	2	1	1.68	42	0	8	3.5	0.8	1.3	0.2	1.5	3.5
Mean			1.4	1.3	1.2	3.20					0.9	1.4	1.5	2.6	2.4
LSD.05			0.20	0.50	0.50	1.30					0.6	0.6	0.4	0.5	0.73

† Scored on a scale of 1 = 0-10% leaf necrosis, 2 = 11-25%, 3 = 26-50%, 4 = 51-70%, 5 = 71-90%, 6 = 91-100% leaf necrosis.
‡ Scored on a scale of 1 = 0=10% leaf tissue covered by aphids, 2 = 11-25%, 3 = 26 - 50%, 4 = 51-70%, 5 = 71-90%, 6 = 91-100% leaf tissue covered by aphids.
§ Scored on a scale of 1 = 0-10% aborted kernels, 2 = 11-20% aborted kernels, up to 9 = 81-100% aborted kernels.
¶ Scored on a scale of 1 = Seed bright, free from mold damage, 2 = Moderately resistant to mold and seed slightly discolored, 3 = Moderately susceptible and considerable seed discoloration, 4 = susceptible with extensive seed discoloration and deterioration, 5 = Very susceptible with extensive seed deterioration.
# Scored on a scale of 0 = no disease symptoms up to 5 = heavy infestation and near total leaf death.
†† Score on a scale of 0 = no grain mold up to 5 = heavy infestation and blackened grain.

Table 3. Leaf blight, anthracnose and grain mold ratings for entries in the ADIN at Cedara, KwaZulu-Natal, South Africa.

Entry	Designation	Plant Color†	Grain Color‡	Leaf Blight	Anthracnose	Grain Mold
1	B35	P	LY	0.30	0.00	4.50
2	SC326-6	P	W	0.00	0.00	4.00
3	SC414-12E	P	W	0.50	0.00	4.30
4	86EON361	T	W	1.80	0.80	2.80
5	Tegemeo	T	W	0.30	0.30	1.80
6	Macia	P	W	0.00	0.50	3.00
7	Tx2880	P	W	1.30	1.00	4.50
8	Tx2911	P	R	2.00	1.30	2.80
9	Malisor 84-7	T	W	0.30	0.80	2.30
10	SRN39	T	R	1.80	0.30	3.80
11	Sureno	T	W	1.80	0.00	2.30
12	Tx436	T	W	1.30	0.00	3.80
13	Tx2783	P	R	2.80	0.30	2.80
14	BTx635	T	W	2.00	0.80	2.00
15	BTx623	RP	W	2.30	0.00	3.30
16	BTx631	T	W	0.80	0.30	3.80
17	Tx430	P	W-YE	1.80	0.00	3.50
18	TAM428	P	W	1.80	0.00	1.80
19	Tx7078	P	R	2.80	0.00	4.50
20	BTx378	P	R	0.80	0.00	4.30
21	99GWO92	T	R	0.00	0.30	3.80
22	B.HF14	T	W	1.00	0.00	3.50
23	B.LD6 (wxy)	T	W	0.30	1.30	3.80
24	02CA4624	T	W	0.00	1.00	4.30
25	Tx2963	T	R	0.00	1.80	2.80
26	Tx2961	T	R	0.00	1.30	3.30
27	Tx2957	T	W	0.80	1.38	2.30
28	Tx2950	T	R	1.00	0.30	2.00
29	Tx2952	T	R	1.00	0.50	2.50
30	Tx2955	T	R	0.00	0.80	3.00
31	01BRON186	T	W	0.30	0.00	3.30
32	01BRON195	T	W	1.80	0.30	4.50
33	03BRON172	T	R	2.30	0.80	3.30
34	04BRON267	T	R	1.30	0.00	2.30
35	04BRON275	T	R	1.80	0.00	3.50
36	R.01122	T	R	3.50	0.00	2.50
37	R.01302	T	R	2.80	0.30	3.00
38	R.02107	T	R	2.50	0.80	4.30
39	R.04060	P	R	2.50	0.80	4.30
40	R.04064	T	R	2.00	0.00	0.80
41	R.04153	T	R	2.00	0.30	3.00
42	B.9883	T	W	0.30	0.50	4.00
43	B.01021	P	R	2.80	0.00	1.80
44	B01035-CS2-WF1	T	W	2.00	0.00	3.30
45	B01046-CS2-WF2	P	W	3.00	0.50	2.80
46	B.01067	P	R	2.80	0.80	3.30
47	B.01074-CS2-WF1	T	R	2.50	0.30	3.00
48	B.01362	T	W	1.30	0.00	3.50
49	B.03289bmr	T	W	1.00	1.00	2.80
50	B.03290bmr	T	W	0.00	1.30	4.30
	Mean			1.40	0.40	3.20
	LSD (P>0.05)			0.66	0.43	0.83

† P = purple; RP = reddish-purple; T = tan.
‡ R = red; W = white; W-YE = White-yellow endosperm; LY = lemon yellow

West Africa
(Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal)

Bruce Hamaker and Bonnie Pendleton
Purdue University and West Texas A&M University

Co-Coordinators

Bruce R. Hamaker, Dept. of Food Science, Purdue University, West Lafayette, IN 47907-1160
Bonnie B. Pendleton, Entomology, Div. of Agriculture, Box 60998, West Texas A&M Univ, Canyon, TX 79016

Collaborators

Ababacar N'Doye, Food science sub-project coordinator, Food Scientist, ITA, Senegal
Bougouma Boniface, Food Scientist, IRSAT, Burkina Faso
Moustapha Moussa, Food Scientist, B.P. 429, INRAN CERRA, Niamey, Niger
Iro Nkama, Food Scientist, University of Maiduguri, Nigeria
Salissou Issa, Poultry Scientist, INRAN, Niger
Mamourou Diourté, Production sub-project coordinator, Plant Pathologist, IER, B.P. 262, Bamako, Mali
Adama Neya, Pathologist, INERA, Farako-Ba, B.P. 910 Bobo Dioulasso, Burkina Faso
Hamé Abdou Kadi Kadi, Entomologist, INRAN, Kollo, Niger
Niamoye Yaro Diarisso, Entomologist/Scientific Coordinator, IER, B.P. 258, Bamako, Mali
Seyni Sirifi, Agronomist, INRAN, Niger
S. Jean B. Taonda, Agronomist, INERA, Burkina Faso
Abdoul Wahab Toure, Agronomist, IER, Sotuba, Mali
Ignatius Angarawai, Millet Breeder, Lake Chad Research Institute, Maiduguri, Nigeria
N'Diaga Cisse, Breeder, ISRA, Senegal
Niaba Teme, Sorghum Breeder, IER, Sotuba, Mali
Souley Soumana, Sorghum Breeder, INRAN, Niger
Hamidou Traore, *Striga* project coordinator, INERA, Burkina Faso
Mountaga Kayentao, Weed Scientist, IER, Mali
Nouri Maman, INRAN, Niger
Moctar Wade, ISRA-CNRA, B.P. 53, Bambey, Senegal

Introduction and Justification

Multi-agency, multi-disciplinary teams of agronomists, entomologists, food scientists, plant breeders, plant pathologists, poultry scientists, extension educators, and others from Burkina Faso, Mali, Niger, Nigeria, Senegal in West Africa are developing, evaluating, and transferring technologies to improve production and marketing of sorghum and pearl millet and manage *Striga*. Agronomic and pest management technologies include use of resistant cultivars, crop rotation, intercropping, fertilizer, and herbicides to manage such pests as anthracnose and other diseases, millet head miner, sorghum midge, panicle bugs, stalk borers, storage weevils, and *Striga*. FAO estimates $7 billion annual crop losses from *Striga* that affects 100 million people in Africa. Losses of 10-100% occur and result in abandonment of arable land. Pest-resistant cultivars and improved crop, soil, water, and pest management will reduce pesticide use, conserve soil and water, more efficiently use fertilizer, and increase food and feed for domestic use and income from marketing. Development and adoption of high-yielding, quality sorghum and millet with increased nutritional value can improve nutrition and health. Work in the marketing sector links farmers to output markets involving assistance to cereal processors to develop high quality, competitive products for urban consumers and advancing sorghum and millet for poultry feed and broiler operations. Partnerships among host-country scientists, NGOs, international agencies, extension, and farmers will ensure transfer of technologies for improved agricultural production and marketing. Greater, more stable yields will better the livelihood of people dependent on sorghum and millet and help end hunger in Africa by increasing farm incomes and agricultural development.

Objectives and Implementation Sites

This regional program with collaboration among scientists at Institut D'Economie Rurale (IER) in Mali, Institut National de la Recherche Agronomique du Niger (INRAN) in Niger, INERA and IRSAT in Burkina Faso, Institut Sénégalais de Recherches Agricoles (ISRA) and Institut de Technologie Alimentaire (ITA) in Senegal, the Lake Chad Research Institute and University of Maiduguri in Nigeria, universities in the US, volunteer organizations, and private industries is contributing to INTSORMIL objectives to facilitate markets; improve food and nutritional quality to enhance marketability and consumer health; increase stability and yield through crop and natural resources management; develop and disseminate information on stresses to increase yield and quality; enhance stability and yield through genetic technologies; and better the lives of people dependent on sorghum and pearl millet.

Ababacar N'Doye, food scientist for ITA, Senegal, coordinate the processing and marketing systems component of Project 1 "Increasing farmers' and processors' incomes via improvement in sorghum, pearl millet, and other grain production, processing, and marketing systems" that focuses on processed food and animal-feed markets and their expansion through development of high-quality, competitive millet and sorghum-processed products and expanded use of sorghum in poultry feed. The overall goal is to enhance urban markets for improved and hybrid sorghum and millet cultivars for farmers to sell surplus grain with emphasis on development and transfer of food technologies to farmers, NGOs, and food processing and marketing entrepreneurs and consumers.

Mamourou Diourte, plant pathologist for IER in Mali, coordinates the production component of Project 1. The goals are to: 1) disseminate the best existing cultivars in combination with fertilizer and other crop management options; 2) identify storage pests and control measures to manage grain harvesting and storage practices; 3) develop base populations of adapted sorghum and millet cultivars resistant to pests and drought; and 4) generate new dual-purpose varieties and hybrid parental lines adapted to target environments.

Hamidou Traore with INERA in Burkina Faso is coordinator for Project 2 "Integrated *Striga* and nutrient management for sorghum and pearl millet." The goals of Project 2 are to identify and characterize *Striga*-resistant sorghum and millet; characterize and implement integrated *Striga* management systems for millet that incorporate fertilizer and crop rotation or intercropping millet and cowpea; characterize and implement integrated *Striga* management systems for sorghum rotated with cotton; assess effects of herbicidal seed treatments on crop performance and *Striga* management; evaluate ALS-resistant genotypes; and transfer *Striga* control methods to increase yield of sorghum and millet and the incomes of farmers across West Africa.

Research Methodology and Strategy

The processing and marketing systems component of Project 1 coordinated by Ababacar N'Doye, food scientist from Senegal, involves food scientists Boniface Bougouma from Burkina Faso, Iro Nkama from the University of Maiduguri in Nigeria, Moussa Moustapha and Kaka Saley from Niger; and Salissou Issa, poultry scientist from Niger. The project focuses on processed food and animal-feed markets and their expansion through development of good-quality, competitive millet- and sorghum-processed products and greater use of sorghum in poultry feed. Activities focus on processed products that contribute to development of markets for sorghum, millet, and fonio by development and transfer of technologies to entrepreneurs. Technologies for production of breads and other products based on sorghum, millet, and fonio will be diffused; local processing groups will be assisted to diffuse new processing technologies and initiate businesses; and sorghum, millet, and fonio will be characterized as "functional foods" for health. Additionally, research from Purdue University has shown the potential of using sorghum grain proteins as active viscoelastic components of composite bread so that sorghum flour can be incorporated at high levels with wheat flour. The goal is to have new competitive composite flours and other products in the marketplace. For animal feed, use of sorghum in poultry feed in West Africa is being validated and education provided on availability of low-tannin varieties and aflatoxin-free sorghum grains, with the goal to increase use of sorghum grain for poultry.

The production component of Project 1 is coordinated by Mamourou Diourte, plant pathologist in Mali, and involves pathologist Adama Neya in Burkina Faso; agronomists Jean B. Taonda in Burkina Faso, Abdoul Wahab Toure in Mali, and Seyni Sirifi in Niger; entomologists Niamoye Yaro Diarisso in Mali and Hame Abdou Kadi Kadi in Niger; and plant breeders Niaba Teme in Mali, Souley Soumana in Niger, N'Diaga Cisse in Senegal, and Ignatius Angarawai at Lake Chad Research Center in Nigeria. The scientists are using seed multiplication, on-farm testing, and exchange of varieties of sorghum and millet with the goal of disseminating the best cultivars in combination with fertilizer and other crop management options such as legumes in crop rotations and crop protection options. They also are identifying storage disease and insect pests and control measures. They are developing base populations of cultivars of sorghum and millet with known adaptation, stability, and acceptability through multi-environment experiments and resistance to pests and drought. They are using conventional and/or marker-assisted recurrent selection to generate adapted dual-purpose varieties, open-pollinated varieties, and hybrid parental lines.

Project 2 on "Integrated *Striga* and nutrient management for sorghum and pearl millet" is coordinated by Hamidou Traore from Burkina Faso. Involved are Mountaga Kayentao from Mali, Nouri Maman and Souley Soumana from Niger, and Moctar Wade from Senegal. The scientists are identifying *Striga*-resistant sorghum and millet; combining and implementing methods such as fertilizer, rotation of sorghum with cotton, and intercropping millet and cowpea to control *Striga*; evaluating herbicidal seed treatments; evaluating ALS-resistant genotypes; and transferring control technology packages for farmers.

Research Results

Funds were not distributed to the scientists under the new project until May 2008. Most sorghum and millet will not be mature or harvested until October or later, so yield data were not yet available.

Project 1 - Increasing Farmers' and Processors' Incomes Via Improvement in Sorghum, Pearl Millet, and Other Grain Production, Processing, and Marketing Systems

For the processing and marketing component of Project 1, Moustapha Moussa reported 1.5 tons of Sepon 82 and MR732 sorghum grains obtained from INRAN Maradi 2007 sorghum nursery production and 1 ton of millet grain purchased from the market by processing groups were processed to quality sorghum flour and agglomerated products (couscous, degue and boulettes) using the optimized cereal processing pilot unit at the INRAN food technology laboratory through funding from INTSORMIL. Four women's associations (Marie Tout, Lakal Kaney, Multimetiers, and Eden) with 20 members each that process and market sorghum and millet foods in Niamey were involved. After testing for quality and safety, 2 tons of sorghum and millet products (flour, couscous, degue, and boulettes) were marketed with collaboration of processors working with the project.

INRAN contracted with 2 farmers at N'Konni and 1 at Maradi to grow 15 tons of good-quality grain of SS-D35, Sepon 82, and IRAT204 sorghum for making agglomerated products, instant flour, and composite bread. The grain will soon be harvested, processed, and marketed with the collaboration of the processing groups involved in the project. INRAN scientists are training sorghum- and millet-based processing groups in Niamey in processing and business planning to help develop and expand processing activities.

At ITA in Senegal, the baking group tested a sorghum high digestible mutant developed at Purdue in composite flour breads. This grain has the storage protein, kafirin, in a form whereby proteins can interact with wheat glutens. Initial testing shows a potential to mobilize the kafirin proteins to participate in dough and bread development. Further testing is ongoing between ITA and Purdue laboratories.

For the production component of Project 1, Hame Abdou Kadi Kadi in a survey with 290 men and 30 women farmers from 16 villages in 2 regions, 14 extension agents, and 4 interns from University Abdou Moumouni of Niamey, identified storage insects, evaluated facilities, and assessed botanicals and cultural methods to prevent damage to millet and sorghum. The storage facilities differed by region; Andropogon was used for cylindrical granaries covered with grass at Maradi and bricks with grass were used at Tahoua. Dry spikes and/or panicles were stored. Grain was stored in barrels, burlap bags, plastic bags, and storage houses. (Table 1)

Niamoye Yaro Diarisso in Mali assisted farmers with evaluating Andropogon gayanus in 3 border rows 50 cm apart and 30 cm between plants on 7 and 8 July 2008 at Finkolo and Zanradougou, respectively, in the Sikasso region of Mali, to draw stalk borers away from millet. Andropogon was selected based on use and economic return by farmers during a Participatory Rural Appraisals and Structured Socio-economic Survey. Andropogon was attractive to stalk borers and/or parasitoids in a study funded by UNEP through ICIPE. A randomized complete block with 5 farms was used. Millet was planted on 17 and 18 July in 15 x 10-m plots 2 m apart at Zanradougou and Finkolo. Millet was surrounded by Andropogon or millet (check). Pests and natural enemies were sampled on 10 plants of millet and Andropogon 30, 70-80, and 100-110 days after emergence. Percentage of deadhearts and numbers of larvae and pupae were determined on 6 and 7 September 2008, 30 days after emergence at Zanradougou and Finkolo. Damage was greater at Finkolo than Zarandougou. Millet was less damaged surrounded by Andropogon (1.7%) than millet (5.3%). Damage scores were 5.8, 4.4, and 1.7 for millet surrounded by millet, Andropogon, and millet surrounded by Andropogon, respectively, at Finkolo. Damage scores at Zanradougou were 4.7 for millet surrounded by millet, 2.2 for Andropogon, and 1.7 for millet surrounded by Andropogon. Damage will be assessed again at harvest. (Table 2)

Hame Abdou Kadi Kadi, with help from Dr. Kadri Abooubacar and an intern from the University Abdou Moumouni of Niamey, evaluated at Kollo resistance to millet head miner of millet developed with Issaka Ahmadou, INRAN millet breeder. Genotypes were HKB, H 80-10 GR, TARAM, SOSAT–C, MANGARANA, HKP-GMS, ICMV IS 89305, ZATIB, MANGARANA x ICMV IS 89305, SOSAT-C x HKB, SOSAT-C x ZATB, and TCHOUMO. A completely randomized block with 3 replications was used. Each sub-plot 12 m2 had 4 rows 3 m long, with 1 m between rows and 1 m between hills. The millet was not harvested and yield data not available yet.

Hame Abdou Kadi Kadi helped introduce sorghum midge-resistant 99-SSD35 and its parent Mota Maradi (early maturing from Niger) at farms in 5 villages of 2 regions of Niger. The activity involved 4 extension agents, 12 men and 4 women farmers from 4 villages and a farmer's association ("TAYMAKO") of 74 men and 6 women. The group conducted 4 tests with 2 planting dates at 1 site. The group is eager to continue testing and be involved in seed production. Farmers are producing SSD35 in many fields at 1 site. The farmers' association and FAO grew 60 and 30 hectares of 99-SSD35 to give to farmers. The sorghum was not harvested and yield data are not available yet.

Mamourou Diourte reported results from preliminary evaluation in an anthracnose nursery in Mali indicated only 07CZF5P-56, 07CZF5P-11, 07SIRF5P-143, 07KEGIIT-122, 07SBF3DT-64, and 07SIRF5T-16 of the 45 breeding accessions scored no more than 5% (less than 2 on a 1-9 scale) of foliar disease severity at physiological maturity. Almost all 45 accessions are fairly resistant.

The ongoing crossing program in Mali assures improvement of breeding stock through recombination of the best materials. Crosses were made at Sotuba. New crosses will be made in the off-season nursery. Crossing will be done to maintain A/B lines.

Single-plant selections of F2 families at multiple locations in Mali were advanced by the pedigree method. A total of 34 F2, 201 F4, and 210 F5 progeny lines was evaluated. Early F4 progenies were evaluated at Béma and Cinzana, medium at Sotuba and Kolombada, and late at Farako and Kita. Early F5 were selected at Béma and Cinzana and late at Longorola and Kita.

Advanced elite early varieties were evaluated in a randomized complete block at Bema and Cinzana in Mali. Each plot had 4 rows 0.75 m apart and 5 m long. Farmers compared 20 early-maturing sorghums to a local check. Each plot was 500 m2 with rows 0.75 m apart and 5 m long. Yield of 25 GI and 18 GII agronomically elite, medium-maturing varieties and local check were evaluated in a randomized complete block at 3 stations in the Sudan Zone of Mali. Each plot was 4 rows 0.75 m apart and 5 m long. Ten medium-maturing breeding lines were compared to local checks by farmers at Bancoumana and Kafara and at Katibougou station. Each plot was 22.5 m2; 6 rows were 0.75 m apart and 5 m long. Yields of 23 agronomically elite, late-maturing breeding lines and 3 local checks of GI and 20 lines and 2 local checks for GII were evaluated at 3 locations in a randomized complete block in Mali. Each plot had 4 rows 0.75 m apart and 5 m long. Seven late-maturing varieties were compared by farmers to the local check at Kita. Each plot was 21 m2, with rows 0.75 m apart and 5 m long. At harvest, the cultivars will be evaluated for maturity, yield, agronomic desirability, and food quality.

Table 1.

Pest	Botanical plant/method of use	Inert
Grain moth, Sitotroga	Cowpea, Vigna inguiculata, leaves repulse storage pests;	Ash,
cereallella;	Zouray, Boscia Salicifolia, leaves under spikes or panicles during drying,	
Confused flour beetle,	leaves superposed between tied spikes or panicles within granary;	Salt,
Tribolium confusum;	Yakuwa, Hibiscus sabdariffa,leaves and branches pounded and put on	
Red flour beetle,	granary poles;	Ash and
Tribolium castaneum;	Karanguia, Cenchrus biflorus, spiny fruit used on path of mice and rats;	salt mix
Lesser grain borer,	Komeya, Erasgrostis tremula, threading of the superior part of Erasgrotis	to control
Rhyzopertha dominica;	and superposed between tied spikes or panicles in granary;	termites
Grain trogoderma,	Dorowa, Parkia biglobos, fruit pounded and powder used around granary	and ants,
Trogoderma granarium;	poles;	
Flour pyralid, Ephestia	Rumfu, Cassia singueana, and neem, Azadirachta indica, flowers of	Fine sand,
kuehniella;	Cassia and leaves of neem mixed with seeds of cereals;	
Birds;	Houda Sartche, Caralluma dalzielli, leaves and branches pounded and put	Sun
Mice;	in granary poles;	drying
Rats;	Onion, Allium cepa, and garlic, Allium sativum, powder to prevent	
Mold;	damage	
Humidity		

Table 2.

		% vegetative plants with deadhearts by stalk borers		
Village	**Farmer**	**Millet surrounded by *A. gayanus***	**Millet surrounded by millet**	***Andropogon gayanus***
Finkolo	Diakalia BALLO	1.5	10.3	2.0
	Issouf BALLO	1.5	4.3	3.0
	Abdoulaye KONE	2.8	5.2	5.5
	Seybou KONE	2.3	6.6	7.1
	Oumar TRAORE	0.5	2.5	4.6
Zanradougou	Nouhoum DJOURTHE	3.7	0.0	1.2
	Siaka DJOURTHE	0.0	12.5	3.0
	Tidiani SANOGO	1.5	1.5	2.4
	Adama SONOGO	Plants damaged by animals		
Mean damage		1.7	5.3	3.6

Grinkan caudatum-guinea sorghum distributed to 42 farmers in Kaniko village in Mali was extremely infested by panicle bugs but had hard grain and was not damaged. The sorghums are not mature or ready to harvest yet.

N'Diaga Cisse from Senegal reported that Foundation seeds of CE151-262 and F2-20 sorghum varieties were produced and harvested by ISRA in October 2007. The seeds were made available for certified seed production to ANCAR, EWA, and CPFP organizations that are respectively an extension service, a NGO, and a training center for producers. CPFP produced CE151-262 on 1hectare during 2008. The field was visited by 44 producers from 10 farmer organizations. One ton of seed will be distributed to seed producers for a second production before large-scale production. EWA distributed CE151-262 and F2-20 to 3 cooperatives it organized. These varieties were planted on 7 and 1 hectares, respectively. As many as 10,000 farmers can benefit from multiplication of seeds of these sorghums. Seeds of F2-20 produced on 4 hectares this season with ANCAR supervision will be available to farmers' communities participating in the INTSORMIL production and marketing project. The F2-20 seeds produced last year were used for the program this year.

Yields of 52 new sorghum lines to improve quality of current varieties were evaluated by ISRA at Bambey Station. Lines with good yield potential (3-4 tons per hectare) were observed. The lines were divided into 3 maturity classes: less than 65, 65-69, and more than 70 days to flowering. These classes had 15, 20, and 20 entries, respectively, and were introduced in 3 experiments at Bambey and Nioro stations. The plants are now being harvested, and yield data soon will be available.

S. J. B. Taonda, agronomist for INERA in Burkina Faso, trained technicians of the Hunger Project NGO and farmers in technology of micro-dose; technical characteristics and techniques for using improved varieties of sorghum, millet, and cowpeas in tests; and warrantage. The training scheme involved indigenous resource people who diffused the technology in their core communities. After the courses by the research team, a research technician was assigned to provide supervision to the village. Farmers trained in the field school plots transmitted knowledge and skills to at least other 4 farmers. Two endogenous leaders were identified to benefit training of trainers and technicians of the Hunger Project. They effectively train other farmers. (Table 3)

Following the project, the Hunger Project NGO took over and asked for research expertise to continue to train farmers for adoption of micro-dose technology in all agricultural areas of Burkina Faso. (Table 4)

Twenty tests were used in 2008 at Nagreongo, Burkina Faso, to compare Sariasso11 and local "Raoumdé" sorghum varieties in combination with no or micro-dose of 15:15:15 NPK fertilizer. Following training, farmers with their own funds or financial support through implementation of the new warrantage system of micro-credit from the Hunger Project adopted micro-dose technology in fields at Nagreongo. (Table 5)

Adama Neya, plant pathologist for INERA in Burkina Faso, was involved in: (a) advanced screening sorghum lines/varieties for disease resistance; (b) a field day; (c) using on-farm tests to transfer new technologies to farmers; (d) and training farmers and technicians. An advanced screening experiment was started in July 2008 at Farako-Ba using the 6 best sorghum lines from the INERA breeding program and 5 best lines from the Mali breeding program. Most sorghum lines had good resistance to diseases under natural and high disease pressure (using susceptible infector rows).

A Field Day at Farako-Ba Station in Burkina Faso in October 2007 demonstrated 7 improved varieties (Framida, Sariaso 01, Sariaso 02, Sariaso INI-20, Sariaso INI-24, ICSV 111, and Sariaso 03) and the effect of seed treatment with Calthio DS chemical

Table 3.

Training theme	Participants		
	Male	Female	Total
Micro-dose technology	79	71	150
Characteristics and technical itinerary of sorghum, millet, and cowpea improved varieties	80	72	152
Warrant credit system (negotiation, purchase, storage techniques, maintenance of stock, credit monitoring)	82	28	110
Field day	104	80	184
TOTAL	345 (58%)	251 (42%)	596 (100%)

Table 4.

Province/zone	Epicenter/site	Participants		
		Male	Female	Total
Bam (Kongounssi)	Loaga	64	36	100
Gourma (Fada)	Diapangou	44	16	60
Balé (Boromo)	Vy	48	22	70
Boulgou (Tenkodogo)	Bissiga	38	22	60
Houet (Bobo)	Yéguérésso	68	32	100
Kouritenga (Koupéla)	Liguidimalguem	32	28	60
TOTAL		294	156	450
Percentage		65	35	100

Table 5.

Village	Crop	Number of farmers	Cultivated land (hectares)
Nahartenga	Sorghum	36	53
	Millet	28	27
Nagreongo	Sorghum	72	150
	Millet	52	78
Tanghin	Sorghum	30	44
	Millet	22	11
V2	Sorghum	44	48
	Millet	16	8
V5	Sorghum	86	160
	Millet	54	84
Saraogo	Sorghum	38	58
	Millet	22	36
Kologkoom	Sorghum	24	14
	Millet	20	12
TOTAL		544	783

against cover smut on sorghum. More than 160 people (farmers, students, processors, extension workers, and leaders of farmer`s organizations) viewed the plots. The same plot was used at Farako-Ba to transfer new technologies to end-users in July 2008.

Since July 2008, a technology transfer test was used in Karangasso-Vigueé and Klesso villages in western Burkina Faso to show performance of 4 white improved sorghum varieties (Sariaso 01, Sariaso INI-20, Sariaso INI-24, and ICSV111) and seed treatment with Calthi WS to control seed-borne diseases. More than 260 people, mostly farmers and extension workers, visited the on-farm tests. All are willing to adopt the new improved sorghum varieties. They will be provided seed for the next rainy season. In May 2008, 3 extension agents and 32 farmers from Karangasso-Vigué, Bio, Bio-Djosso, Wara, and Klesso villages in western Burkina Faso were trained in impact and control of diseases of sorghum and millet. Production and control were by improved varieties and chemical treatment by Apron Star against downy mildew of millet and Calthio WS against covered smut on sorghum. Activities are on-going to identify methods to control storage pests on farms.

A student from the Polytechnic University of Bobo Dioulasso in Burkina Faso was trained for 2 months in the plant pathology laboratory at Farako-Ba in using laboratory tests for chemical control of sorghum seed-borne diseases.

Ignatius Angarawai, millet breeder with Lake Chad Research Institute in Maiduguri, Nigeria, worked to improve productivity and yield stability of millet in semi-arid zones of Nigeria that will spill over to neighboring West African countries. He identified SOSAT-C88 as resistant to downy mildew. Hybrid 25B-4 X SOSAT-C88 was very resistant to downy mildew and may be advanced. He identified PS563 monodii as a source of a *Striga* resistance gene and deployed it to the Ex-Borno cultivar. He found the hybrid of Ex-Borno x PS563 very resistant to *Striga* emergence. It was backcrossed to BC3F1. Results were disseminated in on-farm experiments, with 17 experimental varieties for selection by farmers in 12 villages each with an average of 200 farm families.

Project 2 – Integrated Striga and Nutrient Management for Sorghum and Pearl Millet

For Project 2, Souley Soumana reported effects of herbicidal seed treatments on crop performance and *Striga* management at Sotuba and Samanko in Mali, Konni in Niger, and Kamboinse in Burkina Faso. ALS-herbicide tolerant, food-grade sorghum was evaluated in replicated experiments with metsulfuron-methyl seed treatments in *Striga*-infested plots. The experiment was a randomized complete block with 6 replications. Treatments were evaluated in single-row plots (3 x 1.6 m). Ten seeds of sorghum and *Striga* seeds were planted per hill. Traits measured for each plot were: day when the first *Striga* emerged, numbers of *Striga* plants at 60 days and 90 days after planting, and day when 50% of sorghum was flowering. Treatments were: 0, 0.003, 0.006, 0.0125, and 0.025 mg ai MET/seed.

Souley Soumana also helped characterize the most resistant sorghum varieties in the region and develop and transfer an integrated *Striga* management system for guinea sorghum and non-guinea zones of West Africa. Fifteen genotypes provided by the PIs were evaluated at IER, Sotuba, Mali; Konni, INRAN, Niger; Bambey, Senegal; Kamboinse, Burkina Faso; and ICRISAT, Mali. Genotypes were F220, CEF322/35-1-2, SARIASO-14, SARIASO-9, ICSV1049, SRN-39, Brhan, Mota Galmi, WASSA, SEGUETANA, CSM388, Malisor 92-1, Linea3, CE145-66-V, and SL246. A randomized complete block with 3 replications in 1-row plots 3 x 1.6 m was used. The same data as for the herbicide seed treatment will be collected.

Sorghum breeding lines from SRN-39 or Brhan that combine tolerance to ALS herbicides with resistance to Striga were evaluated. Sixty ALS herbicide-resistant genotypes that segregate for low-germination stimulant production were evaluated in 1-row plots (3 x 1.60 m) with 2 replications. The same data as for the *Striga* experiment will be collected.

Sorghum for the 3 experiments was planted on 30 June at Konni Station in Niger. Plants were thinned to 3 on 20 July. To ensure uniform infestation, 0.55 g of *Striga* seed collected from the previous year were planted with the sorghum seeds in each hill. Plots were hand-weeded to control non-target weeds 14 and 30 days after planting and as needed later. *Striga* was counted on 29 August and 30 September in all plots.

During 2008, more than 200 F1 are being grown to produce F2 seeds in Niger. The F3 and F4 generations were evaluated and selections advanced by the pedigree method. The backcross program was continuous for development of new adapted A lines. Seeds of parental lines of N223A*N223B, TX623A*TX623B, and 150A*150B were increased.

In Mali, advanced sorghum breeding lines were evaluated under artificial infestation by *Striga*. Six replications of 4 doses of herbicide and a check were used to evaluate the effectiveness of herbicide doses in treating sorghum seed against *Striga* at Sotuba. To develop an IPM package to control *Striga* in different agroecological zones of West Africa, 15 genotypes from Burkina Faso, Mali, Niger, Senegal, and ICRISAT Bamako were grown with 3 replications at Sotuba. Sixty lines derived from SRN39 and Brhan sorghum tolerant to herbicide resistance to *Striga* were grown at 2 research stations. *Striga* plants per plot were estimated 60 and 90 days after planting. In general, infestation by *Striga* was low probably because of sufficient rain during 2008. The sorghum plants have not been harvested yet.

Moctar Wade from Senegal reported the extent and intensity of infestations by *Striga* hermonthica have increased and threaten production of cereals in the peanut belt. A Farmers' Field School was used for participatory diffusion of integrated *Striga* management. During 2008, a Farmer Field School was implemented in one field-school village (Tounghor) 30 km from Bambey. Extension workers previously trained in Farmer Field School techniques (2005 and 2006) acted as facilitators. The facilitators held a field school once per 15 days.

Three plots 400 m² were delimited in a field naturally infested by S. hermonthica: one for the innovations suggested for integrated *Striga* management (Souna millet with 2.5 tons/hectare of sheep or goat organic manure, 150 kg/hectare NPK, 100 kg/hectare of urea, and mechanical weeding at 15, 35, and 65 day after planting), another for usual farmer practices (Souna millet and mechanical weeding at 15 and 35 days after planting), and the third for niébé IS86-283:Mélakh false host (suicidal germination) of *Striga*.

Weekly activities at the Farmer Field Schools were: (1) agroecosystem analysis, (2) implementation of agroecosystem analysis decisions, (3) special topics, (4) data collection, (5) icebreaker, (6) evaluation, and (7) planning for the Farmer Field School the following week. In addition to the 2 weekly Farmer Field Schools, exchange visits were organized between farmers to allow those from other villages to find solutions to their *Striga* problems through the Farmer Field School and confront their knowledge and exchange experiences in *Striga* control and agricultural production. There were 27 participants from 5 villages. Thirty non-participant farmers from other villages visited the Farmer Field School experiments. The program made farmers better able to understand the *Striga* life cycle (germination to flowering and seed production); understand cereals and false host cropping and *Striga* management strategies for more sustainable production; understand how false hosts like cowpea (IS86-283:Melakh) deplete the *Striga* seed bank in the soil while producing food and improving soil fertility; and develop technical skill for using integrated *Striga* management. Participants were convinced nutrients such as sheep or goat manure, NPK fertilizer, and urea significantly delay *Striga* emergence and enhance plant growth and increase millet productivity.

Methods to control *Striga* were demonstrated in fields of 20 farmers -- 4 per the villages of Daadack, Baaback, Batal, Ngoye, and Ngayokhème in the peanut belt near Bambey. The same treatments as used at the Farmer Field School site were used on plots 500m². Visits and training meetings for farmers were once a month. The plots were Souna millet with 2.5 tons per hectare of sheep or goat manure, 150 kg per hectare of NPK, 100 kg per hectare of urea, and mechanical weeding 15, 35, and 65 days after planting; Souna millet weeded mechanically 15 and 35 days after planting; and a niébé IS86-283:Mélakh false host. Cultivated were 1,500m² x 20 = 30,000 m². Twenty farmers were taught integrated *Striga* management. Fifty farmers from the village and surrounding villages visited the demonstration fields. Field demonstrations require less time and funds and are a good tool for diffusing technologies but are less effective than Farmer Field Schools.

Sorghums F220, CEF322/35-1-2, SARIASO14, SARIASO9, ICSV1049, SRN39, Brhan, Mota Galmi, WASSA, SEGUETANA CZ1, CSM388, MALISOR 92-1, Lina3, CE145-66-V, and SL246 from Burkina Faso, Mali, Niger, Senegal, and ICRISAT were evaluated in a *Striga*-infested area of the field and pots in Senegal. The plot was 3 x 1.6 m = 4.8 m². In both field and pot culture, CEF322/35-1-2 (Burkina Faso), Brhan (Niger), Lina3 (ICRISAT), and SL246 (Senegal) were resistant. All 11 genotypes were susceptible to the *Striga* Senegalese race, with 50-100 *Striga* per square meter. Experiments are ongoing until harvest. Resistant lines accepted by farmers will be cultivated at several locations next year.

Networking Activities

Workshops and Meetings. The PI and collaborators presented research and discussed workplans at the Sorghum, Millet and Other Grains West Africa regional meeting, Bamako, Mali, 14-16 April 2008. Hame Abdou Kadi Kadi taught farmers in the field in Niger identification, biology, and ecology of millet head miner and sorghum midge. Information on sorghum was provided to researchers, extension, NGOs and development project personnel, private sector, and farmers at an ICRISAT/INRAN open house.

Research Investigator Exchanges

The scientists met for a Sorghum, Millet and Other Grains West Africa regional meeting in Bamako, Mali, 14-16 April 2008. Information on sorghum was provided for researchers, extension, NGOs and development project personnel, private sector, and farmers at an ICRISAT/INRAN open house.

Research Information Exchange

Ignatius Angarawai was a team member for marker-assisted selection in pearl millet for downy mildew resistance, in collaboration with ICRISAT Nairobi, sponsored by Syngenta Foundation. Several scientists, including Niamoye Yaro Diarisso in Mali, Hame Abdou Kadi Kadi in Niger, Eva and Fred Rattunde with ICRISAT in Mali, and Alain Ratnadass with CIRAD/ICRISAT in Niger planned collaborative research for the “Cereals for the Drylands” proposal to the Gates Foundation.

Germplasm Conservation and Distribution

Fifteen tons of sorghum grain and tons of sorghum and millet products were produced and marketed in Niger. Hectares and tons of seeds of sorghums were produced for farmers in Mali, Niger, and Senegal. Resistant millet was disseminated to 200 farm families in Nigeria. Bougouna Sogoba with AMEDD NGO in Koutiala assisted with transferring seeds of resistant sorghums to farmers in villages in Mali.

Training

Ignatius Angarawai completed Ph.D. training at Federal University of Technology, Yola, and participated in molecular training, University of Georgia, USA, in collaboration with Professor Katrien Devos, sponsored by the National Science Foundation.

Publications and Presentations

Journal Articles – Angarawai, I.I, A.M. Kadams and D. Bello. 2008. Gene effects controlling heritability of downy mildew resistance in Nigerian elite pearl millet lines. International Digital Organization for Scientific Information (IDOSI) Publications P-100, St. # 7, Sohailabad, Peoples Colony No 2, Faisalabad, Pakistan.

Angarawai, I.I, A.M. Kadams, D. Bello and S.G. Mohammed. 2008. Quantitative nature of downy mildew resistance in Nigerian elite pearl millet lines. Journal of Semi Arid Tropical Agricultural Research, Patancheru, AP, India.

Wilson, J.P., M.D. Sanogo, S.K. Nutsugah, I. Angarawai, A. Fofana, H. Traore, I. Ahmadou, and F.P.Muuka. 2008. Evaluation of pearl millet for yield and downy mildew resistance across seven countries in sub-Saharan Africa. African Journal of Agricultural Research 3: 371-378.

Presentations

Host-country and U.S. PIs reported at the Sorghum, Millet and Other Grains West Africa regional meeting, 14-16 April 2008, Bamako, Mali.