

# Host Country Program Enhancement





## Central America (El Salvador, Nicaragua)

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### 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 productivity, 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 Nacio-

nal de Tecnología de Agropecuaria y Forestal (CENTA), El Salvador; Instituto Nicaraguense de Tecnología 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 Agrícola Panamericana (EAP), Honduras based upon past collaboration. INTSORMIL maintains a Memorandum of Understanding with the Dirección de Ciencia y Tecnología Agropecuaria (DICTA) in Honduras, and program activities continue on a limited basis. Historically, INTSORMIL has developed linkages with the regional seed companies Cristiani Burkart (now owned by Monsanto) 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 2008-2009 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.

## 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<sup>-1</sup>, the average grain yield was 1.5 Mg ha<sup>-1</sup> (FAO, 2004). More recently, statistics in El Salvador document an average yield of > 2.0 Mg ha<sup>-1</sup> 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 sys-

tem is maize intercropped with maicillos criollos (called millón in Nicaragua). These tropical grain sorghums are three to four meters tall, drought tolerant, and photoperiod sensitive. The grain is used as human food and a feed grain for livestock, and the stover is used for livestock forage. Although maicillos criollos produce low yields, they are planted on approximately 67% of the grain sorghum area in Central America. The limited grain yield response of traditional maicillo criollo varieties to management practices is a primary constraint to increased production. Soil and water conservation, improved production practices and soil fertility management, and increased genetic potential of both maicillos criollos and other sorghum varieties is essential to obtain economical yield increases. To date, increased grain sorghum production, yield and area are due primarily to utilization of improved cultivars (hybrids and varieties), 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

Collaborative research plans of work are planned and organized within both Nicaragua (INTA) and El Salvador (CENTA). Within each research agency, scientists interested in conducting funded research within the mandate of the INTSORMIL program are invited to submit proposals for funding. Projects are reviewed by the regional coordinators and funding is allocated based on mutual agreement on the projects. The areas of emphasis were plant breeding, agronomy, plant pathology, entomology, economics, quality and extension. As the primary cropping year for sorghum begins in August, funding and research are slightly ahead of the INTSORMIL funding year. Activities in this report are associated with the crop year 2008 (May – December 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.

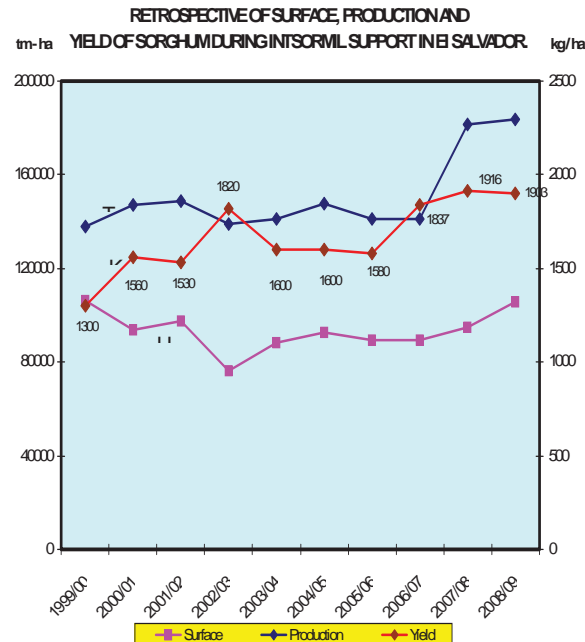


Table 1. Results of the PCCMCA sorghum trial, combined across seven locations in Central America.

HIBRIDO	Rendimiento grano. (tn ha <sup>-1</sup> )	Días floración	Altura planta (cm)	Largo Panoja (cm)	Exersión (cm)	Enferm. Foliar (1-5)	Color grano
MSG 540	6.08a	68	161	28.1	17.0	2.60	Rojo
MSG 541	5.76ab	67	152	28.6	14.8	2.40	Rojo
SR-340	5.46 bc	66	153	29.1	18.9	2.43	Rojo
AMBAR (TC)	5.38 bcd	66	147	27.4	14.7	2.67	Rojo
SR-360	5.34 bcd	66	151	29.3	18.6	2.58	Rojo
ESHG-3	5.19 bcde	68	137	30.7	19.9	1.85	Blanco
CBH-8078	4.97 cdef	65	145	28.5	17.9	2.60	Rojo
CBH-8076	4.95 cdef	68	150	26.8	18.4	2.55	Rojo
BORA	4.83 defg	65	122	27.5	18.4	2.72	Rojo
CBH-8075	4.73 efg	63	147	31.0	17.6	3.10	Rojo
CBH-8077	4.43 fg	64	118	32.7	14.6	3.67	Rojo
81T91	4.27 g	65	149	25.3	18.3	3.08	Rojo
X	5.12	66	145	28.6	17.2	2.66	
Significancia	**						
DMS	0.61						
CV(%)	16.95						

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 of 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. The most advanced selections are now at the F5 and are ready for replicated testing.

In hybrid testing, the PCCMCA was coordinated by Rene Clara. A total of 8 locations were planted and grown throughout Central America. In El Salvador and Nicaragua, INTSORMIL

collaborators conducted these PCCMCA trials. In 2008, the trial had 13 entries with 10 of these entries coming from private industry and the remainder from INTSORMIL supported breeding activities (Table 1). In these trials, the hybrid ESHG3 (CENTA hybrid with INTSORMIL developed parentage) produced the highest yields in both 2005 and 2006.

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,

**Table 2. Data obtained from seed production trials of the grain sorghum hybrid, ESHG-3 in Santa Cruz Porrillo, El Salvador 2007.**

Planting Ratio (Relaciones de siembra)	Planting Time	Height Cms.	Days to Flowering	Seed Set %	Seed Yield kg.ha <sup>-1</sup>
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

**Table 3. The effect of nitrogen rate on biomass yield and plant height in multiple cuts of the INTA forage hybrid in Managua, Nicaragua.**

Nitrogen Rate	Biomass Yield (Kg/ha)	Height (cm.)	Biomass Yield (Kg/ha)	Height (cm.)
	Primary Cut	Primary Cut	Second Cut	Second Cut
65 Kg/ha	8405	184.88	3531	128.25
130 Kg/ha	9118	194.25	4727	134.69
195 Kg/ha	12571	196.81	5612	143.94
0 Kg/ha	5269	125.25	1979	108.69

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 2). This trial was repeated in 2008; while not shown the trends were exactly the same and the recommendations are that the male and female lines be planted simultaneously with a 3:1 ratio for maximum productivity.

### **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 m<sup>2</sup>, 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 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 1000m<sup>2</sup>, divided into 500m<sup>2</sup> for 99ZAM 676-1 and 500 m<sup>2</sup> 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 asociado 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 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: In 2007, four populations of the Forage Variety INTA were evaluated (266,000, 332,500, 399,000 and 465,500 plants per hectare). 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 and 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. The N rate study was repeated in 2008 with an essentially linear response to N being observed (Table 3).

### **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.gov.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 Eduvigis, 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.

Sorghum milling capacity is slowly but consistently increasing. In 2007 two Omega VI mills were purchased by INTSORMIL and are 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. To supplement this work, an additional five omega mills were distributed at strategic locations throughout the country. Training for their use was provided as part of the INTSORMIL technology training.

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

**Table 4. Grain quality parameters and milling quality of grain from El Salvador Macio Criollos grown commercially in 2008.**

Sorghum Variety	Endosperm Texture	Test Weight (Kg./hl)	100 grain weight (g)	Grain Color	Glume Color	Diám . (mm)	Mill Yield (90 mesh) (%)
Centa-textistep	Soft	65.27	2.33	Cream	Purple	3.6	32.19
Punta de Lanza	Soft	59.95	3.6	Cream	Red	4.0	43.57
Zapa Sonsonate	Soft	62.33	2.46	White	Red	3.3	45.51
Cacho de Chivo	Soft	60.28	3.35	White	Tan	3.2	51.37
Mnzano	Hard	64.68	2.53	Cream	Purple	3.6	48.83
Guacotex	Soft	60.10	2.87	White	Purple	3.7	47.15
Sapo %	Hard	60.95	3.53	White	Purple	4.6	38.95
Nueva Guadalupe	Soft	59.71	2.70	Pearly	Red	3.2	41.70

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.

The quality of sorghum produced domestically becomes a more important issue when the grain is sold for commercial use. Samples of commercially produced grain were evaluated for milling quality; some were better than others (Table 4). Quality will continue to be a critical component as grain is moved for commercial food use purposes.

Interest in sorghum as a supplement to wheat flour is now gaining interest in Nicaragua. Ing Eliette Palacios, INTA sorghum specialist who was trained as part of INTSORMIL activities in El Salvador has is now developing a program in Nicaragua and will be training interested bakery owners on milling and using sorghum flour in their bakery operation.

## 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. In addition, in 2008, seed of the variety 'Soberano' was increased by four farmer groups for sale/distribution to local farmers in El Salvador. From these growouts, overseen by INTSORMIL funded scientists, almost 100 hectares of seed were grown, producing approximately 475 metric tons of seed (Table 5).

### *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.

**Table 5. Seed production of the sorghum variety 'Soberano' in El Salvador in 2008.**

Farmer Group	Hectares	Production (tons)
ADISA	56	280
ACOPAI	12	55
FECASAL	14	70
FORO AGRO	14	70
Total	96	475

## ***Sorghum Utilization***

Since March 2008, sorghum utilization experts at CENTA have conducted 26 workshops on sorghum utilization for food and flour production and 5 additional workshops to demonstrate Omega VI mill functionality to interested people. From these demonstrations, there is now one large scale sorghum flour producer in country and approximately 125 small bakeries using sorghum flour to some extent in their operation. These bakeries are associated with the Artisan Bakers Association (data provided from the president of the bakers association, Nelson Calderon). Finally, there are at least eight small food industries using sorghum in their commercial and mass distributed products.

Ms. L. Taylor, Compatible Technology International (CTI) Volunteer presented workshop on the utilization and production of Omega VI attrition mills for use in grinding sorghum and other grains. This workshop was instrumental in gaining significant interest in locally producing the grinders using blueprints and key parts from CTI. The Omega VIs in Salvador continue to perform efficiently and interest in their use is growing. They are relatively inexpensive to buy and maintain. They are useful for grinding other commodities as well. The Children's Relief Foundation close to CENTA's headquarters have used the grinders to prepare blends of sorghum flour with wheat/maize to produce more foods with existing resources. The sorghum based foods have been readily accepted and are less expensive.

The WINROCK Foundation approved a two week Farmer to Farmer program for a specialist to spend two weeks in Salvador working with the use of the mills and developing information on food processing using sorghum blends. Ms E. Pinella, Graduate Student, Cereal Lab, TAMU will be the volunteer.

Ms. Eliette Palacios, INTA, in Nicaragua has utilized the Omega VI mill to improve sorghum processing similar to what has been done in El Salvador. The interest is high and a substantial increase in consumption of sorghum foods is occurring where the technology has been introduced. Ms Palacios received \$2500 from FAO to expand her activities. The results in Salvador are being transferred to Nicaragua with similar positive results especially for the small producers and bakeries.

## **Networking**

Several INTSORMIL collaborators attended and made presentations at the 54th annual PCCMCA meetings held in Mexico in September 2009. INTSORMIL regional fund supported the travel of Vilma Calderon, Salvador Zeledon and Rene Clara to the meeting to make presentations. 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. Additional agreements with other NGOs are in the discussion phase of development. In sorghum utilization, five Omega mills have been purchased and distributed to bakeries in small regions to promote the use and integration sorghum flour into bakery products in El Salvador. Ing Vilma Calderon has made numerous demonstrations throughout the country regarding the use of sorghum flour as a substitute for wheat flour, including several popular press articles in both print and broadcast media.



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

Gebisa Ejeta  
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## Coordinators

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## Ethiopia

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Gebreyesus Brhane, Axum University, Faculty of Agriculture and Rural Development

## Uganda

Robert Olupot, Serere Research Station, NARO, Serere  
Kaiizi Kayuki, NARO, Kampala

## Tanzania

Elias Letayo, Hombola Research Station, Dodoma  
A. Mbwaga, Dept of Crop Research  
Dr Joseph J. Mpagalile, Dept. of Food Science & Technology, Sokoine University of Agriculture (SUA), Morogoro  
Emmanuel R. Mbiha and Fredy Kilima, Sokoine University of Agriculture (SUA), Morogoro

## Kenya

Clement Kamau, Machakos Research Station, KARI, Machakos  
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## Regional Program Description

The Horn of Africa Regional Program now encompasses four countries of the Horn of Africa Region: Tanzania, Uganda, Kenya and Ethiopia. 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.

## Sorghum/Millet Constraints

Sorghum and millet constraints in the region continue to be low productivity and limited markets for the grain produced. Major production constraints include water deficits, stem borers, nitrogen deficiency, *Striga*, weeds and quela quela. Farm household interviews in Tanzania show a low rate of adoption for production technologies, often due to lack of knowledge and availability of technologies (e.g., improved seed varieties) or market instability and seasonal price fluctuations. The market limitations are perpetuated by a general lack of reliable quality grain production. Storage and transport infrastructure deficiencies compound the product / market disconnect. The INTSORMIL regional project team continues address these constraints from developing production tech-

nologies, extending these to farmers in the region and exploring new market outlets for sorghum and millet while enhancing and protecting profits for all involved in the supply chain. Studies of the sorghum based clear beer value chain in Tanzania is an excellent example of this holistic approach. The study included interviews with sorghum farmers, traders, transporters, processors, distributors and warehouse owners. There has been a modest increase (4%) of sorghum based product in the clear beer industry in the region over the last two years of the study. The study concludes that continued growth in the sorghum beer industry depends on potential demand of the buyers, consistent and high quality grain from farmers, adequate transportation and storage infrastructure, profitability for all chain members and trust and contract enforcement mechanisms. This study validates the INTSORMIL/SMOG objectives for regional development.

## Institution Building

Dr. Gebisa Ejeta (Purdue) 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 (UNL) 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 progressed with their research objectives in the areas of promoting information on tie-ridging and fertilizer use in Ethiopia, skip-row planting in Ethiopia and expanded dissemination for soil fertility management options in Uganda through community based farmer facilitators. Their monumental Atlas of Sorghum Production in Eastern and Southern Africa was also published in 2009, wherein they evaluated 43 production constraints affecting sorghum producers in the area.

Mark Erbaugh and Don Larson (OSU) and collaborators advanced their research activities in Tanzania to identify value chain factors that affect the use of improved sorghum and millet seed, to study the feed concentrate and fortified food value chains, examine the supply chain for sorghum-based clear beer and to collect information on seasonal variability of sorghum and millet prices.

David Jackson (UNL) and colleagues advanced in their project for developing products and markets for sorghum in Tanzania through entrepreneurial assistance to existing clients, identifying new clients and conducting training workshops for food processing entrepreneurs and educational programs for sorghum and millet producers.

Human resource development objectives for the region are being met through training of graduate students and collaborations with faculty based in the areas where specific studies are being conducted. Farmer facilitators were trained in Uganda to assist with extension of soil fertility management options. Ms. Salome Maseki, a masters degree student in agricultural economics at Sokoine University of Agriculture, is conducting the study in Tanzania on the improved sorghum and millet seed value chain as her thesis research. The feed concentrate study in Tanzania is being conducted by Mr. Joseph Mgaya in pursuit of his M.Sc. degree in

Agricultural Economics at the OSU. This candidate has completed his coursework at the OSU and is currently collecting data for the feed concentrate value chain study in Tanzania. Freddy Kilima and Emmanuel Mbiha are Sokoine University of Agriculture faculty leading the fortified food value chain study in Tanzania. Jeremia Makindara, a faculty member of Sokoine University of Agriculture and Ph.D. candidate, is conducting the sorghum beer supply chain analysis in Tanzania. Collaborators from Sokoine University of Agriculture developed the protocol for collecting the monthly price data to assess sorghum and millet seasonal price fluctuations.

## Networking

The INTSORMIL/SMOG team consists of scientists from various disciplines that develop research and outreach programs for sorghum, millet, and other grains. The Horn of Africa regional program maintains important linkages to the INTSORMIL programs in other regions, in the U.S. and with the USAID missions in each country. The scientists include Mark Erbaugh (rural sociologist) and Don Larson (agricultural economist) at The Ohio State University, Charles Wortmann (soil scientist) and David Jackson (food scientist) at the University of Nebraska, Gebisa Ejeta (plant breeding and Regional Program Coordinator for the Horn of Africa) at Purdue University, as well as collaborating scientists in Ethiopia, Kenya, Tanzania and Uganda. Numerous outreach partners in host countries include government and non-government agencies and community-based organizations.

U.S. PIs met at the University of Nebraska in Lincoln to coordinate regional activities. Eleven publications, listed in the individual reports for the HOA region, appeared in Year 3 of this project.

In addition to data collection trips and interviews conducted by the research teams, two 2-day introductory processor workshops were held at Sokoine University of Agriculture involving sorghum processors, farmers, non-university researchers and extension officers in Tanzania to teach potential new clients about sorghum based products. Current sorghum processor clients were also facilitated by the Project to attend the farmers shows to display their products and meet other sorghum processors and producers.

## Research Accomplishments

### ***Crop, soil and water management to optimize grain yield and quality for value-added markets in eastern and southern Africa***

*Project coordinated by Charles Wortmann, University of Nebraska*

As part of SMOG/CRSP project UNL-101, an experiment conducted on tef agronomy in the Tigray region of Ethiopia suggested that reduced tillage resulted in lower yields, N and P applications did not increase yield and weed control was effective with one low dose application of 2,4-D. Results of several experiments on grain sorghum production in Ethiopia evaluating tillage, skip row planting and fertilizer application were published. Tied-ridging and

plant 2: skip 1 appears to be a promising configuration in northern Ethiopia. Planting beans in the skipped row is being investigated as a production option for the region. Tied-ridging also increased maize production in the Central Rift Valley but skipped row planting had no yield advantage. In eastern Uganda, soil sampling from 80 on-farm trial demonstrations showed that the sandy loamy soils had low organic matter and moderate P availability. Mean grain yields there were quite responsive to N and N plus P applications. In Tanzania, mean grain sorghum yield was less with reduced tillage compared with tied-ridging and pot-hole tillage based on six on-farm trials conducted in the Singida region.

***Identifying ways to improve production and stabilize and develop markets for sorghum and millet farmers in Tanzania***

*Project coordinated by J. Mark Erbaugh and Donald W. Larson, The Ohio State University*

Operating under SMOG/CRSP project OSU-101 a study was conducted to follow the sorghum-based clear beer value chain in Tanzania. The study showed that sorghum beer has increased in clear beer market share from 0 to 4% over the previous 2 years. In addition to lager beer, two potentially valuable by-products (spent grains and yeast) are generated through processing the sorghum. These by-products could be marketed for use in animal feeds. Brewers buy sorghum through traders from small farmers and would generally like to increase those purchases, but have concerns about consistent and high quality grain from small farmer producers. Long term sustainability of the sorghum-based clear beer value chain depends on potential demand of buyers. Poor transportation and storage infrastructure continues to constrain the sorghum beer value chain by increasing cost. Profitability for all value chain members is necessary for success. Lack of trust and effective contract enforcement also remain a constraint on the sor-

ghum clear beer value chain. Lack of access to modern production technologies remains a constraint on sorghum production for smallholder farmers. Low sorghum prices at harvest that increase substantially during the year may create farm storage opportunities. Investors perceive high business risks in sorghum processing because of supply and market demand uncertainties.

***Product and market development for sorghum and pearl millet in east Africa***

*Project coordinated by David Jackson, University of Nebraska*

Under INTSORMIL project UNL-102, entrepreneurial assistance for sorghum and millet processors continues with existing clients in Tanzania. Workshops in grain processing and products were conducted for potential new clients. These new clients were also provided with assistance to develop their initial business plans. Workshop offerings for food processing entrepreneurs were strengthened and educational programs for sorghum and millet producers were developed.



## **Southern Africa (Botswana, Mozambique, South Africa, Zambia)**

**Gary C. Peterson  
Texas A&M University**

### **Coordinators**

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## Regional Program Description

The Southern Africa regional program is composed of 12 research projects directed by 14 scientists representing 8 agencies in 4 countries. Eight U.S. based principal investigators collaborate with the regional scientists. Countries and agencies represented are the Botswana College of Agriculture; the Mozambique National Agrarian Research Institute; in South Africa the University of the Free State, the ARC-GCI (pending acceptance of MOU), the University of Pretoria, and the Medical Research Council, and in Zambia the Zambia Agricultural Research Institute and the University of Zambia. The scientists represent the disciplines of agronomy (1), breeding (3), socio-economics (2), entomology (3), food science (1), and pathology (1). A regional planning meeting to identify and guide 2006-2011 activities developed the following 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. Regional scientists were selected for the 2006-2011 program with the expectation each has expertise to contribute to achieving the goal of improving sorghum and millet for the regions farmers and end-users. Individual work plans are developed using a format similar to that for U.S. investigators. Each scientist 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 should be used to evaluate progress and performance. Each collaborating scientist brings to INTSORMIL individual 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. Technical backstopping 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, as building material for fences and traditional storage facilities, and sweet sorghum juice 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 include 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 can place sorghum and pearl millet at a disadvantage relative to other commodities. Socio-economic constraints including lack of credit for farmers/associations, market structure, and lack of promotion of sorghum for the end-use food and feed markets hinder development of a diversified sorghum and millet industry. 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.

## Institution Building and Networking

### Networking

#### *Workshops and Meetings*

A database of sorghum and millet food scientists and technologists in sub-Saharan Africa with their specific areas of expertise was developed and posted on the INTSORMIL website.

A three-day workshop entitled "Alternative Cereal Processing Technologies" for existing and potential sorghum food processors was held in Lobatse, Botswana in November 2008. The workshop

was jointly organized by the Botswana National Food Technology Research Centre, INTSORMIL and Cereal Science and Technology-SA. There were some 60 participants representing all players in sorghum value-chain in Botswana. In addition to lectures there was hands-on training in sorghum end-use quality evaluation, demonstration of sorghum processing technologies and product making, and technical visits.

Joaquim Mutaliano (IIAM) participated in a workshop sponsored by AGRA on the Program for Africa's Seed Systems held in Bamako, Mali.

### ***Research Investigator Exchanges***

John Leslie visited Mozambique and South Africa October 27-November 8, 2008. The objectives in Mozambique were to help establish better Kansas State linkages in the country and to explore a larger education program for Mozambiquan agricultural scientists. At Cape Town, was an invited speaker at the PAEMS meeting organized by PROMEC, presented at one-day scientific writing seminar, discussed collaborative research projects, and recruited a new (non-INTSORMIL supported) student. Visited the Univ. of the Free State and Univ. of Pretoria to discuss collaborative projects and present a scientific writing workshop.

David Jackson (Nebraska), Don Larson (Ohio State), Lloyd Rooney and Gary Peterson (Texas A&M) participated in the Alternative Cereal Processing Technologies workshop at Lobatse, Botswana, November 2008.

Don Larson, Lloyd Rooney and Gary Peterson reviewed the status of current activity in Zambia and the potential for expanded collaboration. Evaluated on-going research at Golden Valley and the University of Zambia, and the potential for collaboration with representatives of the National Institute for Scientific and Industrial Research, and SABMiller, November, 2008.

Gary Peterson traveled to Mozambique, South Africa and Zambia, February 24 to March 13, 2009. In Mozambique met with entomology and breeding collaborators to evaluate development of their respective research programs and evaluation of germplasm selected from Texas developed populations. In South Africa met with University of the Free State collaborator to discuss graduate training and evaluation of sugarcane aphid resistant germplasm. Met with ARC collaborator to discuss re-starting the germplasm evaluation program for resistance to sugarcane aphid. In Zambia met with collaborators from the Zambia Agricultural Research Institute and reviewed status of the regional program.

Bonnie Pendleton (West Texas A&M Univ) visited with collaborators in Botswana and Mozambique April 16-28, 2009. The status of on-going activity in entomology, breeding and on-farm seed multiplication was reviewed.

Don Larson and Mark Erbaugh visited Zambia April 27 - May 2, 2009 to meet with UNZA collaborators and discuss progress in the research activities. Discussions were held to discuss progress in studies on improved seed value chain, price data collection, and clear-beer chain; interview students for additional training opportunities, and plan future training activities.

Lloyd Rooney discussed research activity with Prof J. Taylor at the AACCC meeting, Baltimore, MD, September, 2009.

### ***Research Information Exchanges***

Texas A&M University is working with the University of Pretoria and the Zambia Agricultural Research Institute on a program to develop sorghum cultivars with improved malting and brewing quality. The research will be conducted in collaboration with SABMiller.

### ***Germplasm Conservation and Distribution***

The Zambia national program continued to produce seed with the revolving fund at Nanga in collaboration with the Food Crop Diversification (FODIS) project supported by JICA. Seed of Kuyuma (1.0 ton), Sima (1.0 ton), ZSV-15 (0.8 ton) and [Fram x SDS 3845]16 – 2 – 2 (1.5 tons) were produced. This seed will be distributed in Shangombo, Sinazongwe, Siavonga, Rufunsa and Luangwa districts. It is expected that about 1,300 smallholder farmers will benefit from the seed distribution program this coming season. It is also projected that 700 hectares will be planted to improved seed from this effort. Not enough seed of WP-13 was increased and the demand remains high among smallholder farmers in region III.

The Zambia national program assists with seed production at the Foundation or Basic seed level collaboration with NGOs such as CARE International, Harvest Help and FODIS. The program offers technical expertise and the NGOs the financial resources to produce the seed.

In Mozambique seed of Macia and Sima was planted for increase at 7 research stations and 5 on-farm sites. The on-station increases produced a total of 35.5 tons (combined) and the on-farm sites produced 11.35 tons. Seed from the on-station production was sold and will represent a planted area of 3,550 hectares of certified seed in the 2009-10 growing season. Seed from the on-farm increases will be planted in the districts where it was produced. It is anticipated that the seed will plant 1,100 ha with an expected production of 3,300 tons.

The Mozambique national program is collaborating with several partners including ICRISAT-Mali, the Zambia Agricultural Research Institute, IER-Mali and Texas A&M University on genetic resources exchange.

The Mozambique national program carried out local landrace collection and mass selection for varietal improvement in the provinces of Nampula and Cabo Delgado which covered seven districts (Montepuez, Namuno, Ancuabe, Balama, Chiure, Ribaue and Malema). A total of 12 local landraces were collected. The landraces were found to be similar to those of West Africa guinea type sorghums.

### ***Spreading Research Results***

Prof John Taylor participates in the South African Sorghum Forum (sorghum stakeholders group) and in August 2009 gave a

talk to their sorghum producers group on “Food, feed and industrial opportunities for sorghum”.

Prof John Taylor and Dr Janet Taylor delivered papers on sorghum brewing related research and development work at the Institute of Brewing and Distilling convention in South Africa in March 2009.

The Zambia national program participated in on-station field days at GART, Manza, Lusitu, Mt. Makulu and Mponge, and on-farm field days in Rufunsa and Shikabeta. All the field days were well attended and the interest from farmers on seed availability and markets was high.

The Zambia national program distributed 1,200 booklets on sorghum and pearl millet production.

The Zambia national program collaborated with World Vision, CARE International, PAM and Oxfam on seed distribution and sorghum/millet production.

The Mozambique national program collaborates with Helvetas, Aghakan, FHI-USAID Mozambique and Oxfam-Belgica on farmer seed production promotion training and capacity building at the village level.

The Mozambique national program collaborates each growing season with NGO's IKURU and CLUSA on seed production with IIAM being responsible to produce and supply seed with good quality and improved yield performance for each agro-ecological zone.

F.P. Muuka trained nearly 40 agricultural extension staff and lead farmers based in southwestern Zambia on how to improve the productivity and production of both pearl millet and sorghum grain as well as potential ways to add value to the grain and generate income.

The Zambia national program distributed to nearly 2,000 farmers 1 kg seed packets of improved varieties. Distribution was in the least developed and difficult part of Zambia to access due to sandy terrain, rivers, and no road infrastructure.

## 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 seven graduate students studying Food Science at the University of Pretoria.

Dr Gyebi Duodu is coordinating a Certificate Course in Opaque Beer Brewing (training course in industrial sorghum beer brewing technology) run by the University of Pretoria. In 2009, more than 30 persons from the industry in southern Africa are taking the course.

Rebecca Lubinda, a faculty member in the Department of Agricultural Economics and Extension Education at UNZA, was not able to begin PhD studies in agricultural economics this fall

through the RUFORUM program located at Bunda College in Malawi. The Bunda College program has been delayed. She will most likely begin studies at the University of Pretoria in early 2010. Her studies will be partially supported by the INTSORMIL/Zambia project.

Gloria Musaba, a final-year student in the Department of Agricultural Economics and Extension Education, University of Zambia, is using the price study from the University of Zambia/INTSORMIL (Ohio State) project as her senior thesis project. INTSORMIL supported her senior thesis research work.

Lloyd Mbulwe has returned to the Zambian breeding program after completing an M.Sc. program at Nottingham University in the UK.

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

Three primary studies were initiated or conducted. An on-station push-pull study in grain sorghum was initiated. Napier grass (variety ‘Banna’) was planted around an experimental site. Desmodium will be planted in the experimental site. Sorghum will be sown between the desmodium rows. The objective of the experiment is to study whether stem borer moth will prefer Napier grass over sorghum.

The response of entries in two trials (25 and 17 varieties, respectively) for stem borer damage was evaluated. Significant differences among varieties for resistance were identified in both trials. In the 25 entry trial the varieties 104GRD, ICSB654, ENT#64DTN and SPV111 sustained less damage than other varieties while ICSR 93034, ICSV 700, E36-1 and ICSB 324 sustained high damage. In the 17 variety trial 04CS-452-4-1, 04CS-573-3-1, 02CS-30932, and 02CS-30445 exhibited less damage while 03CM-1104-BK, 04CS-798-7-1, and 03CM-15012-BK exhibited higher damage.

Twelve varieties were evaluated for response yellow sugarcane aphid. Generally aphid population density was low due to moist conditions during the growing season. The varieties SDS-3047/722E-8, Sima, GVSIMS710E-2 and SDSs-1958-1-3-2/724E-5 exhibited less damage with the varieties ICSV-93010-1/708E-9, Macia, ZSV15-4/723E-3 and (SDS-5006\*USV-187) sustained high damage.

#### Botswana and South Africa

Primary research activity is directed to developing varieties resistant to the sugarcane aphid (*Melanaphis sacchari* (Zehntner)). The sugarcane aphid infests sorghum during all growth stages, but

infestations of economic significance usually occur during the late growth stages, more commonly during dry periods. Yield losses to sugarcane aphids in South Africa can be as high as 46-78% annually where insecticides are not used. Management of the sugarcane aphid by using resistant sorghum cultivars will reduce the usage of insecticides and save on input costs for purchasing of insecticides without sacrificing crop yield. It will also provide a solution to resource poor farmers who cannot afford insecticides for control of the sugarcane aphid. Promising high yielding sorghum genotypes resistant to sugarcane aphid had been developed by INTSORMIL over the years and could now be included in on-farm trials with the aim of release for use by the small-scale farmer market.

Sugarcane aphid screening/yield trials with 24 entries each were planted at Cedara Research Station (Table 1). The trial consisted of 16 entries from the 2008/09 sugarcane aphid trial, six entries from the 2008/09 sugarcane aphid yield trial and two local hybrid checks. The entries were selected to be evaluated for

sugarcane aphid resistance and along with additional entries for resistance to grain mold. Severity of infestation was evaluated when the majority of entries grain was in the milk stage. Severity of infestation was evaluated on a 1 to 5 scale, where 1 = no aphids present on plants, 2 = light infestation with aphids present on a few leaves (no dead leaves), 3 = moderate infestation with aphids present on two to three leaves (one or two dead leaves may be present), 4 = high infestation with aphids on nearly all leaves (many dead leaves) and 5 = majority of plants in plot dying. Plants with a rating of 1 or 2 were considered resistant, while a rating of 3 indicated an intermediate level of resistance. Plants with a rating of 4 and 5 were considered susceptible.

Results indicated that 42 % of the entries rated 1 on a scale of 1 to 5, indicating none to very little damage. Ratings of 2 were scored for 33 % and ratings of 3 were scored for 17 % of the entries. Eight percent of the entries were highly susceptible to aphids with a rating of 4. Aphid damage ratings therefore ranged between

**Table 1. Evaluation of sorghum lines for disease resistance, sugarcane aphid resistance and grain yield.**

Pedigree/Designation	Sooty stripe†	Leaf blight†	Anthracnose†	Grain molds‡	Sugarcane aphid damage§	Grain Yield t/ha
(Segaolane*WM#322)-LG2-LG2-(03)BG1-LG1-LBK	1.25	0.75	0.25	2.25	1	4.46
(Macia*TAM428)-LL2	1.00	1.25	2.75	3.75	1	3.59
CE151	0.00	2.00	2.00	2.00	4	3.52
(6BRON161/(7EO366*Tx2783)*CE151)-LG5-CG2-(03)BG1-BG2-LBK	2.25	0.00	1.00	3.50	1	3.17
(Macia*TAM428)-LL9	1.25	1.50	0.00	2.25	1	3.15
Tegemeo	1.00	1.50	0.00	3.25	2	2.73
(9MLT176/(MR112B-92M2*Tx2880)*A964)-CA3-CABK-CCBK-CABK	1.25	1.25	0.00	3.00	3	2.36
(LG35*WM#322)-BE40-LG1-CA1-LGBK-CABK	2.50	1.00	0.00	3.25	2	2.14
(9MLT176/(MR112B-92M2*Tx2880)*A964)-LG8-CABK-LGBK-LGBK	1.25	0.50	2.50	2.50	2	2.06
TAM428	0.75	2.25	2.75	2.75	2	1.90
(5BRON151/(7EO366*GR107B-90M16)*Tegemeo)-HG7-CC2-CABK	1.25	1.50	0.00	3.25	2	1.85
Segaolane	2.25	2.50	0.00	2.75	3	1.66
(Dorado*Tegemeo)-HW13-CA1-CC2-LGBK	1.25	0.75	0.25	2.25	2	1.54
(5BRON151/(7EO366*GR107B-90M16)*Tegemeo)-HG1-LGBK-CABK	1.25	0.50	0.00	2.00	2	1.43
(Kuyuma*5BRON155)-CA5-CC1-CABK	0.50	1.25	1.50	2.50	1	1.43
Kuyuma	1.00	1.25	1.75	2.50	1	1.42
(A964*P850029)-HW6-CA1-CC1-LGBK	0.25	0.00	2.25	3.25	2	1.42
(Dorado*Tegemeo)-HW14-CA1-CC2-CABK	1.00	1.25	0.25	1.50	3	1.38
SRN39	1.00	2.00	0.00	3.25	4	1.31
Ent62/SADC	1.50	2.00	2.00	2.75	1	1.22
(Dorado*Tegemeo)-HW15-CA1-CC2-LG1	1.50	1.75	0.00	2.00	2	0.94
Macia	0.25	1.25	0.75	3.00		
(SV1*Sima/IS23250)-LG15-CG1-BG2-(03)BGBK-LBK	1.00	1.50	2.25	2.25		
(Macia*TAM428)-LL9	0.50	0.00	0.50	2.50		
(6BRON168/6OB172/(88CC445*Tx2862*Tegemeo)/HG5-CC2-LGBK	1.00	1.00	0.00	2.00		
(Town*EPSON2 – 40/E#15/SADC) – CG2 – BGBK	0.00	1.50	0.50	1.50		
BTx635	1.00	1.00	1.00	3.00		
Ent.62/SADC	0.00	1.00	0.50	3.50		
((ISCV401*S34)*R9204)-CS7-CS1-BE1	0.00	1.50	0.00	2.50		
Tx2957	0.00	1.00	0.00	2.00		
(SRN39*87ED366)-L039-BE1	1.00	2.00	0.00	2.00		
Sureno	1.50	1.00	1.50	3.50		

**Table 1 cont'd: Evaluation of sorghum lines for disease resistance, sugarcane aphid resistance and grain yield.**

86EON361	1.00	2.00	0.00	3.00
Macia*Sureno	1.50	1.50	0.00	2.50
Macia	2.00	1.25	0.00	2.50
EPSON2 – 40/E#15/SDAC*A964) – CG3 – BGBK	1.00	1.50	0.00	1.50
(Dorado*Tegegeo)-HW13-CA1-CC2-LGBK	2.50	1.00	1.50	2.00
Tegegeo	1.50	2.50	0.00	2.50
Malisor 84-7	0.00	2.00	0.50	3.00
LSD (P>0.05)	0.92	1.2	0.3	1.4

†Rated on a scale of 0 = no damage to 5 = plant necrosis.

‡Rated on a scale of 0 = no grain mold to 5 = grain deterioration due to molds.

§Rated on a scale of 1 = no aphids present on plants, 2 = light infestation with aphids present on a few leaves (no dead plants),

3 = moderate infestation with aphids present on 2 or 3 leaves (one or two dead leaves may be present), 4 = high infestation with aphids on nearly all leaves (many dead leaves) and 5 = majority of plants in plot dying.

1 and 4, which indicate the presence of low, intermediate to susceptible levels of resistance.

Yield of the entries at varied between 0.94 and 4.5 tons/ha. Five genotypes yielded significantly better than the standard check, PAN 8240 and only one genotype yielded significantly better than both the standard checks, viz PAN 6848 and PAN 8240. Promising white genotypes should be included in on-farm trials with the aim of release for use by the small-scale farmer market.

Studies at the Botswana College of Agriculture showed that sugarcane aphids and sorghum stem borers were the most destructive field pests during the 2008-09 cropping season. Results from studies on the sugarcane aphid led to the conclusion that abundance of the pest increases with plant age. The lines (Macia\*TAM429)-LL9, TAM428, (6BRON161\*CE151)-LG5-CG2-(03)BG1-BG1, and (Segaolane\*WM#322)-LG2-LG2-(03)BG1-LG1-LBK had low levels of aphid abundance and should have higher levels of resistance and should be further investigated. The abundance of coccinellid predators also increase with the age of the plants. Overall abundance of coccinellid predators increased by 8.8x from about 4.5 on 40-47 day old plants to 39.8% on 74 day old plants. The findings indicate that the indigenous predators can play an important role in the management of the sugarcane aphid. Analysis of results on relative susceptibility of Texas bred lines to stem borers has not been completed.

At the Botswana College of Agriculture experiments were conducted on two sets of lines from the Texas A&M sorghum program. An advanced trial was composed of 22 lines previously identified with resistance to sugarcane aphid and acceptable adaptation. The advance trial was evaluated for incidence and abundance of major pests (panicle pests, aphids, shoot flies and stem borers) under field conditions and in field cages. Genotype and plant age significantly affected the average abundance of the corn leaf aphid (*Rhopalsiphum maidis* Fitch). Corn leaf aphid appeared to be an early season pest with the greatest overall average proportion of infested plants (33.2% per plot) found on 40 day old plants while the smallest (1.3%) was on 54 day old plants. The entry (Dorado\*Tegegeo)-HW14-CA1-CC2-CABK-CABK had the greatest portion of infest plants per plot (29.2%) while (Macia\*TAM428)-LL9 had the lowest proportion (1.3%). The majority of Texas lines were moderately resistant to the corn

leaf aphid, and (Macia\*TAM428)-LL9 would be an excellent line to use in an IPM program against the pest.

For sugarcane aphid, overall date averages show that the level of sugarcane aphid infestation increases with plant age. This indicates a rapid spread of the pest once initial infestation has occurred. The implications are that the sugarcane aphid becomes more abundant later in the season coinciding with the grain filling and grain maturation plant growth stages. The lines with the lowest abundance and thus least suitable for aphid were (Macia\*TAM428)-LL9, (6BRON161\*CE151)-LG5-CG2-(03)BG1-BG1, and (Segaolane\*WM#177)-LG2-LG2-(03)BG1-LG1-LBK. These lines should be considered relatively more resistant than those with significantly higher proportions of infested plants per plot. The overall abundance of coccinellid beetles did not vary significantly but was significantly influence by the age of the plants. The increase in predator abundance corresponded to an increase in abundance of sugarcane aphid infestation per plot, suggesting that the predators responded positively to the increasing number of aphids. There did not appear to be a relationship between corn leaf aphid abundance and coccinellid predator abundance. This suggests that sugarcane aphid is a more important prey of coccinellid and enhances abundance and spread of coccinellid. An additional forty-five lines were subjected to an initial evaluation for resistance to sugarcane (Table 2). No significant differences were identified in the average abundance of sorghum plants attached. Damage rating ranged from 1 (resistant) to 3 (moderately resistant). Six experimental entries – (9MLT176\*Dorado)-CA4-CA1-CC2-CABK-LGBK, (9MLT176\*A964)-CA3-CABK-CCBK-CABK-CA2, (5BRON154\*Macia)-HG10-CA1-LG2, (Tegegeo\*WM#322)-CA1-CC1-CABK-CA2, (Tegegeo\*ICSB12)-CA12-CC1-LG1-LG1, and (5BRON139\*Tegegeo)-HG7-LG1-LG2 showed relatively low sugarcane aphid damage per plant and displayed some level of resistance to the pest. The six entries should be subjected to additional evaluation in developing cultivars resistant to sugarcane aphid.

### Food Science

Four major activities were undertaken: 1) Dissemination of technology know-how between scientists and industrial end-users in southern Africa; 2) Create and maintain a database for scientists and processors on the end-use quality attributes of the major sor-

**Table 2. Abundance of sugarcane aphid and coccinellid predators on 45 Texas bred sorghum lines during the 2008-2009 cropping season at the Botswana College of Agriculture.**

Source Code	Pedigree/Designation	47 Days After Emergence				74 Days After Emergence			
		% Plants with Sugarcane aphids	Sugarcane aphid damage rating†	% Coccinellids	% Plants with Sugarcane aphids	% Plants with Sugarcane aphids	Sugarcane aphid damage rating†	% Coccinellids	% Plants with Coccinellids
07LI 35536-BK	TAM428	33.3	2.0	0.0	3.7	1.0	0.0	0.0	
07LI 3557	Segaolane	32.4	2.0	29.8	43.8	2.0	24.3	24.3	
07LI3538-BK	Kuyuma	25.7	2.0	31.6	29.2	2.0	17.5	17.5	
07LI 3535-BK	CEI51	4.4	1.0	0.0	3.7	1.0	7.9	7.9	
07LI 3537-BK	Macia	2.1	1.0	0.0	4.2	1.0	0.0	0.0	
07LI 3542-BK	Tegemeo	19.0	1.0	4.7	27.8	2.0	6.7	6.7	
07LI 3543-BK	WM#177	4.7	1.0	1.6	16.7	1.0	7.6	7.6	
07LI 3541-BK	SRN39	15.2	1.0	3.0	14.3	1.0	4.2	4.2	
07LI 3545-BK	Ent62/SADC	2.2	1.0	4.4	11.7	1.0	12.8	12.8	
08LI 10311	(Dorado*Tegemeo)-HW13-CA1-CC2-LGBK-CABK	17.9	1.0	36.1	28.7	2.0	28.1	28.1	
08LI 10317	(A964*P850029)-HW6-CA1-CC1-LGBK-CABK	27.5	2.0	43.1	32.3	2.0	32.6	32.6	
08LI 10320	(R.88B928*Tegemeo)-HW1-CA1-LGBK-CABK-CABK	50.0	2.5	8.3	27.5	2.0	4.2	4.2	
08LI 10324	(Kuyuma*5BRONI55)-CA5-CC1-CABK-CABK	40.5	2.0	6.2	32.4	2.0	22.8	22.8	
08LI 10331	(5BRONI51)/(7EO366*GR107B-90M16)*Tegemeo)-HG1-LGBK-CA-CABK	42.2	2.0	29.2	34.8	2.0	19.0	19.0	
08LI 10332	(5BRONI51)/(7EO366*GR107B-90M16)*Tegemeo)-HG7-CC2-CAB-CABK	38.2	2.0	23.9	20.1	1.0	8.3	8.3	
08CA 6-BK	(Malisor84-7*(60B172/88CC445*Tx2862))-LG19-CG1-CA1-CABK-CC1-CABK-CA1	28.5	2.0	1.9	23.9	1.0	15.5	15.5	
08CA 28-BK	(Segaolane*KS115)-HW3-CA3-LD1-CABK-CA2	33.3	2.0	20.9	44.3	2.0	23.1	23.1	
08LG 6028-BK	(9MLT176)/(MR112B-92M2*Tx2880)*Segaolane)-CG1-LG1-CA1-CC2-CA2-CA2	36.1	2.0	16.7	0.0	1.0	38.9	38.9	
08CA 39-BK	(9MLT176)/(MR112B-92M2*Tx2880)*Dorado)-BE1-CA1-CA2-CC2-LGBK-CA1	45.0	2.0	14.4	62.5	2.7	50.0	50.0	
08LG 6038-BK	(9MLT176)/(MR112B-92M2*Tx2880)*Dorado)-BE9-CA1-CA2-LGBK-CABK-CA2	34.9	2.0	13.5	22.6	1.0	5.5	5.5	
08LG 6041-BK	(9MLT176)/(MR112B-92M2*Tx2880)*Dorado)-CA4-CA1-CC2-CABK-CABK	51.2	2.8	24.5	70.0	3.0	70.0	70.0	
08CA 49-BK	(9MLT176)/(MR112B-92M2*Tx2880)*Dorado)-CA4-CA1-CC2-CABK-LGBK	7.5	1.0	33.3	0.0	1.0	27.8	27.8	
08CA 6045-BK	(9MLT176)/(MR112B-92M2*Tx2880)*A964)-CA3-CABK-CCBK-CABK-CA2	12.1	1.0	3.0	0.0	1.0	41.7	41.7	
08CA 6061-BK	(CEI51*Tx430)-HW2-CA1-CG1-LDBK-CA1	69.0	3.0	50.0	75.0	3.0	41.7	41.7	
08LG 6060-BK	(CEI51*Tx430)-BE3-CA1-LGBK-CABK-CA2	17.9	1.0	2.6	38.9	2.0	36.1	36.1	
08CA 70-BK	(Kuyuma*LG35)-CA6-CC2-CABK-CABK	39.8	2.0	11.1	34.1	2.0	22.5	22.5	
08CA 74-BK	(Kuyuma*LG35)-CA10-LGBK-CABK-LG1	36.5	2.0	34.9	15.8	1.0	18.8	18.8	
08CA 80-BK	(Kuyuma*5BRONI55)-CA5-CC1-CABK-CA1	27.5	2.0	17.0	37.9	2.0	17.9	17.9	
08LG 6074-BK	(5BRONI39)/(6EO361*GR107-)*Kuyuma)-HG3-LD2-CABK-CA1	51.2	3.0	14.4	30.0	2.0	6.7	6.7	

**Table 2 cont'd: Abundance of sugarcane aphid and coccinellid predators on 45 Texas bred sorghum lines during the 2008-2009 cropping season at the Botswana College of Agriculture.**

Source Code	Pedigree/Designation	% Plants with Sugarcane aphids	Sugarcane aphid damage rating†	% Plants with Coccinellids	% Plants with Sugarcane aphids	Sugarcane aphid damage rating†	% Plants with Coccinellids
08LG 6076-BK	(5BRON139/(6EO361*GRI107-)*Kuyuma)-HI7-CG2-LDBK-CA1	33.3	2.0	16.7	45.9	2.4	3.2
08LG 6079-BK	(5BRON154/(87BH8606-4*GR127-90M46)-HG10-LG1-LG3-CGBK*Macia)-HG3-CA1	45.1	2.5	13.1	45.9	2.4	3.2
08LG 6082-BK	(5BRON154/(87BH8606-4*GR127-90M46)-HG10-LG1-LG3-CGBK*Macia)-HG10-CA1-LG2	6.7	1.0	0.0	9.5	1.0	17.9
08CA 101-BK	(99GWO92*ZSV15)F3-H55-HW1-HW1-LG1	49.0	2.5	9.0	49.0	2.4	8.4
08LG 6095-BK	(R.88B928*Tegeo)-HW1-CA1-LGBK-CABK-CA1	48.3	2.5	13.9	42.2	2.0	24.4
08CA 112-BK	(Tegeo*WM#322)-CA1-CC1-CABK-CA2	14.3	1.0	7.1	10.0	1.0	10.0
08LG 6106-BK	(Tegeo*WM#322)-CA2-CC2-CABK-CA2	0.0	1.0	45.6	16.7	1.0	12.8
08LG 6109-BK	(Tegeo*ICSR-939)-CA7-CC1-CABK-CA1	43.2	2.0	16.7	27.8	2.0	13.8
08LG 6114-BK	(Tegeo*ICSB12)-CA2-CC1-CABK-CA2	21.1	2.0	29.4	26.9	2.0	25.9
08LG 6119-BK	(Tegeo*ICSB12)-CA12-CC1-LG1-LG1	9.4	1.0	19.7	18.2	1.0	16.4
08LG 6125-BK	(5BRON151/(7EO366*GRI07B-90M16)*Tegeo)-HG7-CC2-CABK-LG1	7.2	1.0	2.2	26.4	2.0	13.4
08LG 6134-BK	(Dorado*Tegeo)-HW13-CA1-CC2-LGBK-CABK	42.9	2.0	21.9	23.8	1.0	8.5
08LG 6136-BK	(Dorado*Tegeo)-HW15-CA1-CC2-LG1-LGBK	27.5	2.0	4.8	57.1	2.6	21.4
08LG 6183-BK	(5BRON139/(6EO361*GRI107-)*Tegeo)-HG7-CA1-LG1	24.8	2.0	8.3	16.7	1.0	13.3
08LG 6186-BK	(5BRON139/(6EO361*GRI107-)*Tegeo)-HG7-LG1-LG	10.9	1.0	0.0	18.2	1.0	8.9
08LG 6306-BK	(Sureno*LG70)-HW5-CA1-CC2-CA1-LG1	38.8	2.0	33.3	5.6	1.0	5.6

†Rated on a scale of 1 = 0-20% damaged leaves, 2 = 21-40%, 3 = 41-60%, 4=61-80%, and 5=81-100%.

ghum and millet varieties in southern Africa; 3) Promote sorghum within the health food niche market; and 4) Improve the viability of sorghum as a lager/stout brewing raw material.

There is a reasonable-sized corps of food scientists and technologists in sub-Saharan Africa who are highly knowledgeable about sorghum and millet science and processing technologies. However, their know-how is currently poorly transferred to existing and potential processors of these grains. Existing and potential processors of sorghum in southern Africa are generally confused as to which of the large number of available and potentially available sorghum varieties are most appropriate to their needs. Further, there is often a mismatch between the varieties that the farmers produce and hence are available and their suitability for processing into different food and beverage products. For example, in one particular country a company wants to build a sorghum maltings in order to malt local produced sorghum for commercial beer brewing. However, at present there is essentially no production of suitable sorghum cultivars in that country. In South Africa, because of the 14% Value Added Tax on sorghum, sorghum products are considerably more expensive than their maize equivalents. Hence, in order to grow the market for sorghum, less price-sensitive products are required. A promising area are products that exploit sorghum's health-promoting properties. The SABMiller Africa company, which is the major beer brewer in almost all countries in southern Africa, has committed itself to source locally produced brewing materials in each of the countries it brews in with an activity called the "Enterprise Development Project". Major among the raw materials targeted in the Enterprise Development Project is sorghum for lager beer brewing. There are, however, several sorghum-related technical aspects that require research and development work in order to improve the economic viability of sorghum lager beer brewing.

Data on the general physical characteristics of available and potentially available sorghum cultivars is being collated. Limited research work to determine malting and brewing qualities of some of these cultivars is being undertaken. Progress on the database of sorghum varieties has been slow because of human resource issues, and work on the database is neither education nor scientific research. With specific commercial industry interest in the database progress in creating the database should be more rapid. Simple technology to produce good quality cookies from 100% sorghum has been developed. The antioxidant activities of the cookies produced from different types of South African sorghums has been determined. A sensory evaluation trial of the whole sorghum cookies and soya protein enriched sorghum cookies has been undertaken at a primary school in Mamelodi near Pretoria. A short training course was given for mothers of the children on how to make these cookies. Research has been undertaken to try to improve the free amino nitrogen (FAN) content of sorghum worts. FAN is an essential nutrient for yeast fermentation in brewing and similar bioethanol processes. However, in sorghum FAN can be limiting, which inhibits fermentation efficiency. Various methods to improve FAN were investigated, including malting the sorghum, addition of commercial proteases, use of "high protein digestibility" sorghum cultivars and chemical treatments.

As was believed, it appears that white, tan-plant type sorghums give the highest hot water extract (yield of beer) in lager brewing.

Also, it was found that there is an inverse relationship between grain protein content and hot water extract. Protein content could therefore serve as simple indicator of the potential brewing quality of a batch of sorghum. Cookies made from tannin sorghum had the highest antioxidant activity, but were sensorially poor. Those made from red, non-tannin sorghum had lower antioxidant but better sensorial characteristics. Sensory evaluation of these and the sorghum-soya by primary school children revealed that within a short period of time the children adjusted to the taste of sorghum cookies and liked them just as much as cookies made with wheat flour. This is a very promising finding with respect to using sorghum and sorghum-soya cookies in school feeding schemes. Malt-ing sorghum was found to be the most effective way of improving sorghum wort FAN levels. Some improvement in wort FAN was obtained by the addition of potassium metabisulfite (KMS) in conjunction with certain commercial protease enzymes. This later process is now being implemented in commercial sorghum brewing through a major international enzyme company.

### ***Market Development***

The research strategy is to identify new market opportunities, related constraints in the supply chain and ways to better link farmers to markets so as to improve the income and food security of small-scale sorghum and millet farmers in Zambia.

The major achievements in the past year were completion of the project activities as specified in the work plan. These include 1) a study of the sorghum based clear beer value chain, 2) analyzing the baseline farm household surveys in high potential areas, 3) completing a study of the improved seed value chain in Zambia and beginning studies of the feed concentrate industry and food processing chain in Tanzania, 4) continuing the collection of monthly retail, wholesale and farm price information, and 5) Initiation of M.S. course work at The Ohio State Univ. by Bernadette Chimai (Zambia), autumn term 2009.

In the past, sorghum was considered a traditional crop with limited industrial uses such that most of it was used for household consumption. However, in recent years, the crop has been identified as a possible substitute for maize. Research and transformations in consumer tastes and preferences have led to the development of new uses for sorghum. In particular, four major industrial uses of sorghum have thus far been identified, including food processing, beer brewing, feed concentrates and energy production. Previous studies identified the main players in the clear beer supply chain and provided useful insight into the activities of the chain and how the different chain members are inter-related. No study is available that has assessed the performance of Eagle Lager and the opportunities and challenges it presents to smallholder farmers in Zambia. As a major player in the chain, it is necessary to assess the performance of Eagle Lager since its introduction as well as estimate future market opportunities that it may present.

Zambian Breweries (owned by SABMiller) introduced Eagle Lager; sorghum based clear beer to the market in 2005. Eagle Lager offers an alternative to the traditional maize-based clear beer; it entered the market at a much lower price than its close competitors, Mosi and Castle Lagers. Eagle Lager has become an important new market for sorghum in Zambia. Eagle Lager enjoys

a 15-17 percent clear beer market share, and is reportedly growing at 5-10 percent per annum. Such a market growth rate will very likely encourage increased brewer demand for sorghum production. To cope with the increasing demand, it is estimated that the existing processing plant in Ndola needs to be expanded at least fourfold. Most importantly the introduction of Eagle Lager has created new value chain relationships involving farmers, traders, transporters, wholesalers and retailers. For the farmers, the beer provides a stable market at a known price for their sorghum. The distributors and retailers are provided with more service-provision activities making it possible for them to expand their businesses.

Initially, Zambia Breweries (ZB) used the Cooperative League for the USA (CLUSA), a USAID-funded NGO, to sensitize up to 4,000 local farmers to produce the sorghum required for brewing by providing technical advice and loans for production inputs. Purchase arrangements were signed between farmers and Zambia Breweries in advance to guarantee a ready market for the farmer's crop at a price considerably higher than the market rate. The CLUSA project no longer has this USAID funded program. Recently, Zambia Breweries has obtained all its sorghum supplies from a local commodity broker, CHC Commodities. The broker entered into an agreement with Zambia Breweries to be its only supplier of sorghum. CHC Commodities purchases sorghum from smallholder farmers, small traders, and large-scale farmers. However, the contribution by large-scale farmers has been declining such that in 2008 all the sorghum was sourced from smallholder farmers. The new value chain is increasing employment, smallholder incomes and promoting local development.

An improved seed value chain study has been completed. The study began by mapping the seed chain functions, actors and identifying key informants at critical points (such as production, distribution, consumption) in the value chain. The value chain has three interlinked components; namely the value chain actors, enabling environment (policies and institutions and that shape the market environment) and service providers (business services that support the value chain's operations). Factors affecting the competitiveness of the chain include the enabling environment such as the crop diversification policy, and changes in market trends which may have a positive impact on sorghum and millet use. Other factors such as the fertilizer and price subsidy programs for maize adversely impact the competitiveness of the sorghum and millet seed chain.

This study found that smallholder adoption of improved practices particularly the use of improved seed and fertilizer is very low. The result is low yields for sorghum and millet (national average about 500 kg/ha) with no increasing trend in yield (productivity) since 1990. Yet, sorghum breeders have varieties on the shelf that yield 3-6 tons/ha on experiment station farms. The low rate of adoption raises questions of whether the goals of research and development of new technology are being met.

A procedure is established to collect monthly price data for sorghum and millet for 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.

## ***Pearl Millet Breeding***

### *Zambia*

Experimental protogyny population hybrids based on inter-varietal crosses and top-cross hybrids based on the male-sterility systems are being developed. It is envisaged that appropriate hybrids will generate interest to solve the persistent seed issues and problems being experienced. During this research year nearly 46 experimental population hybrids were made through hand crossing using the varieties Lubasi, Dola and SOSAT-C88 as seed parents and several other varieties from Zambia, Southern Africa, Western Africa, India and the USA as pollinators. The hybrids will be evaluated during the 2009/10 season to establish their potential. The three seed parents were carefully selected: Lubasi is a very popular improved variety; Dola is an improved and popular variety in the public and private sectors of Zambia and other Southern Africa countries due to its bristled characteristic which protects grain from damage by birds in the fields; SOSAT-C88 originated from West Africa has good combining ability. Fifteen other varieties were selected for development of genotypes having light colour of the grain to address the problem of food colour preferences (other than gray) and improve acceptability among consumers.

## ***Sorghum Breeding***

### *Zambia*

In general, 2008/2009 was yet another wet season characterized by late and heavy rains. Local landraces of sorghum on farmers' fields that normally fail benefited from these late rains. Multi – location trials were reduced due to insufficient funds from government. Trials at Mpongwe, Mansa, Lusitu and Golden Valley performed well and valuable data was collected.

The program is largely collaborative involving disciplines in breeding, pathology, entomology and food quality. Expertise drawn from these disciplines is critical in the development of varieties that are useful to both farmers and end-users. Local germplasm is used in hybridization followed by evaluation and selection in subsequent generations. Several crosses were made between WP-13, Malisor 84-7 and other elite lines. The progeny of these crosses is being evaluated at Golden Valley and Mansa. Work on understanding the gene action conferring acid tolerance in sorghum and on transferring the same through backcrossing was initiated several years ago. Several crosses have been made and selections to identify and evaluate the crosses are being made in Mansa. The use of biotechnology (Random Amplification of polymorphic DNA – RAPDS) is another option that the program is contemplating in identifying potentially successful varieties for the region.

There were 20 entries in the Sorghum Advanced Variety Trial for region III evaluated at Mansa and Mpongwe. Results from Mpongwe are yet to be received. The trial at Mansa showed significant differences among entries but had a high CV (Table 3). This is expected as different varieties react differently to low pH conditions. The checks ZSV-12 and WP-13 had lower yields than the highest yielder SDS 4378-1-1-1. Several other entries

**Table 3. Sorghum Advanced Variety Trial – III in 2008 – 2009 season at Mansa, Zambia**

Designation	Days to 50% flower	Plant height	Harvested rows	Grain Yield kg/ha
SDS89426	80	138	56	1703
PRGC/E3#69414	82	180	50	1078
ICSV1089BF	88	139	45	939
MACIA x DORADO	80	94	50	1131
ZSV-18	85	114	45	1294
ZSV-30	79	160	49	1872
ZSV-31	78	155	42	1233
SDS4378-1-1-1	71	128	49	2519
SDS1023-10-2-4-1-3-2	80	109	38	1372
SDS876-3432(OT)8-2-1	83	141	47	914
[SDS3845 x SDS4548]F6-10-2	78	159	42	2161
[SDS3845 x SDS4548]F6-10-3-2	84	169	39	1292
[SDS2690-2 x M91057]8-2-1-1	65	94	38	1275
SDS2690-2-3-5-1	82	146	46	789
KSV-7	73	116	31	969
KSV-10	79	199	49	1300
KSV-4	77	220	58	1619
SDS4380-S7	71	134	49	1592
ZSV-12	78	108	45	850
WP-13	81	154	41	1814
MEAN	79	143	45	1386
LSD	14.5	39.4	14.1	989
CV %	6.9	23.3	13.9	33

had higher mean yield than the trial mean ([SDS3845 x SDS4548] F6-10-2, ZSV-30, SDS89426). These entries also showed high agronomic scores.

The sorghum research programme has released a number of varieties for the three agro – ecological regions. Varieties Kuyuma, Sima, ZSV-15 and hybrids MMSH-1257, MMSH-1324 are popular with farmers in region I and II. The acceptance and adoption rates of these varieties are good and fairly high. However varieties released for region III have not had the same success. The varieties needed for this region need to be late maturity (photoperiod sensitive) and withstand low pH. The programme has released two varieties ZSV – 12 and WP – 13 for region III. The adoption rates of these varieties is low largely on account of poor grain quality (soft endosperm) and non – availability of seed.

The development of sorghum varieties with improved grain quality that can withstand low pH should see high adoption rates in region III. Increased sorghum production in region III will also increase commercialization by smallholder farmers as the market (Zambia Breweries plant) is located in the region. It will be cheaper to source the grain in region III than from region I and II. Seed availability and limited markets remain a big challenge to the adoption and utilization of improved sorghum varieties.

There is a growing interest in identifying sweet sorghum varieties for silage and biofuels. The current focus is on dual purpose varieties. Most of the varieties are photoperiod sensitive and this work has to be done in Mansa.

#### *Mozambique*

Research methods include pedigree selection, mass selection for local collections and germplasm characterization. Macia and Sima sorghum improved varieties are produced in the country and farmers are becoming familiar with growing improved sorghums. Nine introductions from Texas germplasm were selected for potential use based on tolerance to drought, midge, and grain quality. Exotic germplasm from Zambia and Mali sorghum breeding programs was introduced to enhance the germplasm base of the national program.

Collection, conservation and use of local landrace varieties important in developing the national sorghum breeding program. In present year 12 local landraces were collected. This represents an increase of 33% of local germplasm collected and characterized. The collected materials are showing good performance and resistance to bird and insect damage, and because of hard endosperm appear to exhibit some resistance to stored grain insects.

Multi-location National Performance Variety trials with the following germplasm were conducted:

- 12 early maturing genotypes,
- 17 early maturing genotypes resistant to midge, down mildew, Head smut, Ergot and drought; this materials were selected from Texas (ADIN, DLT, MLT, and UHSN nurseries) introductions;
- 25 open pollinated sorghums trial in central and north Mozambique. The varieties have multiple uses (food, feed and bio-ethanol).

- 5 sweet sorghum hybrids for planting date trial

Eighteen inbreed lines were selected from 70 segregating populations for stability and uniformity after six years of selection. This represents an 11% increase of improved sorghum varieties in Mozambique over the two most popular varieties Macia and Sima. The sorghum market in Mozambique is gaining space and present demand is growing. Seed companies such as LONZAN, PAN-NAR and SEMOC-Mozambique are requesting huge quantities of Sima and Macia improved sorghum varieties. In the next two years production area is expected to increase by 25%.

A replicated yield trial composed of 15 introductions from the Texas A&M program along with two local checks (Sima and Macia) was grown at four locations (Table 4). At each location entries were identified with grain yield at least equal to the standard checks. Under low rainfall conditions, the introductions demonstrated good yield performance with an average grain yield of 2,950 kg/ha. This represents a yield increase of 20.33% over local landraces. The trials will be repeated to confirm this year's results and identify potential new varieties with the characteristics needed for increased production in Mozambique.

*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. Twenty-six sorghum hybrids from the current and previous National Cultivar Trials were planted at Cedara for root rot

evaluation. Root health is important for optimal water and nutrient uptake by plants and previous studies have indicated that subtle losses of up to 25% may occur due to the disease complex. Evaluations were conducted using a root efficiency index based on visible root infection severity and root volume. Analyses of the data indicated a limited range of disease severities with all cultivars showing relatively high levels of infection (lowest = 29.42 and highest = 45.60). However, when root rot severity was combined with root volume to determine effective root volume, the latter ranged from 14.42 ml per plant to 2.72. Root rot severity is not directly correlated with plant growth reductions and the effect of root rot on the host plant is dependent on the initial/inherent root volume. Regression analyses using the reduction in root volume vs plant height as an indicator of plant vigour indicated a tendency for reduced plant vigour although the R<sup>2</sup>-value was not significant.

The relationship between host structural and biochemical characteristics and root diseases are being evaluated. The degree of root exodermis lignification, as indicated by root cross sections and microscopic examination after staining with phloroglucinol, in relation to root rot resistance was evaluated in four resistant and six susceptible lines. Anatomical studies of roots indicated a significant relationship between the degree of exodermis lignification and root rot resistance. Data suggest that genotypes with resistance to root colonization also have a greater structural barrier to infection. Susceptible roots do not possess a significantly thickened exodermis.

Forty advanced selections from the Texas A&M program were evaluated for response to the diseases of sooty stripe, leaf

**Table 4. Mozambique elite sorghum variety trial of germplasm introduced from Texas A&M University.**

Designation	Source Code	Namialo	Namapa	Mapupulo	Sussundenga	Average
		t/ha	t/ha	t/ha	t/ha	t/ha
Sureño	03CS-GWT 115	3.50	2.30	3.00	3.09	3.02
Sima		3.30	1.73	2.90	3.14	2.79
(ICSV-LM-88511*R9120)-F1-CS	04CS-884-5-1	2.40	2.80	2.20	3.16	2.66
((Sepon82*87eon366)-H38/Jocoro)-CSF1-CS	04CS-452-4-1	1.80	2.20	3.10	3.34	2.64
(R01125/CE151*Macia)-LD3)-CSF1-CS	04CS-523-2-1	1.00	2.53	3.80	3.06	2.64
Macia	02CS-30932	2.30	2.41	2.90	2.51	2.54
(Tx2880*(Tx2880*(Tx2864*(Tx436*(Tx2864*PI50607))))DER	03CM-1104-BK	6.10	0.68	1.40	1.74	2.51
Macia		2.60	2.07	2.40	2.72	2.48
(87BH8606-6*RTx430)-CS-CA	02CS-30445	1.70	2.40	2.50	3.05	2.44
B.HF8/(BTx643*BTx635)	02CS-5067	2.40	2.14	2.50	2.20	2.34
(Tx2880*(Tx2880*(Tx2864*(Tx436*(Tx2864*PI50607))))DER	03CM-15067-BK	2.20	1.72	2.10	3.13	2.30
(05OG4300-5*Tx2782)DER	03CM-15012-BK	3.30	1.78	2.00	2.00	2.28
(RTx2917*Tegemeo)-CSF1-WFF2-CS	04CS-573-3-1	3.00	1.64	2.00	2.36	2.27
B409/(B1*B9501)	02CS-30331	2.40	1.86	2.10	2.26	2.18
(91BE7414*R01160)-CSF1-CS	04CS-798-7-1	2.00	1.97	1.80	1.62	1.86
(R01165*R0036)-CEF1-CS	04CS-608-6-1	2.00	1.69	1.51	1.35	1.64
	02CM-19225	1.90	0.84	0.84	1.10	1.19
Mean		2.60	1.87	2.33	2.45	2.34
LSD .05		1.62	1.07	1.34	0.74	
CV		37.0	34.5	34.6	18.0	

blight, anthracnose and grain mold (Table 1). For each disease the response ranged from no infection (rating = 0.0) to a moderate to high level of susceptibility. For the foliar diseases several entries exhibited very good resistance to each disease. Several of the entries produced excellent grain yield. The entries were mostly moderately susceptible, at least, to grain molds. Research is ongoing to improve the grain mold resistance in potential varieties but this is a slow process. No entries had excellent resistance to each disease. These are primarily white-tan selections aimed at the development of white grained genotypes with acceptably grain characteristics. Analyses of multi-seasonal data from line and cultivar trials are being conducted to determine the stability of genotype response to diseases over changing environments. These will be conducted using AMMI analyses.

Sorghum panicles were inoculated with five fungi frequently isolated from sorghum grain to determine the relationship between fungal pathogenicity and host genetic resistance. A collection of 11 sorghum genotypes from Southern Africa regional trials supported by the International Sorghum and Millets Collaborative Research Support Program (INTSORMIL CRSP) was used. Panicles of selected genotypes were inoculated at anthesis with *Fusarium graminearum*, *Fusarium thapsinum*, *Curvularia lunata*, *Phoma sorghina* and *Alternaria alternata* spores. There were highly significant differences in the levels of fungal pathogenicity on the different sorghum genotypes. These differences accounted for 58.4% of observed variation in ergosterol concentration. Genotype by pathogen (G x P) interactions accounted for 33.5% of the observed ergosterol concentration variation. The implication is that different genotypes reacted differently to different fungi. The genotypic reactions of the hosts accounted for 8.1% of the observed ergosterol concentration variation. Overall, fungal pathogenicity is the most important factor to consider in the evaluation of germplasm for grain mould resistance. However, fungal pathogenicity also depends on host genetics. Individual host genes associated with resistance to individual grain mould fungi need to be identified and manipulated into sorghum hybrids and cultivars. Possible sources of resistance could be identified by use of biplot analysis of G x P interactions. Visual scoring for grain mould is insufficient without identifying causal fungi. A multiple regression model involving all the fungal species accounted for 67% of the variation in the final visual grain mould damage rating. *Alternaria alternata* accounted for 52% of the final visual grain mould damage rating. However, *Fusarium thapsinum* and *Phoma sorghina* were the most abundant fungi across all genotypes. Thus, it should be possible to identify individual host resistance genes and pyramid them in order to get a broad sense resistance mechanism that will hold against all important fungi across environments and seasons.

Gene action and heritability for grain mould resistance in sorghum were investigated using a selection of specific parental lines. The combining ability of 9 random pollen parents with varying levels of grain mould resistance to a different set of three random seed parents was evaluated. The combined analysis of variance showed no genotypic variance for grain mould resistance. The expression of grain mould resistance was also not stable with significant genotype x location interactions. Additive genetic variance was greater than dominance variance for all traits except grain mould resistance. A significant heterosis of -20.15% was observed for grain mould resistance indicating the importance of use of hybrid seed.

Due to very high environmental variance, grain mould heritability could not be detected. The variation in genotype performance for grain mould resistance was studied using the same parents to assess significance and nature of genotype by environmental interactions in the expression of grain mould resistance. Differences in ergosterol concentration in mature grain were evaluated and used as the primary measure of the level of grain colonization in genotypes. Significant G x E interaction effects on ergosterol were detected. Single site analysis was conducted to better explain the nature of the G x E interaction.

The Medical Research Council PROMEC Unit studies the ability of *Fusarium* spp. to produce mycotoxins that have detrimental health effects for both humans and animals make it very important to evaluate their toxin production in diverse crops that are intended for human consumption. This is even more applicable for those *Fusarium* spp. that are found occurring in crops such as sorghum and millet without any disease symptoms on the plant hosts. *Fusarium* species produce a number of mycotoxins, including fumonisins and moniliformin, which have been shown to have negative health effects or implications on both humans and animals that consume agricultural crops that are infected by them.

The current research project concentrated on the determining the fumonisin (FUM) and moniliformin (MON) profiles of 20 *Fusarium* strains previously isolated from maize, millet and sorghum patty media in the laboratory. In order to achieve this, millet patty cultures were developed, and the results compared to those of the same fungi grown on maize and sorghum patties. A total of 92 cultures were successfully grown on maize, sorghum and millet patty cultures and will be chemically analyzed for both, fumonisin and moniliformin mycotoxins in 2010 (total of 184 analyses).

Previously, it has been shown that both FUM and MON occur naturally in maize, sorghum and millet, and that selected potentially toxigenic *Fusarium* strains isolated from maize, sorghum and millet samples from Nigeria, both maize and sorghum grains can potentially harbor high fumonisin producing *Fusarium* species, and that the unidentified new *Fusarium* species isolated from sorghum and millet needed to be further investigated and their toxin profiles determined. This part of the research plans to confirm that the fungi isolated from maize, sorghum and millet, do have the ability to produce mycotoxins in *in vitro* cultures.

## Publications

Condensed tannins in traditional wet cooked and modern extrusion cooked sorghum products. Dlamini N.R., Dykes, L., Rooney, L.W., Waniska, R.D. and Taylor J.R.N. 2009. *Cereal Chem.* 86: 191-196.

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### ***Other Publications***

Guide to floor malting of sorghum and millets. Taylor, J.R.N. 2008. [www.intsormil.org](http://www.intsormil.org)

Food security in Africa: The role of sorghum and millet. Taylor, J.R.N. 2009. Brew. Distill. Int. (3) 22-25.

### ***Book Chapter***

Applications for non-wheat testing methods. Taylor, J.R.N. and Duodu, K.G. In "The ICC Book of Cereals, Flour and Dough Testing (S. Cauvain and L. Young, eds), DEStech Publications, Lancaster, PA 2009, pp. 197-235. ISBN978-1-932078-99-2.

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

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

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### Regional Program Description

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, and Senegal are developing, evaluating, and transferring technologies to improve production and marketing of sorghum and pearl millet and manage *Striga* in West Africa. The West Africa regional program with collaboration among scientists at Institut D'Economie Rurale in Mali, Institut National de la Recherche Agronomique du Niger, INERA and IRSAT in Burkina Faso, Institut Sénégalais de Recherches Agricoles and ITA in Senegal, 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.

Hamidou Traoré from Burkina Faso coordinated the “Integrated *Striga* and nutrient management for sorghum and pearl millet” project. Involved are Mountaga Kayentao from Mali, Nouri Maman and Souley Soumana from Niger, and Moctar Wade from Senegal. The goals were to identify and characterize *Striga*-resistant sorghum and millet; characterize and implement integrated *Striga* management systems for millet that incorporate fertilizer, 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 as technology packages to increase yield of sorghum and millet and the incomes of farmers throughout West Africa.

Mamourou Diourté from Mali coordinated the production component of the “Increasing farmers’ and processors’ incomes via improvement in sorghum, pearl millet, and other grain production, processing, and marketing systems” project. This production sub-project involves agronomists S. Jean B. Taonda in Burkina Faso, Seyni Sirifi in Niger, and Abdoul Wahab Toure in Mali; entomologists Hame Abdou Kadi Kadi in Niger and Niamoye Yaro

Diarisso in Mali; plant pathologist Adama Neya in Burkina Faso; and plant breeders Ignatius Angarawai in Nigeria, N'Diaga Cisse in Senegal, Souley Soumana in Niger, and Abocar O. Touré and Niaba Témé in Mali. 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 to manage grain harvesting and storage practices. 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 for targeted environments.

Ababacar N'Doye from Senegal coordinated the processing and marketing systems component of the project "Increasing farmers' and processors' incomes via improvement in sorghum, pearl millet, and other grain production, processing, and marketing systems." The processing and marketing sub-project involves food scientists Boniface Bougouma from Burkina Faso, Moussa Moustapha from Niger, and Iro Nkama from Nigeria, and poultry scientist Salissou Issa 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. 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, food processing and marketing entrepreneurs, and consumers. Activities were focused 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 were transferred; local processing groups were assisted to disseminate new processing technologies and initiate businesses; and sorghum, millet, and fonio are being characterized as "functional foods" for health. The goal was to have competitive composite flour 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 grain, with the goal to increase the use of sorghum for poultry.

### Sorghum/Millet Constraints Researched

Teams of scientists, extension educators, and farmers in Burkina Faso, Mali, Niger, Nigeria, and Senegal are developing, evaluating, and transferring technologies to manage *Striga* and improve production and marketing of sorghum and millet. Sorghum and pearl millet, the staple foods of people in Sub-Saharan Africa, suffer significant yield losses because of poor soil fertility, scarce and erratic rainfall, warm temperature, and insect, disease, and weed pests such as *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. In addition to *Striga*, major pests of sorghum and millet in fields in West Africa include anthracnose and other diseases, mil-

let head miner, sorghum midge, and stalk borers. *Colletotrichum*, *Curvularia*, *Aspergillus*, and *Fusarium* that cause human cancers, lymphatic diseases, and gastritis and insect pests such as beetles and moths cause loss of grain quality and weight within only a few months in storage. Pest-resistant cultivars and packages of improved crop, soil, water, and pest management technologies would reduce pesticide use, conserve natural resources of soil and water, more efficiently use fertilizer, and increase stability and yield of food and feed for domestic use and income from marketing. Cultivars of sorghum and millet with known adaptation, stability, and acceptability and resistance to drought and pests in multiple environments are being identified and developed. Agronomic and pest management technologies that include the use of resistant cultivars, crop rotation, intercropping, fertilizer, and herbicides are being developed to manage diseases, insects, and *Striga* in the field. Pests are being identified and control measures developed and transferred to manage grain harvesting and storage practices. Development and adoption of high-yielding, quality sorghum and millet with increased nutritional value would improve human nutrition and health. Enhanced urban markets are needed for farmers to sell surplus grain of improved sorghum and millet. Processed products such as competitive composite flour would contribute to development of markets for sorghum, millet, and fonio through transfer of the technologies to entrepreneurs to initiate businesses. Use of sorghum in poultry feed in West Africa needs to be validated and education provided on availability of low-tannin varieties and aflatoxin-free grain. Partnerships among host-country scientists, NGOs, international agencies, extension, and farmers are needed to ensure transfer of technologies for improved agricultural production and marketing. Greater, more stable yields and enhanced markets will better the livelihood of people dependent on sorghum and millet and help end hunger in West Africa by increasing farm incomes and agricultural development.

### Institution Building

A prototype baking oven and groundnut roaster were constructed and tested in Nigeria. A dehulling machine for sorghum and millet was purchased and installed for testing in Nigeria. A project on implementation of a couscous line for millet/maize couscous preparation was supported by a regional World Bank program called "West African Agricultural Productivity Programme" that allocated to ITA 17 000 000 CFA F to complete the couscous line using the agglomerator developed by ITA in Senegal. A color brochure in French entitled "Les insectes nuisibles du sorgho stocké et la gestion intégrée des insectes nuisibles des stocks" was given out when discussing with 199 farmers how to manage insect pests of stored grain at seven villages in Mali in March 2009.

Sorghum and millet scientists who worked in West Africa during the year included food scientist Bruce Hamaker, animal scientist Joe Hancock, entomologist Bonnie Pendleton, plant breeder Mitch Tuinstra, agronomists Vara Prasad and Scott Staggenborg, economist John Sanders, and Short Heinrichs.

One Ph.D., 2 M.S., and more than 15 undergraduate students from Nigeria assisted through the INTSORMIL grant in 2008-2009. The Ph.D. program of Mohammed Diarra from Mali started in January 2009 in Food Science and Technology at the University of Maiduguri, Nigeria was supported by INTSORMIL under

the collaborative supervision of Professors Iro Nkama (Nigeria) and Bruce Hamaker (Purdue University). The student completed most coursework. Research is expected to begin after the student's examinations which were delayed by an industrial dispute at Nigerian universities. Tuition, fees, and research costs of the Ph.D. program of Amina Jato, staff of the Department of Food Science and Technology, University of Maiduguri, have been paid from INTSORMIL funds for the past 3 years. She started research to improve the nutritional quality of millet/sorghum-based sinasin (injera-like food) through supplementation with grain legumes (cowpea).

Hame Abdou Kadi Kadi in Niger collaborated with Dr. Kadri Aboubacar, Faculté d'Agronomie, Université Abdou Moumouni de Niamey, to supervise internship activities of five students for practical field training, writing reports, and defense committees in 2008. In 2009, Mr. Kadi Kadi worked with two interns at Tahoua, Niger. One intern assessed evaluation and adoption of SSD-35 sorghum at Doguéraoua (Birni N'Konni) and the second intern was posted at Madaoua to survey farmers' knowledge about insect pests of sorghum.

## Networking

### *Workshops and Meetings*

The pilot plant of the research institute DTA Technopol and bakeries and breweries in Burkina Faso were used to teach new technologies for bread, biscuits, and dolo. Two sessions from 23-28 February and 13-22 July taught new technologies for dolo based on a gas-improved fire box and optimized brewing process. Twenty females who are members of the Association des Dolotières et Revendeuses du Kadiogo and two men were trained to use the new technology, with collaboration from a Sodigaz project.

## Research Investigator Exchanges

In addition to visits by various PIs involved with INTSORMIL, the West Africa coordinators met in August 2009 at Bamako, Mali, to prepare annual sorghum and millet production, marketing, and Striga-management workplans and budgets.

## Research Information Exchange

Entomologists Niamoye Yaro Diarisso in Mali, Hame Abdou Kadi Kadi in Niger, Alain Ratnadass with CIRAD/ICRISAT in Niger, and Bonnie Pendleton discussed in October 2008 collaborative research for the "Cereals for the Drylands" proposal to the Gates Foundation. A color brochure translated into French was given out when discussing with 199 farmers how to manage pests of stored grain in March 2009 in Mali. Sorghum midge-resistant SSD-35 developed at INRAN was evaluated by 48 farmers and produced by 184 farmers in Niger. In six villages, 171 farmers adopted SSD-35 and Mota Maradi. Technologies for danwake (sorghum/cowpea-based dumpling), biscuits, dakuwa, sorghum and millet grits and flour and couscous developed through INTSORMIL were transferred to entrepreneur Al-Muneer, Nigeria Limited in Maiduguri. Products are being analyzed to enable the company to obtain National Agency for Food and Drug Administration registration

numbers and begin full operation. Based on results from INTSORMIL projects on sorghum and millet, a proposal for training and establishing two small-scale value-added product enterprises in Tikau (Nengere government area) and Jimbam (Tarmuwa government area) in Nigeria was submitted to the Community Based Agricultural and Rural Development Programme, Yobe State in Partnership with Intellectual Property and Technology Transfer Office of the University, coordinated by Iro Nkama. Products to be processed include weaning foods, biscuits, couscous, and dakuwa (snack food like chocolate). The MOU has been signed and the partner is seeking a No Objection Letter from the sponsors so the project can begin.

## Germplasm Distribution

Twenty early-, 10 medium-, and seven late-maturing sorghum breeding lines developed by IER in Mali were transferred to farmers to compare with local checks. Nine extension agents, 28 farmers, and an organization of 80 farmers multiplied seed of sorghum midge-resistant SSD-35 on 3.5 hectares in Niger. SSD-35 was evaluated by 48 farmers and produced by 184 farmers on 67 hectares. In six villages, 171 farmers adopted SSD-35 and Mota Maradi planted on 40 hectares. Seeds of SSD-35 and Mota Maradi were multiplied on 55 hectares by 92 farmers from eight villages. Bagged grain of SSD-35 is being sold by the private "Semences Améliorées ALHERI" seed company in Niger. Three millet head miner-resistant millets developed by INRAN were transferred to farms in Niger.

## Research Accomplishments

### *"Integrated Striga Management in Sorghum and Pearl Millet in West Africa" Project*

Weed scientist Hamidou Traoré used an agar gel assay method for in vitro evaluation of 15 landraces of sorghum (five from INERA Burkina Faso, four from IER Mali, one from ICRISAT-Samanko, three from INRAN Niger, and two from ISRA Senegal) for resistance to *Striga* from Burkina Faso, Mali, and Niger in a laboratory at Kamboinsé research station in Burkina Faso. The 15 landraces of sorghum were evaluated to confirm resistance to *Striga* in fields at Kouaré and Farako-ba research stations in Burkina Faso, Sotuba and Samanko research stations in Mali, Konni research station in Niger, and Bambey research station in Sénégal. At Kouaré, seeds of the landraces were sown on 17 July, while seeds were sown on 24 July 2009 at Farako-ba. Data were collected on the number of plants per plot, date of flowering of sorghum, sorghum height (21 days after sowing and at harvest), days until emergence of the first *Striga*, and numbers of *Striga* 60 and 90 days after sowing. At Kouaré, few *Striga* plants were recorded at 60 days after sowing (0 to 27 per plot), but at 90 days, *Striga* plants ranged from 6 to 289 per plot. The sorghum is not yet ready to harvest.

Integrated sorghum management systems that include water management, improved variety, improved fertility, and non-target hosts for sorghum in Burkina Faso were evaluated starting in 2008. Treatments included: 1) improved sorghum variety, 2) improved sorghum variety with 2 to 5 tons of manure per hectare, 3) improved sorghum variety with 2 to 5 tons of manure and inorganic fertilizer per hectare, 4) improved sorghum variety with 2 to 5 tons

of manure and inorganic fertilizer per hectare and weeding 60-65 days after planting, and 5) improved sorghum variety in rotation with cowpea in 2008 and sorghum in 2009. Four experiments were done on farms in eastern Burkina Faso, each farm representing a replication. In each experiment at each location, days to first emergence of *Striga*, numbers of *Striga* at 60 and 90 days, plant height, days to flowering, and plants per plot will be recorded. Plots were not yet harvested; yield will be determined at harvest.

Mountaga Kayentao in Mali evaluated sorghum varieties for resistance to *Striga* and used herbicide to control *Striga* under artificial infestation of the parasite. Three experiments were done at Sotuba and Cinzana with the objectives to 1) verify the effectiveness of herbicide doses in treating sorghum seed to control *Striga* and 2) develop and transfer an integrated approach to control *Striga* throughout the Sudanese and Sahelian zones of West Africa. The first experiment used three sorghum genotypes treated with three doses of herbicide and one nontreated check planted on 15 July at Sotuba and 17 July at Cinzana with three replications at both locations. The second experiment involved 14 entries from Burkina Faso, Mali, Niger, and Senegal planted on 15 July at Sotuba. The experiment was done for the second year in the four countries. Data on *Striga* rating and yield will be available at harvest.

#### **“Increasing Farmers’ and Processors’ Incomes via Improvement in Sorghum, Pearl Millet, and Other Grain Production, Processing, and Marketing Systems” Project – Production**

Agronomist Abdoul Wahab Touré evaluated optimal plant population for newly released tan sorghum varieties to express their full yield potential at Sotuba, Mali. A strip-plot design with four blocks was used. The treatments were six populations of 0.75 x 0.50 m with 2 plants per hill (53,333 plants per hectare), 0.75 x 0.50 m with 3 plants per hill (79,999 plants per hectare), 0.75 x 0.25 m with 2 plants per hill (106,666 plants per hectare), 0.50 x 0.40 m with 1 plant per hill (50,000 plants per hectare), 0.50 x 0.40 m with 2 plants per hill (100,000 plants per hectare), and 0.50 x 0.40 m with 3 plants per hill (150,000 plants per hectare) in combination with the four sorghum varieties of CSM388 (check), Séguifa, Tiandougou, and Niaticama, for 24 treatment combinations in each block. One hundred kilograms per hectare of d-iammoniac phosphate were applied at planting and 50 kg/ha of urea 30-40 days after planting. Table 1

Harvested plant population fluctuated between 80 and 114% of recommended but should have been 90-283%. Compared to expected, the harvested plant population fluctuated between 36 and 80%. Harvested plants averaged 46,365 per hectare; the most was 64,684 and least 21,111 plants per hectare. No differences among

varieties were observed. Compared to the recommended 53,333 plants per hectare, plant populations of CSM388 (local), Séguifa, and Tiandougou were 101, 93, and 76%, with 53,889, 49,537, and 40,663 plants per hectare, respectively. Tiandougou and Niaticama had less than 50,000 plants per hectare (-24 and -22 %). Tiandougou yielded 2,000, while Niaticama yielded 1,700 kg per hectare. Two classes were distinguished based on grain yield: yield less than 2,000 kg and plant population less than 50,000 per hectare and yield greater than 2,000 kg, with plant population more than 50,000 plants per hectare. Regression analysis of harvested plants on grain yield led to the equation: grain yield (kg/ha) = 0.02295 \* number of stalks + 937.49 (R<sup>2</sup> = 31.8). A change of 10,000 plants would result in 230 kg/ha more grain. Table 2

Abdoul Wahab Touré compared new tan sorghum varieties Niaticama and Tiandougou at 100,000 plants per hectare with CSM388 (check) at the normal 50,000 plants per hectare to assess response to fertilizer rates and use efficiency at Sotuba, Mali. A split-plot design was used with three blocks. Six amounts of fertilizer were main plots and sorghum varieties were subplots. Data collected will be germinated hills before thinning, plant population after thinning and at harvest, biomass at flowering and physiological maturity, and panicle and grain weights at physiological maturity. Table 3

Niaticama and Tiandougou sorghum varieties at 100,000 plants per hectare were compared to CSM388 at 50,000 plants per hectare for early (27 June), intermediate (8 July), and late (18 July) planting dates. Data to be collected at harvest in November are biomass, panicle, and grain weights per variety per date at flowering and physiological maturity.

Plant breeders Abocar O. Toure, Adoulaye G. Diallo, and Niba Teme made new crosses at IER during the rainy season to assure improvement of breeding stocks through recombination of the best materials. From multi-location evaluation of 30 F<sub>2</sub> families, they made single-plant selections to advance by pedigree method. One hundred fourteen F<sub>3</sub> and 466 F<sub>5</sub> generations were planted and will be evaluated according to maturity group. The early 140 F<sub>5</sub> progenies were at Béma and Cinzana. The intermediate 202 F<sub>5</sub> progenies were at Sotuba and Kolombada. The late 124 F<sub>5</sub> progenies were at Farako and Kita. Thirty F<sub>2</sub>, 114 F<sub>3</sub>, and 466 F<sub>5</sub> progeny lines were evaluated.

The plant breeders at IER evaluated 35 advanced elite early-maturing varieties in a randomized complete block design at Bema and Cinzana stations in Mali. Each plot was 4 rows 0.75 m apart and 5 m long. Farmers were selected to compare their local checks with 20 early-maturing breeding lines in plots 500 m<sup>2</sup> with rows

**Table 1.**

Variety	Pedigree of variety	Year obtained	Plant height (m)	Range (m)	Cycle (days)	Sensibility to photoperiodism	Yield (kg/ha)	1,000-grain weight (g)
Niaticama	97-SB-F5-DT-150	1997	1.75	1.75-2	110-120	LS	2000	23
Tiandougou	98-SB-F2-78	1998	1.75	1.75-2	120	NS	3000	21
Séguifa	MLS-92-1	1992	2	1.75-2	100	NS	3000	30
Jigiseme	CSM388	1984	3.7	3-4	120-125	S	2500	25

**Table 2.**

Treatment	Expected plant population per hectare	Harvested plants per hectare	Harvested plant population in % of expected	% of recommended plant population	Grain yield (kg/ha)	% of 0.75 x 0.50 m 2 plants per hill
Density of population (DP)						
0.75 m x 0.50 m 2 plants/hill	53333	42639	80	80	2021	100
0.75 m x 0.50 m 3 plants/hill	79999	60694	76	114	2375	118
0.75 m x 0.25 m 2 plants/hill	106666	56667	53	106	2035	101
0.50 m x 0.40 m 1 plants/hill	50000	21111	42	40	1774	88
0.50 m x 0.40 m 2 plants/hill	100000	42639	43	80	1875	93
0.50 m x 0.40 m 3 plants/hill	150000	54445	36	102	1930	95
Mean		46365.66			2002	
s (ddl = 15)		16469 **			875	
CV		35.51			44	
Variety (V)						
CSM388		53889		101	2611	
Séguifa		49537		93	1644	
Tiandougou		40463		76	2067	
Niatichama		41574		78	1685	
Mean		46366			2002	
s (df = 9)		19054 **			1415	
CV		41			71	
Interaction (DP x V)						
S		8780.26 ns			472	
CV		18.93			23.58	

**Table 3.**

		PNT		Dolomite		Urea	Potassium sulfate	
		kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	
		P2O5	MgO	CaO	N	K2O	S	
F1	No fertilizer				0	0	0	
F2	200 kg/ha of tricalcic phosphate	54			0	0	0	
F3	F2 + 43.5 kg/ha of urea + 300 kg/ha dolomite	54	60	90	20	0	0	
F4	F2 + 87 kg/ha of urea + 300 kg/ha dolomite	54	60	90	40	0	0	
F5	F2 + 130 kg/ha of urea + 300 kg/ha dolomite	54	60	90	60	0	0	
F6	F2 + 87 kg/ha of urea + 300 kg/ha dolomite	54	60	90	40	15	5.4	

0.75 m apart and 5 m long. At harvest, the varieties will be evaluated for maturity, yield, agronomic desirability, and food quality.

Agronomically elite medium-maturing varieties and a local check were planted in a randomized complete block design at three locations in the Sudan Zone of Mali. Each plot was 4 rows 0.75 m apart and 5 m long. There were 25 GI and 25 GII entries. Ten medium-maturing breeding lines were compared to a local check used by farmers in plots of six rows 0.75 m apart and 5 m long at Bancoumana, Kafara, and Katibougou. At harvest, maturity, yield, agronomic desirability, and food quality will be evaluated.

Abocar O. Toure, Adoulaye G. Diallo, and Niaba Teme tested agronomically elite late-maturing varieties and local checks in a randomized complete block design at three locations on stations in the North-Guinea Zone of Mali. Each plot was 4 rows 0.75 m apart and 5 m long. Twenty-three breeding lines were compared with three local checks for GI, and 20 breeding lines for GII were compared to two local checks. Seven late-maturing lines were compared to a local check of a farmer at Kita. Each plot had rows

0.75 m apart and 5 m long. At harvest, the cultivars will be evaluated for maturity, yield, agronomic desirability, and food quality.

The plant breeders at IER crossed sorghums to maintain A/B lines and R to A lines for the sorghum hybrid program in Mali. Sewa, Fadda, 97-SB-F5DT-150A\*Grinkan, O2-SB-F5DT-12A\*02-SB-F4DT-298, and 97-SB-F5DT-150A/B hybrids were grown in isolation on farms at Kirina, Faraba, Samanko, and Sabalibougou to produce seed for testing in the region. The parent sorghums were grown on 1 hectare.

Plant pathologist Mamourou Diourté identified fungal pathogens on stored sorghum grain at three locations in Mali. Sorghum grain stored in November 2008 at Kaniko, Garasso, and Dioila was sampled in February-March 2009. A minimum of 20 samples each of 5 kg per storage facility was taken. One hundred seeds per sample were randomly selected and disinfected with 2% sodium hypochlorite for 15 minutes and rinsed in sterile distilled water. The seeds were spread on PDA and cultures were incubated at 25°C at a photoperiod of 12 hours. After incubation for 48 hours, the mono-emerged colonies were re-isolated and grown on new

Table 4.

Morphological characteristics of fungal species from stored grain of sorghum varieties at three locations in Mali			
Location	Variety	Fungi isolated	Colony characteristic on PDA
Garasso	Grinkan	Fusarium sp.	White cottony
	Grinkan	Aspergillus sp.	Green dark in the center
	Grinkan	Colletotrichum sp.	Gray fluffy
	Grinkan	Curvularia sp.	Gray – clear
Kaniko	Grinkan	Curvularia sp.	Gray – black
	Grinkan	Fusarium sp.	Pink fluffy
	Grinkan	Fusarium sp.	Pink-yellow fluffy
Dioila	Niatchichama	Colletotrichum sp.	White cottony
	Niatchichama	Colletotrichum sp.	Pink fluffy
	Niatchichama	Aspergillus sp.	Gray – dark

PDA. The cultures were kept at 3°C. Fungi identified were *Colletotrichum* sp., *Fusarium* sp., *Curvularia* sp., and *Aspergillus* sp. All species of fungi were isolated from Grinkan sorghum whereas only *Colletotrichum* and *Aspergillus* were isolated from Natchichama. Badly stored grain could be subject to contamination by fungal microorganisms some of which like *Fusarium* sp. cause human cancers, lymphatic diseases, and gastritis. Table 4

Sorghum leaf anthracnose caused by *Colletotrichum graminicola* is the most destructive disease of newly developed varieties at Sotuba, Mali. Dr. Diourté rated the severity of anthracnose in three breeder experiments under natural conditions. Five sorghum hybrids at the milk stage were resistant, while all other varieties were slightly susceptible to anthracnose. Table 5

Entomologist Niamoye Yaro and Péfoungo Konate assisted 20 farmers in evaluating the use of *Andropogon gayanus* to attract stalk borers away from millet at Finkolo and Zanradougou in different agroecological zones with Sudan climate in the Sikasso region of Mali. They also evaluated farmer awareness of the importance of wild grasses and adoption of the intercropping technique. Each farmer intercropped 5 rows 20 m long of a local variety of millet with or without (check) *Andropogon* at 10 m apart. A randomized complete block with each of 10 farmers as a replication was used per village. *Andropogon* plants were transplanted on 6 and 7 July at Finkolo and 8 and 9 July at Zanradougou in rows before millet was planted on 11 July at Finkolo and 12 July at Zanradougou. Damage by stalk borers and head miners on millet spikes was evaluated from planting to tillering and boot to flowering stages. Ten plants of millet and 10 of *Andropogon* were selected randomly from the diagonals of each plot to sample numbers of deadhearts and empty spikelets on 5 and 6 September at Finkolo and 7 and 8 September at Zanradougou. Transplanting coincided with a drought in June and July that killed the grasses, so *Andropogon* was transplanted several times. As a result, millet plants in some plots emerged before and were taller than *Andropogon*. After the drought, rainfall was regular and well distributed, and good results are expected after the millet is harvested. Table 6

Entomologist Hame Abdou Kadi Kadi and millet breeder Issaka Ahmadou assessed at the Regional Agricultural Research Center in Kollo, Niger, damage by millet head miner and yield of 12 pearl millets developed at INRAN. The design was a completely randomized block with three replications. Each sub-plot

was 12 m<sup>2</sup> with 4 rows 3 m long and 1 m between rows and hills. Five spikes of each genotype per replication were randomly selected and tagged. Five days later and until maturity, spikes were checked for larvae, pre-pupae, and pupae of millet head miner. At maturity, spikes were cut and damage assessed on a 1-9 scale where: 1 = <10, 2 = 11-20, 3 = 21-30, 4 = 31-40, 5 = 41-50, 6 = 51-60, 7 = 61-70, 8 = 71-80, and 9 = >81%. Infested spikes ranged from 24.2 to 62.4% for Tchoumo and SOSAT-C88 and were correlated with damage that ranged from 1.9 for Tchoumo to 4.3 for HKP GMS (20-50% mined spikes). Infested spikes were 38.4 and 40.9% on HKB and Taram (local varieties from Gaya Zone in Doso); damage was 1.9 and 2.1 (10-30% mined spikes). H80-10GR, SOSAT-C88, and HKP GMS were transferred to farms. The other millets still are being evaluated. Table 7

At Bazaga (Birni N’Konni), Niger, sorghum midge-resistant SSD-35 and its early maturing female parent Mota Maradi were less damaged (1.5 = 10-20% and 3.0 = 20-31% damaged spikelets) and yielded more (862.5 and 737.5 kg ha<sup>-1</sup>) than local El Mota (4.3 and 587.5 kg ha<sup>-1</sup>). At the 1st planting at Doguéraoua, damage by sorghum midge was 1.0, 3.9, and 2.9, but was 1.3, 3.9, and 2.0 for SSD-35, Mota Maradi, and El Mota at the 2nd planting. SSD-35 yielded 687.5 and 700.0 kg ha<sup>-1</sup> from the 1st and 2nd plantings. Yield of Mota Maradi did not differ between the 1st (937.5 kg ha<sup>-1</sup>) and 2nd plantings (1,000.0 kg ha<sup>-1</sup>). Yield of El Mota was greater in the 1st (743.8 kg ha<sup>-1</sup>) than 2nd planting (562.5 kg ha<sup>-1</sup>). Table 8

In 2009, SSD-35 and Mota Maradi were introduced on farms in seven villages of Birni N’Konni and Madaoua, Niger. Nine extension agents, 20 men and eight women farmers, and the “Taymako” organization of 74 men and six women farmers at Doguéraoua multiplied seed of SSD-35 on 3.5 hectares. SSD-35 was evaluated by 48 farmers and produced by 184 farmers on 67 hectares in two areas of Tahoua, Niger. In six villages, 104 and 67 farmers adopted SSD-35 and Mota Maradi planted on 24 and 16 hectares, respectively. Seed of SSD-35 was multiplied on 43 hectares by 84 farmers from five villages, and Mota Maradi was multiplied on 12 hectares by eight farmers from three villages. In 2008, the two varieties were introduced at farms in five villages of two regions by four extension agents, 16 men and four women farmers, and “Taymako” who did four tests with two planting dates at a site. Farmers and extension agents appreciate SSD-35 that yields well, is resistant to sorghum midge, and has good color grain.

Table 5.

<b>Anthraco­nose severity index on a sorghum hybrid at the milk grain stage, Sotuba, Mali, 2009</b>		
<b>Sorghum variety</b>	<b>Disease severity index</b>	<b>Plant reaction</b>
Sewa	2	NS
02-SB-F4DT-12A*04-SB-F5DT-249	2	NS
97-SB-F5DT-150A*03-SB-F5DT-105	2	NS
97-SB-F5DT-150A*Grinkan	2	NS
02-SB-F4DT-12A*02-SB-F5DT-298	2	NS
PR3009A*Latabala	3	SF
02-SB-F4DT-12A*CSM-63E	3	SF
97-SB-F5DT-150A*98-SB-F2-78	3	SF
97-SB-F5DT-150A*MALISOR-84-7	3	SF
97-SB-F5DT-150A*03-SB-F5DT-249	3	SF
97-SB-F5DT-150A* 06-SB-F5DT-15	3	SF
97-SB-F5DT-150A*04-SB-F5DT-203	3	SF
98-SB-F2-82A*04-SB-F5DT-249	3	SF
97-SB-F5DT-150A*02-SB-F5DT-57	3	SF
PR3009A*CSM-63E	4	SF
97-SB-F5DT-150A*Latabala	4	SF
GPNA*Latabala	4	SF
FADA	4	SF
97-SB-F5DT-150A* CSM-63E	4	SF
GRINKAN	4	SF
97-SB-F5DT-150A*07-BE-F5DT-29	4	SF
CSM-63E	4	SF
97-SB-F5DT-150A*07-KO-F5DT-58	4	SF
97-SB-F5DT-150A*05-F5DT-67-1	5	SF
Siguicumbe	5	SF
CSM-388	5	SF
97-SB-F5DT-150A*Malisor-92-1	5	SF
97-SB-F5DT-150A*03-F4T-38	5	SF
GPNA*CSM-63E	5	SF
Malisor-92-1	5	SF
Témoin sensible IS18441	13	SE
NS: not susceptible (2-3), SF: slight susceptibility (3-8); SM: moderate susceptibility (8-13); SE: very susceptible (13-18)		
<b>Anthraco­nose severity index on yield of intermediate-maturing varieties at the milk grain stage</b>		
<b>Sorghum variety</b>	<b>Disease severity index</b>	<b>Plant reaction</b>
09-KO-F5DT-61	3	SF
09-KO-F5DT-79	3	SF
09-KO-F5DT-19	4	SF
09-KO-F5DT-31	4	SF
09-KO-F5DT-32	4	SF
09-KO-F5DT-33	4	SF
09-KO-F5DT-35	4	SF
09-KO-F5DT-42	4	SF
09-KO-F5DT-45	4	SF
09-SB-F5DT-60	4	SF
09-KO-F5DT-63	4	SF
09-KO-F5DT-70	4	SF
09-SB-F5DT-80	4	SF
09-KO-F5DT-81	4	SF
09-KO-F5DT-107	4	SF
Grinkan	4	SF
Darell-Ken	4	SF
Nieta	4	SF
Témoin	4	SF
09-KO-F5DT-18	5	SF
09-KO-F5DT-47	5	SF
09-KO-F5DT-55	5	SF
Nietiama	5	SF
09-KO-F5DT-92	6	SF
09-KO-F5DT-1	7	SF
Témoin sensible IS18441	13	SE
NS: not susceptible, SF: slight susceptibility, SM: moderate susceptibility, SE: very susceptible		

Table 5. cont'd

Anthracnose severity index on yield of intermediate-maturing varieties at the milk grain stage		
Sorghum variety	Disease severity index	Plant reaction
07-SIR-F5T-7 (TYP Grinkan)	3	SF
07-SIR-F5T-9	3	SF
07- KO-F5DT-44	4	SF
07-KO-F5DT-57	4	SF
07-KO-F5DT-62	4	SF
07-SB-F3DT-169	4	SF
07-SB-F3DT-173	4	SF
07-SB-F3DT-52 CT	4	SF
07-SB-F3DT-64	4	SF
07-SIR-F5T-8	4	SF
Darrell Ken	4	SF
Grinkan	4	SF
Témoïn local	4	SF
07-KO-F4DT-28	5	SF
07-KO-F5DT-42	5	SF
07-KO-F5DT-58	5	SF
07-SB-F3DT-52 HT	5	SF
07-SB-F5DT-41	5	SF
CSM-388	5	SF
07-KE-GII T-103	6	SF
07-KO-F5DT-47	6	SF
07-KO-F5DT-78	6	SF
07-SB-F5DT-40	6	SF
07-SB-F3DT-335	7	SF
07-SB-F3DT-55	7	SF
Témoïn sensible IS18441	13	SE

NS: not susceptible, SF: slight susceptibility, SM: moderate susceptibility, SE: very susceptible

Table 6.

Village	Farmer	Millet and Andropogon plant heights	Percent infestation by stalk borers		
			Millet without A. gayanus	Millet with A. gayanus	Andropogon gayanus
Finkolo	Seybou KONE	Same	15.3	8.5	7.0
	Issouf BALLO	Same	9.3	3.5	7.0
	Abdoulaye KONE	Same	5.8	6.1	3.5
	Diakalia BALLO	Same	6.6	6.3	2.1
	Inzan TRAORE	Same	11.5	3.5	9.0
	Abou KONATE	Millet taller	14.5	17.0	3.0
	Lassina BALLO	Same	5.8	4.8	4.5
	Daouda CISSE	Millet taller	15.3	17.2	2.5
	Madou TRAORE	Same	1.5	3.4	3.0
	Amidou DIARRA	Millet taller	5.7	7.8	2.2
Mean			9.1	7.8	4.4
Zanradougou	Adama SANOGO	Same	14.5	6.0	9.3
	Konzié SANOGO	Millet taller	13.7	14.0	0.8
	Daouda DIARRA	Millet taller	8.3	9.3	1.0
	Nouhoum DJOURTHE	Millet taller	5.4	3.7	6.2
	Adama DJOURTHE	Millet taller	12.5	11.0	6.0
	Guédiouma DJOURTHE	Millet taller	6.9	7.1	2.3
	Siaka DJOURTHE	Same	9.3	5.5	5.5
	Abdoulaye DJOURTHE	Same	4.6	1.5	5.4
	Massaba TRAORE	Same	9.5	7.5	4.0
Tidiani SANOGO	Same	17.0	13.7	9.0	
Mean			10.2	7.9	5.0
Overall mean			9.7	7.9	4.7

Table 7.

Millet evaluated at Kollo, Niger	Damage (1-9 scale)	% spikes infested by millet head miner
Tchoumo	1.9 ± 1.0 a	24.2 ± 1.6 a
Mangarana	2.9 ± 2.0 b	28.4 ± 2.2 b
HKB	1.9 ± 1.1 a	38.4 ± 2.1 c
Taram	2.1 ± 1.2 b	40.9 ± 1.5 c
ICMV IS89305	2.2 ± 1.2 b	44.2 ± 2.6 ab
Zatib	2.8 ± 1.9 b	44.9 ± 2.3 ab
Mangarana x ICMV IS89305	2.5 ± 1.4 b	52.8 ± 3.1 bc
SOSAT-C x HKB	2.7 ± 1.3 b	55.6 ± 2.9 bc
H80-10 GR	2.8 ± 1.4 b	57.3 ± 1.3 abc
HKP GMS	4.3 ± 2.7 c	58.1 ± 1.7 abc
SOSAT-C 88 x Zatib	3.1 ± 1.5 ab	59.7 ± 3.3 abc
SOSAT-C88	3.8 ± 2.2 ab	62.4 ± 3.8 cd
CV (%)	2.8	47.2
LSD	2.5	52.3

Table 8.

Sorghum	Damage by sorghum midge (1-9)			Yield (kg ha <sup>-1</sup> )		
	Bazaga	1st planting, Doguérawa,	2nd planting, Doguérawa,	Bazaga	1st planting, Doguérawa,	2nd planting, Doguérawa,
SSD-35	1.5 ± 0.3c	1.0 ± 0.1c	1.3 ± 0.3a	862.5 ± 13.6a	687.5 ± 9.7a	700.0 ± 12.3b
Mota Maradi	3.0 ± 0.4b	3.9 ± 0.4c	3.6 ± 0.3b	737.5 ± 14.7b	937.5 ± 17.3c	1,000.0 ± 7.9c
El Mota (check)	4.3 ± 0.7a	2.9 ± 0.7b	2.0 ± 0.6c	587.5 ± 10.9c	743.8 ± 12.4b	562.5 ± 10.5a
CV (%)	35.5	43.2	36.8	48.6	39.7	45.4
LSD	1.5	1.9	0.3	139.0	193.7	137.5

### “Increasing Farmers’ and Processors’ Incomes via Improvement in Sorghum and Pearl Millet Production, Processing and Marketing Systems” Project – Processing and Marketing

Food scientist Iro Nkama and millet breeder Ignatius Angarawai worked with food scientists Amina Jato and Hadiza Lawan, agricultural process engineer N. A. Aviara, poultry scientist J. Igwebuike, economist Binta Zangoma, and technologist Shuwa Mohammed at the University of Maiduguri in Nigeria, food scientist Mohammed Diarra from the Institut d’ Economie Rurale in Mali, food scientist Bruce Hamaker from Purdue University, and animal scientist Joe Hancock from Kansas State University to analyze physical, chemical, and end-use quality properties of sorghum, millet, and acha (fonio) grown locally and from Lake Chad Research Institute, Institute for Agricultural Research, and ICRISAT. Traditional foods and new products (couscous, extruded fura, weaning foods and biscuits) were prepared to test the quality of the grain samples. Malting properties of some varieties were evaluated.

Performance of broiler chicks fed sorghum ground to different particle sizes was compared to maize as a source of energy. The effect of tray and sun drying on properties of ogi from millet, sorghum, and maize was studied. The viscosity of cooked paste decreased as the shear rate increased and decreased as temperature increased. Data generated were fitted to the power law equation and Arrhenius equation and the consistency index (k), power law index (n), and activation energy determined. All ogi samples were non-Newtonian based on the power law index that ranged from 0.14-0.33. Activation energy of the ogi samples ranged from 0.230-1.382. The drying method did not affect the properties of

the ogi samples. Drying curves were generated from the drying data.

Food scientist Boniface Bougouma from Burkina Faso characterized sorghum and millet to identify suitable varieties for breads, biscuits, and dolo. A malting and brewing survey is being summarized and parameters of dolo characterized. Samples for Ouagadougou were analyzed and GC methods for alcohol, sugar, and organic acids are being set up. Table 9

The pilot plant of the research institute DTA Technopol and bakeries and breweries in Burkina Faso were used to teach new technologies for bread, biscuits, and dolo. Training sessions were held on new technologies for dolo based on a gas-improved fire box and optimized brewing process. The new technology saved 36% energy, increased brewing yield 20%, and improved dolo quality.

Food scientists Ababacar N’Doye, Ndeye Thi Thi Seye Ndoumouya, and Momar Talla Gueye, technologist Ibra Mbaye, bakers Jean Paul Diedhiou and Oscar Sambou, and nutritionist Ndeye Fatou Ndiaye from the Institut de Technologie Alimentaire, Dakar, Sénégal, food scientist Ndeye Thi Thi Seye Ndoumouya from the University of Maiduguri, and food scientist Bruce Hamaker from Purdue University focused activities in Senegal on market promotion of composite flour bread using millet, sorghum, or maize mixed with wheat; development of an economic millet/maize couscous prepared from grits instead of flour; implementing a new couscous line for preparation of new economical couscous; collaborating with Morgan Goodall on a baking test of the sorghum mutant; and training a bakers’ corporation and women’s group to prepare composite flour bread.

An economical millet/maize couscous was prepared from grits instead of flour in the traditional process. Couscous was prepared from thin particles (sankhal) of millet and corn. The couscous was subjected to sensory tests in comparison with a couscous sample bought from a local market (the blank). To prepare couscous, 1.5 kg of sankhal was soaked or dipped in water and the behavior of the two products assessed. The method in the project of ROCAFREMI was used by a panel of 50 tasters to assess color, taste, texture, size of granules, and acceptability of millet and corn products. The three samples (blank, couscous from soaking, and couscous from dipping process) were separated, coded randomly, and presented to tasters in disposable dishes. Tasters graded the products on a scale from 1 (very bad) to 5 (very good). Soaked sankhal of millet required less water for cooking than did dipped sankhal of millet. But, dipped sankhal of corn required less water than did soaked corn. Table 10

Color, size of granules, taste, and acceptability of soaked or dipped couscous from millet were significantly less preferred than

those of the blank from the local market in Senegal. But, the texture of the blank and soaked sankhal did not differ. Samples of sankhal could be used to produce “thiakry” considering the size of the granules would be suitable for that kind of product. Table 11

The three samples of corn differed significantly in color, size of granules, texture, and acceptability but not taste between the blank and soaked sankhal. Table 12

A project on implementation for millet/maize couscous preparation was supported by a regional World Bank program called “West African Agricultural Productivity Programme” that allocated to ITA money to complete the couscous line using the agglomerator developed by ITA.

**Table 9.**

Chemical characteristics of dolo				
Sample	pH	d20/20	Acidity (mg eq lactic acid/l)	% alcohol
Enzymic extract	5.03 ± 0.12		2.99 ± 0.11	
Acidified wort	3.82 ± 0.14	1.0346 ± 0.0092	6.59 ± 0.07	
Concentrated wort	3.78 ± 0.15	1.0427 ± 0.0053	7.04 ± 0.11	
Dolo	3.56 ± 0.18	1.0183 ± 0.0110	7.59 ± 2.38	2.01 ± 1.01

**Table 10.**

Cooking tests of samples from dipped thin particles (sankhal) of millet and corn			
Behavior	Dipped millet (minutes)		Soaked corn (minutes)
Time of dipping	30		30
Time for draining	53		13
Time of cooking	81		44
Cooking tests of samples from soaked thin particles (sankhal) of millet and corn			
Behavior	Soaked millet		Soaked corn
Before cooking	Amount of water (ml)		670
	Time of absorption (minutes)		31
During cooking	Amount of added water		830
Total time of cooking (minutes)			31
Total amount of water used (ml)			1,500
			2,000

**Table 11.**

Millet sample	Color	Size of granules	Texture	Taste	Acceptability
Blank	4.26 ± 0.93a	3.96 ± 0.96a	3.80 ± 0.98ab	3.90 ± 0.98a	3.98 ± 0.88a
Soaked sankhal	3.54 ± 0.94b	3.50 ± 0.85b	3.64 ± 0.91ab	3.44 ± 1.00b	3.44 ± 1.02b
Dipped sankhal	3.22 ± 1.12b	3.34 ± 0.93b	3.38 ± 1.04c	3.06 ± 1.01b	3.36 ± 1.05b

Means followed by the same letter in a column are not statistically different by the Student-Newman-Keuls test.

**Table 12.**

Corn sample	Color	Size of granules	Texture	Taste	Acceptability
Blank	4.50 ± 0.74a	4.34 ± 0.75a	4.32 ± 0.71a	4.36 ± 0.90ab	4.50 ± 0.74a
Soaked sankhal	3.86 ± 1.14b	3.88 ± 0.96b	3.86 ± 0.89b	4.02 ± 1.04ab	4.06 ± 0.96b
Dipped sankhal	3.22 ± 1.04c	3.20 ± 0.95c	3.02 ± 1.00c	3.02 ± 0.98c	3.24 ± 1.02c

Means followed by the same letter in a column are not statistically different by a Student-Newman-Keuls test.

**Figure 1. INTSORMIL/INRAN PIs Moustapha Moussa, Soumana Souley, Hame Kadi Kadi, and Seyni Sirifi; Salami Issoufou, head of INRAN research station; Manzo Moussa, staff; and Haladou Salha, technician for entomology, ICRISAT-Niger discussing research to be done in 2008 at Birni N’Konni, Niger**



**Figure 2. Part of the pilot plant being set.**



**Figure 3. Training to prepare composite flour bread from 85% wheat and 15% millet or maize for market testing by ITA in Senegal.**



**Figure 4. Bagged seeds of sorghum midge-resistant SSD-35 on store shelves of the private seed company “Semences Améliorées ALHERI”, Doutchi, Niger.**

