Germplasm Enhancement and Conservation

Breeding Pearl Millet for Improved Stability, Performance, and Pest Resistance

Project ARS 206
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Summary

Pearl millet [*Pennisetum glaucum* (L.) R. Br] provides a staple, primary caloric source to millions of people in semi-arid tropical areas of Africa and Asia, and a high quality temporary grazing crop in livestock production in the U.S. The characteristics of the crop have encouraged its development for use as grain crop in certain settings in the U.S.

Despite being a hardy crop for dry production areas, yield and stability of grain, stover, and forage are vulnerable to a number of biotic and abiotic stresses. Diseases and pests can be significant production constraints and significant effort is directed toward identifying resistance sources. Primary biotic constraints in West Africa include downy mildew (*Sclerospora graminicola* (Sacc.) Schroet.), *Striga* (*Striga hermonthica* Benth.), and head miner (*Heliocheilus albipunctella* (de Joannis)). Constraints in the U.S. include rust (*Puccinia substriata* var. *indica*), pyricularia leaf blight (*Pyricularia grisea* / *Magnoporthe grisea*), root knot nematode (*Meloidogyne arenaria*), and chinch bug (*Blissus leucopterus leucopterus*).

The goals of this research are to improve the productivity, yield stability, and pest resistance of pearl millet cultivars. Achieving these goals throughout Africa or in the U.S. require 1) identifying constraints limiting production or utilization within and across environments, 2) acquiring and evaluating new germplasm for desirable characteristics, 3) crossing selected germplasm with regionally adapted breeding lines or cultivars, 4) selecting and evaluating improved progeny as potential new cultivars.

Objectives, Production and Utilization Constraints

Objectives

- Broaden diversity of pearl millet germplasm available to breeders and researchers.
- Identify sources of disease and pest resistance for pearl millet improvement
- Identify genetic characteristics associated with desirable pearl millet grain quality, and biotic and abiotic influences on grain quality.
- Develop and release pearl millet with resistance to multiple diseases, high yield, and superior quality.

Developing the commercial potential of pearl millet will require that growers produce a consistent product to sell to processors. In addition to yield stability, grain quality is also likely to be affected by both abiotic and biotic constraints. The impact of pearl millet genotype, diseases, and environmental constraints are not well defined, in part because grain quality standards for pearl millet are poorly defined. Quality represents the combination of several factors, such as grain shape, color, and size, endosperm hardness, proximate composition, and the presence of grain molds, mycotoxins, and insects.

Table 1. Mean values for agronomic characteristics and disease and pest resistance of diverse pearl millet varieties grown in Ghana, Mali, Nigeria, and Senegal in 2003.

Entry	Flowering	Height	Panicle length	Panicle diameter	Downy mildew incidence	Striga emerged	Head miner incidence	Yield
	(days to 50%)	(cm)	(cm)	(cm)				(kg/ha)
CIVT	50.9	231.8	53.2	2.2	9.1	58.6	3.7	1661.5
ICMV IS 89305	56.8	224.8	48.3	2.1	9.2	41.1	3.1	1659.3
SoSat C-88	52.9	193.1	25.0	3.0	13.6	24.5	7.1	1536.3
Gwagwa	57.4	225.4	24.4	2.4	17.9	6.9	2.7	1451.9
SoSank	55.3	191.2	27.9	3.2	8.6	35.8	5.0	1395.8
HKP (GMS)	53.7	227.4	51.6	2.1	9.1	15.5	2.0	1383.7
Taram	56.0	220.4	63.1	2.4	8.0	39.1	3.1	1280.8
Indiana 05	74.0	246.5	43.9	2.4	23.3	13.5	6.3	1226.0
NKK	71.5	263.1	42.5	2.5	26.1	12.3	0.9	1215.2
Zatib	52.5	212.8	52.2	2.4	3.4	26.0	4.9	1158.7
NKO x TC1	71.5	247.7	35.6	1.8	15.1	13.5	2.6	1147.3
Manga Nara	43.8	169.5	19.5	2.9	33.0	9.3	6.1	1120.9
Kapielga (Burkina local)	82.3	243.5	27.2	1.9	33.2	6.0	1.7	1095.1
Guefoue 16	74.4	253.2	35.3	1.9	18.0	9.3	1.1	1079.3
ICMV IS 90311	56.9	205.0	44.0	2.1	5.2	21.4	5.1	1073.0
P1449-2	55.5	166.3	29.7	2.1	27.2	6.5	2.3	1054.7
Synthetic 1-2000	72.4	240.3	33.4	2.7	4.6	34.5	3.9	1048.1
Arrow	47.3	199.7	32.2	2.0	27.2	30.5	2.7	1026.5
Toronio (Mali local)	69.8	262.3	33.9	2.2	33.9	11.3	2.3	1020.2
Sadore (Niger) local	65.0	228.8	52.1	2.1	14.1	7.8	5.4	993.2
GB 8735	43.4	152.7	21.7	2.7	41.8	5.3	6.0	984.8
Tongo Yellow	47.3	171.3	24.7	3.0	38.9	10.5	7.3	961.4
Bongo short head	46.7	169.1	11.5	3.5	30.0	10.5	5.3	960.2
Zongo	60.1	251.3	75.4	2.2	10.4	18.3	2.0	920.3
IBMV8401Mx68A4R4w	46.1	107.8	30.2	2.3	14.4	10.1	2.1	903.9
DMR 15	59.2	168.0	25.0	2.6	18.3	6.6	6.6	858.8
PT732B	54.3	117.6	25.1	2.0	61.3	4.3	8.7	731.7
DMR 72	61.2	204.6	31.1	2.3	13.3	17.5	9.3	730.3
3/4 HK	60.6	130.9	43.4	2.1	9.3	6.3	7.3	710.0
68A x 086R	38.8	100.5	20.2	1.8	45.9	0.4	0.4	709.4
3/4 ExBornu	52.0	122.2	38.5	2.2	6.8	12.8	3.7	699.4
99M59043Mw x 68A4R4	44.3	91.0	22.8	3.0	49.1	2.8	5.9	684.5
DMR 68	60.6	193.3	27.6	2.4	31.8	7.6	7.1	676.8
01Miso NCD2-NE	47.4	98.8	31.7	1.8	30.9	8.9	1.1	655.7
LCIC 9702	48.4	142.2	23.3	2.6	22.6	3.6	3.6	581.7
3/4 Souna	57.1	119.8	36.4	2.1	7.6	5.6	4.6	559.9
TG102	43.1	97.6	23.2	2.3	53.9	16.0	0.3	542.8
99-72	56.3	113.9	19.3	2.5	7.7	9.8	18.0	461.9
T454	50.6	104.8	25.9	2.0	60.9	5.9	3.4	308.7
T99B	45.8	82.8	29.8	1.8	68.4	9.1	3.1	235.0
lsd (P=0.05)	4.2	20.6	5.5	0.5	2.0	34.8	5.6	341.6

Research Approach and Project Output

Genotype and Environmental Effects on Pearl Millet Grain Quality

Research Methods

Collaborative, multi-locational trails throughout West Africa are being used for characterizing germplasm with desirable agronomic characteristics and superior resistance to pests and diseases. Multi-location evaluation of genotype x environment interactions affecting grain quality are needed to identify genotypes with inherently superior grain yield and quality, and the relative importance of diseases and other constraints on yield and quality. These studies were designed in part to define more clearly grain characteristics among genotypes, and the stability of expression over a range of production environments. This study will help to identify characteristics that contribute directly or indirectly to stability of grain yield and quality.

Forty pearl millet germplasms selected by colleagues on the basis of their high grain quality, their fertility restoration for specific cytoplasms, resistance to diseases or pests, agronomic traits, or commercial usefulness were distributed to collaborators in Ghana, Mali, Niger, Nigeria, and Senegal for multilocation evaluation of stability of grain yield and quality traits. Data were recorded for days to flowering, height, panicle dimensions, downy mildew and head miner incidence, *Striga* infestation, and yield.

In an effort to expand the diversity in the breeding populations in the U.S. program, several African cultivars are being used to develop new maintainer and restorer germplasm for the A_1 and A_4 male sterile cytoplasms. Selected germplasm and hybrids of the African germplasm crossed to A_1 and A_4 fertility restorer inbreds were grown in the field in the U.S. Data were recorded for days to flowering, height, panicle dimensions, 1000 seed weight, and yield.

Research Findings

Data was obtained for the first year of this study from collaborators in Mali, Nigeria, Senegal, and Ghana. Although seed was distributed to two collaborators in Niger, no data was obtained. Germplasm varied for several characteristics (Table 1). Zatib had the lowest incidence of downy mildew and Tift 99B

Table 2. Agronomic characteristics of West African pearl millets and hybrids with A_1 (Tift 454) and A_4 (99-70) fertility restorers grown in Tifton, GA in 2003.

Entry	Flowering	Height	Panicle length	Panicle diamter	Seed weight	Yield
	(days to 50%)	(dm)	(cm)	(mm)	(g/1000)	(kg/ha)
3/4 HK-B78 S1	84.0	12.5	34.6	20.7	8.35	190.3
Ankoutess S1	79.0	22.0	23.1	33.7	9.63	520.3
Ex-Bornu	72.3	21.8	26.6	21.9	9.43	220.3
GCP V6 S1	71.0	22.5	23.6	29.0	12.33	295.5
GGT S1	85.0	26.0	35.1	25.9	8.70	440.0
HKP-GMS S1	72.5	21.5	42.2	22.9	8.65	231.8
Iniari	66.3	21.2	22.8	27.6	10.63	570.8
Mansori	71.3	20.5	25.9	22.9	9.85	323.3
P3Kollo	72.8	19.0	35.2	22.6	10.67	205.0
SoSank S1	77.0	23.5	24.9	30.7	10.80	408.0
SoSat C-88 S1	74.8	25.0	24.4	30.7	9.48	732.0
Taram S1	79.5	21.0	44.6	22.3	7.48	294.0
Ugandi	63.3	18.8	18.0	26.4	10.55	295.3
Zatib S1	84.4	21.2	42.2	22.5	9.83	194.6
Zongo S1	87.0	21.7	48.0	20.5	10.90	31.3
99-70	67.3	7.8	16.1	23.3	6.10	53.5
Tift 454	63.8	13.3	26.1	19.8	4.98	72.0
3/4 HK-B78 x Tift 454	61.5	18.3	39.3	24.3	8.80	1316.8
Ankoutess x 99-70	59.5	23.0	25.0	35.0	12.90	2185.3
Ankoutess x Tift 454	68.0	23.8	29.1	34.4	10.15	1368.0
Ex-Bornu x 99-70	62.0	22.3	29.7	27.9	11.95	1789.8
Ex-Bornu x Tift 454	61.0	26.8	31.5	24.9	9.35	1390.8
GCP V6 x 99-70	62.3	23.5	26.7	32.3	14.48	1159.0
GCP V6 x Tift 454	56.8	25.5	30.3	32.1	12.90	2083.0
GGT x Tift 454	74.5	28.8	35.5	29.7	9.30	1871.3
HKP-GMS x 99-70	66.3	25.5	36.3	31.6	13.25	2109.0
HKP-GMS x Tift 454	68.5	28.5	45.1	27.5	10.90	2666.8
Iniari x 99-70	55.7	21.0	21.5	28.7	11.43	1437.3
Iniari x Tift 454	56.8	23.3	34.3	28.2	14.10	1960.8
Mansori x 99-70	54.8	23.0	26.1	29.4	12.15	2333.3
Mansori x Tift 454	57.0	22.8	24.3	27.8	11.25	1512.3
P3Kollo x 99-70	59.0	20.3	28.9	27.2	10.80	1205.0
P3Kollo x Tift 454	59.8	26.3	36.8	26.6	11.40	2137.0
SoSank x 99-70	63.5	24.0	29.5	34.4	12.48	1876.5
SoSank x Tift 454	64.3	27.5	29.8	30.3	10.63	1941.5
SoSat x 99-70	63.0	25.0	27.4	32.0	11.50	2500.0
SoSat x Tift 454	58.8	26.0	28.6	30.8	11.50	2225.5
Taram x 99-70	58.0	23.8	34.9	27.1	12.78	2537.8
Taram x Tift 454	65.5	26.5	42.0	25.1	9.35	1827.8
Ugandi x 99-70	55.3	21.0	23.1	31.6	13.20	2099.5
Ugandi x Tift 454	55.8	23.5	25.9	26.5	14.40	1975.0
Zatib x 99-70	58.3	24.8	34.9	28.4	10.63	1065.0
Zatib x Tift 454	65.5	28.0	41.6	28.2	10.18	1419.0
Zongo x 99-70	63.3	23.0	42.7	30.0	11.63	1719.3
Zongo x Tift 454	65.3	27.8	47.3	26.0	11.95	2040.5
lsd (P=0.05)	4.6	2.9	4.6	2.8	0.25	725.9

was the most susceptible. 68A x 086R had the lowest *Striga* emergence and HKP GMS was most susceptible. Tifgrain 102 had the lowest level of head miner incidence, and 99-72 had the highest level. Grain yield was lowest for Tift 99B and greatest for CIVT and ICMV IS 89305. Grain yield was negatively correlated with downy mildew incidence (R^2=0.268) and positively correlated with plant height (R^2=0.532).

In the U.S. trial, germplasm and hybrids likewise differed for multiple characteristics (Table 2). Most notably, 1000 seed weight was lowest for Tift 454, and greatest for GCP V6 x 99-70. Grain yield was lowest for Zongo, and greatest for HKP-GMS x Tift 454. Neither Tift 454 nor 99-70 exhibited consistently superior heterosis with the African germplasm. Grain yield was negatively correlated with days to flowering (R^2=0.437) and positively correlated with plant height (R^2=0.320).

Nematode Resistance in Pearl Millet

Research Methods

Pearl millet germplasm from African countries can be a source of important characteristics for breeding populations in the U.S. Disease and pest resistances are likely to be identified in the African gene pool. In prior experiments, diverse germplasm of African origin was evaluated for resistance to root knot nematodes (*Meloidogyne incognita*) in two replicated experiments in the greenhouse. Pots containing five plants were inoculated with eggs of *Meloidogyne incognita*. After grain harvest, eggs were extracted from roots. Differential reproduction of the nematode on the different genotypes was determined and assayed as eggs per gram of root tissue. From these experiments, progeny of twenty plants of P3Kollo, Zongo, SoSat C-88, and Gwagwa were evaluated in 5 replicates to determine heterogeneity for resistance within landraces.

Research Findings

In the first evaluation, all African accessions were more resistant to the southern root knot nematode than was HGM 100 when evaluated with several plants per pot. When individual progeny were assessed, distribution of eggs per gram of root was continuously distributed from essentially no reproduction to levels exceeding that on HGM 100. These data indicate that considerable heterogeneity for resistance to reproduction of root knot nematode exists within these four varieties. If these varieties are to be used as sources of nematode resistance, it would be necessary to identify specific resistant progeny to be used as source material. Because each of the tested varieties expressed the continuous distribution of reaction from resistance to extreme susceptibility, it is probable that heterogeneity exists in the other varieties also.

Striga Resistance in Pearl Millet

Research Methods

Wild pearl millets were selected from previous multi-location trials to be used as sources of resistance to *Striga hermonthica*. The genetic variability and the relationship was surveyed among 80 wild pearl millet accessions collected from different regions in Africa that showed various levels of *Striga* resistance, and a selection of cultivars and germplasm from Africa and the United States. We tested 30 PCR primer pairs targeting conserved gene sequences. PCR products of genomic DNA were digested with HinfI restriction enzyme and separated on 8% polyacrylamide gels. Twenty-two primer pairs produced reproducible and scorable DNA fragments. Most loci showed no amplicon length variation, but polymorphisms were revealed upon digestion of the PCR products with restriction enzymes.

Research Findings

Preliminary analysis indicated that the genetic similarity among the accessions ranged from 0.66 to 1.00. Genotypic identity was not resolved in a number of accessions due possibly to the conserved nature of the gene sequences that we surveyed or perhaps that these genotypes are either identical or share a common parentage. For most accessions, the amount of variation that exists was sufficient for us to draw several conclusions regarding the relationships among these accessions. First, the tendency of improved cultivars and germplasm lines from the United States to cluster reflects their shared history in modern breeding. Second, the lack of clear clustering of African varieties and wild pearl millet accessions confirms that cultivation and improvement of pearl millet in Africa is not accompanied by genetic isolation. Finally, the observation that most of the known wild accessions with *Striga* resistance fall into different clusters suggests that different sources of resistance may be available for use in breeding for *Striga* resistant cultivars.

Networking Activities

Attended the American Phytopathological Society meeting, Charlotte, NC. August 10-13, 2003. Served as chair of the Collections and Germplasm Committee, member of the Office of International Programs Research Committee, and as senior editor of *Phytopathology*.

Participated in the McKnight Foundation, Collaborative Crop Research Program "Consultation Workshop on Millet and Sorghum Based Systems in West Africa". Presented " Genetic variability of wild pearl millets with *Striga* resistance". Niamey, Niger, January 27-30, 2004.

Participated in the External Evaluation Panel Review of INTSORMIL pearl millet research, breeding, and technology transfer activities in the Southern Africa Region; Botswana, Zambia, and Namibia. March 3-11, 2004

Participated in Middle Georgia pearl millet production meeting, University of Georgia Cooperative Extension Service, Oglethorpe, GA. March 18, 2004.

Participated in INTSORMIL West Africa Regional Research Meeting. Presented – "Multilocation assessment of yield, disease, and pest resistance of pearl millet germplasms in West Africa". Ouagadougou, Burkina Faso. April 18 to 21, 2004.

Served as member of Sorghum and Millet Crop Germplasm Committee.

Served on Advisory Committee for the University of Georgia's Office of International Agriculture.

Served 30 day detail in the USDA-ARS Office of International Research Programs, Beltsville, MD. Assessed ARS' role in and made recommendations concerning the project "Research Internship for Early Career South African Agricultural Research Scientists". May 10 - June 4, 2004.

Hosted visit to Tifton by Odillio Balbinotti, Luiz Bonamigo, and Jose Franca-Neto, from Adriana Seed Co. Brazil. Developed plans for material transfer agreement for Adriana to evaluate advanced pearl millet germplasm in Brazil. October 8, 2003.

Hosted visit to Tifton, GA by Ouendeba Botorou to cooperate in developing concept paper and progress report on "Market Improvements and New Food Crop Technologies in the Sahel". November 11 to 20, 2003.

Submitted information for the University of Georgia's proposal for SANREM CRSP Management June 18, 2004

Experimental pearl millet germplasm developed in the U.S. was distributed to collaborators at Cornell University, University of Georgia, Cornell University, Kansas State University,

University of Nebraska, University of Natal, South Africa, CSIRO Australia, and seed companies in South Dakota and Brazil. Seed from West Africa was sent to collaborators in Zambia, Botswana, and Namibia.

Publications and Presentations

Journal Articles and other publications

Wilson, J.P., Gates, R.N., and Hanna, W.W. 2004. Strip-till establishment of pearl millet. International Sorghum and Millets Newsletter 44:158-159

Wilson J.P., Hess, D.E., Hanna, W.W., Kumar, K.A. and Gupta, S.C. (In press) *Pennisetum glaucum* subsp. *monodii* accessions with *Striga* resistance in West Africa. Crop Protection. http://www.sciencedirect.com

Lee, D., Hanna, W.W., Buntin, G.D., Dozier, W., Timper, P. and Wilson, J.P. 2004. Pearl Millet for Grain. University of Georgia Cooperative Extension Service Bulletin 1216 (Revised). 8 pp. http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1216.pdf (Extension Service bulletin)

Books, Book Chapters, and Proceedings

Chee, P. and Wilson, J.P. 2004. Genetic variability of wild pearl millets with *Striga* resistance. Proceedings: Millet and Sorghum-Based Systems in West Africa: Current Knowledge and Enhancing Linkages to Improve Food Security. McKnight Foundation Collaborative Crop Research Foundation. Niamey, Niger, January 27-30, 2004. http://mcknight.ccrp.cornell.edu/WEB-INF/documents/partic_docs/Niger04/WAf_Wilson_full(EN).pdf (Conference proceedings)

Angarawai I.I, Wilson, J. Ndahi, W.B., and Turaki, Z.G.S. 2004. Enhancing Resource – Poor Farmers Productivity by Pearl Millet Hybrid (sic). Proceedings: Millet and Sorghum-Based Systems in West Africa: Current Knowledge and Enhancing Linkages to Improve Food Security. McKnight Foundation Collaborative Crop Research Foundation. Niamey, Niger, January 27-30, 2004. http://mcknight.ccrp.cornell.edu/content/Papers%20and%20Abstracts/WAf_Angarawai_full(EN).doc (Conference proceedings)

Abstracts

Wilson, J.P., Hanna, W.W., Wilson, D.M., and Coy, A.E. 2004. Host specific differences in pre-harvest grain infection by toxigenic fungi in dryland pearl millet and corn. Mycopathologia 157: 503.

Development and Enhancement of Sorghum Germplasm with Sustained Tolerance to Biotic and Abiotic Stress

Project PRF 207
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Summary

Breeding sorghum varieties and hybrids for use in developing countries requires proper recognition of the major constraints limiting production, knowledge of germplasm, and an appropriate physical environment for evaluation and testing. Successful breeding efforts also require knowledge of mode of inheritance and association of traits that contribute to productivity as well as tolerance to biotic and abiotic stresses. Research and germplasm development activities in PRF-207 attempt to address these essential requirements.

PRF-207 addresses major biotic and abiotic constraints (drought, cold, grain mold, and other diseases) that limit productivity of sorghum in many areas of the world. Over the years significant progress has been made in some of these areas. Superior raw germplasm have been identified, mode of inheritance established, chemical and morphological traits that contribute to productivity as well as to tolerance to these stresses have been identified. Selected gene sources have been placed in improved germplasm background, some of which have already been widely distributed. In this report, we have included observations relative to identification and characterization of sorghum genetic variants in glycinebetaine accumulation and their role in tolerance to drought and salinity stresses.

Objectives, Production and Utilization Constraints

Objectives

Research

- To study the inheritance of traits associated with resistance to biotic and abiotic stresses in sorghum and/or millets.
- To elucidate mechanisms of resistance to these stresses in sorghum and/or millets.
- To evaluate and adapt new biotechnological techniques and approaches in addressing sorghum and millet constraints for which conventional approaches have not been successful.

Germplasm Development, Conservation, and Diversity

- To develop sorghum varieties and hybrids with improved yield potential and broader environmental adaptation.
- To develop and enhance sorghum germplasm with increased levels of resistance to drought, cold, diseases, and improved grain quality characteristics.

- To assemble unique sorghum germplasm, and to encourage and facilitate free exchange of germplasm between U.S. and LDC scientists and institutions.
- To assess applicability of various statistical and DNA fingerprinting technologies for evaluating genomic similarity or for discerning genetic diversity of sorghum and millet germplasm pools.

Training, Networking, and Institutional Development

- To provide graduate and non-graduate education of U.S. and LDC scientists in the area of plant breeding and genetics.
- To develop liaison and facilitate effective collaboration between LDC and U.S. sorghum and millet scientists.
- To encourage and facilitate positive institutional changes in research, extension and seed programs of collaborating countries involved in sorghum and millet research and development.

Program Approaches

The research efforts of PRF-207 are entirely interdisciplinary. The on-campus research at Purdue is in close collaboration with colleagues in several departments. We undertake basic research in the areas of biotic and abiotic stresses where a concerted effort is underway in elucidating the biochemical and genetic mechanism of resistance to these constraints. Field and laboratory evaluations of sorghum and millet germplasm are coordinated, the results from one often complimenting the other. In addition, there have been collaborative research efforts with colleagues in Africa where field evaluation of joint experiments are conducted.

Our germplasm development and enhancement program utilizes the wealth of sorghum and millet germplasm we have accumulated in the program. Intercrosses are made in specific combinations and populations generated via conventional hybridization techniques, through mutagenesis, or through tissue culture *in vitro*. Conventional progenies derived from these populations are evaluated both in the laboratory and in the field at West Lafayette, Indiana for an array of traits, including high yield potential, grain quality, as well as certain chemical constituents that we have found to correlate well with field resistance to pests and diseases. We also evaluate our germplasm for tropical adaptation and disease resistance during the off-season at the USDA Tropical Agricultural Research Center at Isabella, Puerto Rico. Selected progenies from relevant populations are then sampled for evaluation of specific adaptation and usefulness to collaborative programs in Sudan, Niger, and more recently Mali. Evaluation of the drought tolerance of our breeding materials have been conducted at Lubbock, Texas in collaboration with Dr. Darrell Rosenow, in a winter nursery at Puerto Vallarta, Mexico, as well as the University of Arizona Dryland Station at Yuma, Arizona, and several locations in Africa. Over the years, assistance in field evaluation of nurseries has also been provided by industry colleagues particularly at Pioneer HiBred and DeKalb Genetics

The training, networking and institutional development efforts of PRF-207 have been provided through graduate education, organization of special workshops and symposia as well as direct and closer interaction with research scientists and program leaders of NARS and associated programs. Much of the effort in this area has been primarily in Sudan and Niger, with limited activity in Mali and some in Southern Africa through SADC/ICRISAT.

Project Output

Research Findings

Genotypic variation for glycinebetaine in *Sorghum bicolor*. Glycinebetaine (GB) is thought to play an important role in plant adaptation to saline and arid environments. Genes determining GB accumulation are thus of considerable interest in plant breeding for stress environments. It has been found that GB accumulates in sorghum in response to salinity stress. It was of interest to determine the range and extent of variability for this trait among diverse genotypes of this species. We tested the hypotheses that GB represents the major QAC in sorghum, as it does in maize, and that this QAC is genetically and environmentally regulated. In this paper we also report on the identification and preliminary biochemical characterization of several GB-deficient sorghum genotypes.

A total of 240 sorghum genotypes were initially screened for QAC level at the Purdue University agronomy farm in West Lafayette, IN. Samples were taken from the flag leaf of five individual plants of each genotype. All of the genotypes were at the post-flowering stage at sampling. Leaves were excised from plants selected at random from the center row of 3-row plots. A representative sub-sample of the leaf tissue bulked from the five individual leaves (1 to 1.5 g FW) was taken from the leaf lamina (excluding midrib). Leaf tissue was then extracted by immersion in preweighed vials containing 10 mL methanol at the field site (one sample per genotype).

Two greenhouse studies involving growth of sorghum genotypes under non-salinized and salinized conditions were conducted. The first study was designed to determine the effect of salinization on GB accumulation in a number of GB-deficient or GB-accumulating lines and on GB accumulation in various organs of representative GB-deficient (IS2319) and GB-accumulating (P932296) lines. A second greenhouse study was conducted to evaluate the levels of GB accumulated under various salinity regimes and at different stages of seedling development.

Significant differences were found in the total QAC levels in the betaine fraction of the flag leaves of the 240 sorghum genotypes screened. The maximum-recorded values for GB in

maize are in the range of 10 to 16 mmol·g FW^{-1}. In contrast, total quaternary ammonium compound (QAC) levels in the betaine fraction of the flag leaves were found to range from as low as 0.1 mmol·g FW^{-1} to over 33 mmol·g FW^{-1}. Stable isotope dilution desorption chemical ionization mass spectrometry of six genotypes with high QAC levels and five genotypes with low QAC levels confirmed that this variation could be attributed almost exclusively to genetic variability for GB level. GB-deficient sorghum genotypes were confirmed to be GB-deficient in a second year of field-testing, and in greenhouse studies under salinized and non-salinized conditions. GB levels increased with seedling age and/or salinization in GB-accumulating genotypes. Also, GB levels were highest in the youngest leaves of GB-accumulating sorghum genotypes. This work shows that GB is the major QAC in sorghum, that genetic differences in GB accumulation exist in sorghum as they do in maize, and that the level of GB in GB-accumulating lines is developmentally and environmentally regulated. A list of GB levels of publicly available lines of sorghum is also provided. Certain sorghum genotypes appear to have a much higher capacity for total QAC accumulation than the highest GB accumulating maize genotypes so far identified. Sorghum genotypes that are apparently GB-deficient were also identified. Eight genotypes of sorghum were found that exhibited total QAC levels of <1.0 mmol·g FW^{-1}.

Genetic studies suggest that a recessive allele of a single locus is the cause of this deficiency in one GB-deficient sorghum genotype, IS2319, but it remains to be tested whether the various sources of GB-deficient in sorghum so far identified are allelic. The precise metabolic basis of the GB deficiency phenotype of sorghum also remains to be elucidated. An understanding of the metabolic and genetic basis of this genetic variation in GB level in sorghum should assist in devising breeding strategies to develop near-isogenic lines differing solely for the GB trait. These lines could then be used to test the contribution of this trait to salt and drought tolerance.

Development and characterization of near isogenic lines of sorghum segregating for glycinebetaine accumulation.

The breeding of crop plants for tolerance to environmental stresses is often considered a difficult and slow process. This is primarily because of the quantitative inheritance of the trait of environmental stress and the problems associated with developing suitable testing environments where stress can be reproducibly applied. A better understanding of plant stress tolerance could be developed by identifying and characterizing those traits that are proposed to contribute to stress tolerance and determining their relative importance. Complex quantitative traits such as osmotic stress tolerance can be studied by identifying individual components and then using traditional breeding methods to select plants that possess the specific trait. This approach has been employed to study the osmoregulatory compound, glycinebetaine (GB) accumulation in various crops. Cellular dehydration is a general consequence of osmotic stresses, including water deficit and salinity. In response to this dehydration, many organisms synthesize compatible solutes that help retain water within cells. Accumulation of solutes, either actively or passively, is an important adaptation mechanism for plants in response to osmotic stress. Some of these solutes may also protect cellular components from injury caused by dehydration. Organic compounds that function as solutes include amino acids such as proline, sugar alcohols such as mannitol, and quaternary ammonium compounds (QACs) such as glycinebetaine (GB)

Glycinebetaine is synthesized in plants from serine via ethanolamine, choline, and betaine aldehyde with S-adenosyl methionine serving as the methyl donor. Although other pathways may exist (such as direct N-methylation of glycine), the pathway from choline to GB is the only one that has been identified to date in GB-accumulating plant species

Many cereal crops accumulate GB, although rice is a notable exception. The levels of GB found in sorghum are as much as ten-fold higher than those observed in maize. However, GB-deficient genotypes of both sorghum and maize have been identified. In a screen of over 200 sorghum landraces, approximately 3% were GB-deficient. Furthermore, there is a wide range in the level of GB within both sorghum and maize. Genetic analysis of this trait in several crosses between GB-deficient and GB-accumulating sorghum lines indicated that a single nuclear gene was responsible for GB deficiency Similar results have been obtained in studies on the genetics of GB accumulation in maize, where GB deficiency results from an inability to convert choline to betaine aldehyde, the first committed step in the synthesis of GB.

The primary objective of these experiments was to utilize a recombinant-inbred (RI) population, developed from a cross between a GB-deficient line and a GB-accumulating line, to characterize the genetics of GB accumulation in sorghum. Near-isogenic lines were derived from advanced RI lines. These lines also provide an excellent tool with which to test the hypothesis that GB accumulation is an important factor in sorghum osmotic stress tolerance.

A recombinant inbred (RI) population was developed from a cross between IS2319, a naturally occurring GB-deficient genotype, and P932296, a GB-accumulating. F_2 progeny from this cross were randomly selected and 150 lines were advanced by single seed descent to the F_7 generation. Seed of selfed plants from the F_7 generation of each RI line were grown in a headrow, and several panicles from each row were selfed and bulked to represent the $F_{7:8}$ generation. In each subsequent generation, the RI lines were planted in rows and 10 to 15 plants were selfed and the seed bulked to represent the next generation. For GB analysis of the $F_{7:8}$ generation of the RI population, plants were grown in a growth chamber with a light level of 161 µmol·m^{-2}·s^{-1} and at a constant temperature of 26°C. Four plants per line were grown to the five-leaf stage in 14.4 cm pots, at which time the plants were salinized with 100 mM NaCl for 10 days to stimulate production of GB, and therefore ac-

centuate differences in GB levels between non-accumulators and accumulators. Leaf lamina (including midrib) from the four plants were harvested and combined for analysis. F_5 generation plants that were analyzed for QAC were grown in the greenhouse in individual 9.6 cm pots to the five-leaf stage and then salinized with 100 mM NaCl for 10 days before leaves were harvested for QAC analysis. For each line, a bulk sample composed of equal amounts of tissue from ten F_5 plants was analyzed. Glycinebetaine concentrations of $F_{7:8}$ lines were quantified by plasma desorption mass spectrometry (PD-MS) using a BIOION 20R Plasma.

For all other GB determinations, the spectrophotometric periodide method was utilized. For these assays, the purified betaine fraction eluted from the Dowex-50-H^+ resin was dissolved in 0.5 mL 1N H_2SO_4. After adding 0.2 mL KI-I_2 reagent, the contents were mixed and allowed to precipitate overnight at 4°C. The samples were then centrifuged at 5000 rpm for five minutes and the supernatant discarded. After washing the pellet with 1 N H_2SO_4 and centrifugation, the precipitate was dissolved in 2 mL dichloroethane and absorbance at 500 nm was read. Glycinebetaine amounts were quantified by comparison with a standard curve of GB (Sigma, St. Louis, MO) prepared in dH_2O.

NILs were grown to flowering (50% anthesis) and then destructively harvested for determination of morphological characteristics. Flowering date was determined as the number of days from planting to 50% anthesis. Leaf area was determined using a Li-Cor 1600 area meter (Li-Cor Instruments, Lincoln, NE). Whole-plant dry weight was determined by drying plant tissue in an oven at 80°C to a constant weight (ca. four days). Isolation of total QACs from these plants and quantification by the colorimetric assay were conducted as described above.

Significant variation was found in glycinebetaine levels among the RI lines. Within this population, the predicted percentage of GB-deficient lines should be 47 and 49% in the F_5 and $F_{7:8}$ generations, respectively. However, the proportion of GB-accumulating lines in both the F_5 and $F_{7:8}$ generations of this RI population was higher than expected, possibly due to some beneficial effect of GB accumulation on plant growth, survival, or seed set. GB levels varied widely in lines of the RI population that were grown under controlled conditions, suggesting genetic control not only for the presence or absence of GB, but also for the level of GB. This hypothesis was tested by analyzing individual plants from lines identified as accumulating low, medium, or high concentrations of GB based on the F_5 and $F_{7:8}$ screens. The level of GB was conserved within lines, supporting the hypothesis of genetic control of relative GB levels within accumulating lines. Two pairs of near-isogenic lines (NILs) with contrasting GB levels within pairs were developed from the RI population. The stable inheritance of the GB phenotype and isogenicity of these NILs were confirmed with progeny tests and RAPD analysis, respectively. Labeling studies demonstrated that the deficiency in GB accumulation was the choline oxidation step.

Skewed segregation ratios have been noted in other species when F_1 progeny were selfed to develop an inbred population. In rice, skewed segregation for genes from a single parent was noted, and in maize, higher than expected levels of heterozygosity still existed in advanced generations of a RI population. The observed segregation patterns could be explained if the GB-deficient parent was in fact heterozygous when it was assumed to be a homozygous inbred. However, several experiments have shown that this is not the case. GB accumulation may contribute some selective advantage (plant growth, survival, or seed set) under the conditions used to develop the RI population, resulting in the inadvertent selection of plants that accumulated GB to advance the population.

Among GB-accumulating lines, there was significant variation in the level of GB, which was approximately nine-fold in the $F_{7:8}$ screen and approximately four-fold in the F_5 screen. Several reasons could account for these differences in GB accumulation among lines. Environmental heterogeneity (i.e. light, moisture) could result in accumulation differences. Also, differences in actual salinity level of the medium could influence the final GB level. This may be especially true in the case of plants grown in soil (as opposed to sand or hydroponics), because binding of ions to soil particles or variation in leaching fraction could affect the level of salinity among pots of plants. Furthermore, although plants were all the same age when leaves were harvested, developmental differences could also contribute to the observed differences in GB accumulation. Since the $F_{7:8}$ screen was conducted in a small growth chamber, and the F_5 screen was conducted under controlled conditions in the greenhouse, we consider it unlikely that environmental variation in temperature or light conditions contributed significantly to these differences. While the other factors discussed above may have contributed to the observed variation in GB accumulation, it is possible that the relative level of GB in accumulating lines is under genetic control.

Near-isogenic lines (NILs) provide useful material for studying the effects of specific traits on plant stress tolerance. This is especially true for highly heritable traits in crop plants such as GB accumulation in sorghum or barley. We have used traditional breeding methods to develop sorghum NILs that differ for GB accumulation. The first step in this process was to identify advanced generation RI lines that were heterozygous for the gene responsible for GB accumulation. At the F_7 generation, less than 2% of the individuals in the population should be segregating for a given locus, while the rest of the lines should be fixed at that locus. F_7 lines that are heterozygous at the locus responsible for GB deficiency should have intermediate levels of GB. With this in mind, individual plants from lines that contained low- to mid-level amounts of GB (8 to 20 $\mu mol \cdot gFW^{-1}$) in the $F_{7:8}$ screen were screened in an at-

tempt to identify lines that were still segregating for GB. Plants within these lines that were heterozygous at the major locus that conditions GB accumulation would serve as the starting point to develop NILs that differed in GB accumulation.

Germplasm Exchange

We continue to provide an array of sorghum germplasm from our breeding program to national research programs in developing countries. Our germplasm is provided in either a formally organized nursery that is uniformly distributed to all collaborators that show interest or upon request by a national program of specific germplasm entries or groups from or germplasm pool. Germplasm was distributed to cooperators in 20 countries in 2002. Sorghum germplasm from our program was sent to Ethiopia, Kenya, Tanzania, Eritrea, Niger, and Mali in 2003.

Publications

Refereed Papers

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Invited Presentations

Ejeta, G. 2003. Sorghum and millets: crops of the hungry. Exploring the Potential Use of Biotechnology to Alter Plant Development Programs. 8-14 June, Bellagio, Italy.

Ejeta, G. 2003. A doubly green revolution: only a mirage? In the wake of green revolution: From the green revolution to the gene revolution. Bologna, Italy.

Ejeta, G. 2003. Seed enterprise options for improved cultivars. Training Workshop on *Striga* Management and Control in Eritrea. 1-5 September, Asmara, Eritrea.

Ejeta, G. 2003. Sorghum genetics with a human face. Purdue University, Department of Agronomy Seminar. Lilly Hall of Life Sciences, 7 April, W. Lafayette, IN.

Abstracts

Knoll, J. and G. Ejeta. 2003. QTL analysis of early season cold tolerance in sorghum. Annual Meeting of American Society of Agronomy, Denver, Colorado.

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Germplasm Enhancement for Resistance to Pathogens and Drought and Increased Genetic Diversity

Project TAM 222

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Summary

The principal objectives of TAM 222 are to identify and develop disease resistant and drought resistant sorghum germplasm in genetically diverse backgrounds for use by host country and U.S. scientists, to identify, evaluate, and utilize new elite exotic germplasm, and to collaborate with host country scientists in all aspects of their crop improvement programs. The disease and drought resistance-breeding program continued to develop and evaluate new germplasm for use in the U.S. and host countries. Forty-nine new fully converted exotic lines and 71 partially converted lines from the cooperative TAMU-TAES/USDA-ARS Sorghum Conversion Program were released. Sixty diverse breeding germplasm lines ranging from advanced generation to early generation with Pathotype 3 downy mildew resistance were selected for release. Numerous advanced generation B and R lines developed in TAM 222 were identified as potential releases for distribution to private companies and U.S. and host country public programs as the project moves to closure of the sorghum breeding project with the retirement of the project leader. Over 750 items were distributed to private seed companies with MOA's upon their request based on observation of a 500 entry B/R-line Observation Nursery in 2003. Several very unique and promising new Durra and Durra-Bicolor and Durra-Dochna type cultivars from the dry northern part of Mali were identified in the Mali Sorghum Collection, and hold promise in sorghum improvement in the drought prone areas of Africa and the U.S.A. The B/R-line reaction and hybrid vigor of selected Malian and Sudanese cultivars continued. Twenty-five sorghums from the Mali Collection were selected for entry into the Sorghum Conversion Program. The Conversion Program, however, is in a temporary holding status since the USDA-ARS program in Puerto Rico dropped their portion of the Conversion Program in early 2004.

Breeding progeny developed in TAM 222 which had showed excellent potential in the Zambia, South Africa, Nicaragua, El Salvador, and in south and west Texas with various combinations of high yield, drought resistance, grain quality, and disease resistance was again distributed to several host country scientists. They offer good potential for use as varieties directly where appropriate and also as parental lines for use in hybrids. Macia (an improved cultivar from Mozambique) derivative lines looked especially promising and also offer po-

tential to develop some improved white-seeded, tan-plant parental lines for U.S. use.

Sterilization and evaluation continued on a large number of new B-line breeding genotypes to assist decisions on which ones to release. These lines contain various combinations of stay green drought resistance, lodging resistance, improved grain quality, and head smut resistance. Several are white-seeded, tan-plant A-B pairs that could be useful in food-type hybrids.

The acceptance of white-seeded, tan-plant improved Guinea type sorghum cultivars, developed in the INTSORMIL/IER collaborative breeding program in Mali, by both farmers and in the marketplace has been excellent. The interest of farmers involved in the flawed 2002 identity preserved grain increase with N'Tenimissa in doing a similar thing with a different grain/market entrepreneurs is real encouraging. It shows that new cultivars with improved grain quality traits can stimulate the development and commercialization of new sorghum-based products. Some of the new N'Tenimissa breeding progenies in Mali promise to be superior to N'Tenimissa in production and grain quality. Several (N'Tenimissa*Tiemarfing local Guinea) derivative breeding lines have been given cultivar names and released, including 97-SB-F5DT-63 as Wassa, 97-SB-F5DT-64 as Kénikédiè, 99-BE-F4P-128-1 as Darrellken, 97-SB-F5DT-74-2 as Niéta, 96-CZ-F4P-98 as Zarra-blè, and 96-CZ-F4P-99 as Zarra-djé, along with one intermediate caudatum-guinea type 97-SB-F5DT-150 as Niétichama.

Collaborative INTSORMIL activities recently initiated in Senegal and Ghana continued in the areas of sorghum breeding, disease resistance, and *Striga*, as well as in entomology and agronomy research. The consolidation of all the West African INTSORMIL collaborative programs in six countries into one overall regional program was initiated in early 2004.

Objectives, Production and Utilization Constraints

Objectives

U.S.

- Develop and release agronomically improved disease, drought, and lodging resistant lines and germplasm and identify new genetic sources of desirable traits. Evaluate new germplasm and introgress useful traits into useable lines or germplasm.
- Current year objectives emphasize the evaluation and seed increase of U.S. and Host Country adopted breeding germplasm from TAM-222 for distribution/released/transfer to U.S. and host country collaborators, and private companies as the project is being closed.

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

- Develop, release, and distribute agronomically acceptable white-seeded, tan-plant Guinea type sorghum cultivars to enhance the commercial value and demand for improved value, high quality sorghum grain.
- Develop high yielding white, tan non-Guinea type improved cultivars with high levels of resistance to head bug and grain mold with adaptation to the drought and soil conditions of West Africa, and with acceptable levels of disease resistance. Characterize and describe the selected indigenous Mali and Sudan sorghum cultivars and evaluate for useful traits and breeding potential.
- Strengthen the collaboration with scientists in Ghana and Senegal including breeding, pathology, entomology, agronomy, and *Striga* research, and encourage across country collaboration with scientists in Mali, Niger, Burkina Faso, and Nigeria.

Central America

- Enhance germplasm base with sources of resistance to grain mold, foliar diseases and drought, and food type sorghums, and lines for adapted commercial hybrids.

Horn of Africa and Southern Africa

- Enhance drought resistance, disease resistance, and germplasm base with the development of improved high yielding, adapted germplasm and elite lines.

Constraints

Drought is the major constraint to sorghum and millet production around the world. West Texas has a semiarid environment ideal for large-scale field screening for both pre- and post-flowering drought response and breeding for improved resistance to drought.

Diseases are important worldwide and most internationally important diseases are present and are also serious constraints in Texas, especially downy mildew, charcoal rot, grain mold/weathering, head smut, and head blight. The Texas environment, particularly south Texas, is ideal for screening and breeding sorghums with high levels of resistance to most internationally important diseases.

Poor grain quality is a major problem over much of West Africa and is primarily due to the head bug/grain mold complex. Head bugs are a major constraint to the use of improved high yielding nonguinea type sorghums in much of West Africa, with head bug damage often compounded by grain mold, resulting in a soft, discolored endosperm, which is unfit for decortication and traditional food products. Early maturity of introduced types also increases the grain deterioration problem. In the southern regions, late maturing, photoperiod sensitive sorghums are needed to assure grain maturity after the rainy season.

Much of West Africa, especially the more northern areas, are drought prone areas and drought tolerance is important. Foliar diseases such as anthracnose and sooty stripe are important in the central and southern parts and in certain areas of Southern Africa along with leaf blight. In much of East Africa, the major constraint is drought, and related production problems. Moisture-stress related charcoal rot and subsequent lodging are serious problems. *Striga* is a major constraint in most areas including Mali, Niger, and Sudan.

In Central America, diseases and grain quality are major constraints, with drought also important in the drier portions of the region. Improvement in the photoperiod sensitive, food-type maicillos criollos grown in association with maize on small, hillside farms is a unique challenge and must be done on site in Central America.

There is a constant need in host countries and in the U.S. to conserve genetic diversity and utilize new diverse germplasm sources with resistance to pests, diseases, and environmental stress. Many developing countries are an important source of diverse germplasm in sorghum and millet. The collection, preservation and utilization of genetic diversity in sorghum is important to long-term, sustainable sorghum improvement programs needed to insure sufficient food for increasing populations of the future.

Research Approach and Project Output

Research Methods

Introductions from various countries with drought or disease resistance, or specific desirable grain or plant traits, are crossed in Texas to appropriate elite U.S. or worldwide lines or breeding materials. Seed of the early generations are sent to host countries for selection of appropriate traits and adaptation. Technical assistance is provided, as time and travel permits, in the selection and evaluation and use of such breeding material in the host country.

Disease resistant breeding material is generated from crosses among various disease resistant sources, agronomically elite lines, and new sources of resistance. Initial screening is primarily in large disease screening nurseries utilizing natural infection in south Texas. Selected advanced materials are sent to host countries as appropriate for evaluation and are also incorporated into various standard replicated trials for extensive evaluation at several locations in Texas and host countries.

Breeding crosses involving sources of drought resistance are selected under field conditions for pre- and/or post flowering drought resistance, yield, and adaptation at several locations in west Texas. Selected advanced materials are incorporated into standard replicated trials for evaluation at several locations in Texas and sent to host countries for evaluation and use.

Converted and partially converted lines from the Sorghum Conversion Program, exotic lines, new introductions, and breeding materials are screened and evaluated in Texas for new sources of resistance to internationally important diseases and resistance to drought.

New sorghum germplasm is assembled or collected as opportunities exist and introduced into the U.S. through the quarantine greenhouse (small number of items) or the USDA Plant Quarantine Station in St. Croix (many items), and are then evaluated in Puerto Rico and Texas for useful traits. Selected photoperiod sensitive cultivars are entered into the cooperative TAES-USDA Sorghum Conversion Program. Cooperative work with NARS assures their country's indigenous sorghum cultivars are preserved in long-term permanent storage in the U.S. at the NSSL, as well as evaluated and used in germplasm enhancement programs. Grow outs of entire collections (Sudan and Mali) have been grown in their country of origin for characterization, seed increase and evaluation prior to introduction into the U.S. Assistance is provided in developing smaller working or core collections for the NARS to actively maintain and use in their improvement programs.

Research Findings

In 2002, a new pathotype of downy mildew was identified in the upper coastal region of Texas. This new pathotype of P3 attacked Apron treated hybrids. This created great concern among the sorghum seed trade since Apron seed treatment has been the primary (and very successful) method of central for sorghum downy mildew in south Texas for many years. In 2003 and 2004 a large number of breeding progenies (advanced to early generation) were evaluated for resistance to this new pathotype under field conditions near El Campo, Texas. Fortunately, essentially all the sorghum lines identified with resistance to P3 downy mildew in past years still were resistant to the Apron resistant pathotype. Sixty R and B diverse breeding lines with genetic resistance were identified for release, being derived from nine different sources of resistance (Table 1). These diverse agronomically acceptable breeding lines should be useful to private and public sorghum workers in developing genetic resistance parental lines and hybrids.

Breeding, selection, and screening for drought resistance continued using major field screening nurseries at Lubbock, Halfway, Corpus Christi and Beeville. Extreme late season stress at Lubbock and Halfway resulted in excellent post-flowering stress and lodging ratings. The "stay-green" line, BTx642/B35, continues to be an excellent source of post-flowering drought resistance and lodging resistance in breeding progeny. Breeding derivatives of the parental line, BTX643(B1), a derivative of B35, showed some good drought resistance, with many showing outstanding lodging resistance especially the pedigrees (B1*(B7904*(SC748*SC630))), (B1*BTx635), and (B2-1*BTx635). Sterilization and hybrid evaluation continued on the above mentioned B lines which includes several white seeded, tan plant lines.

Table 1. Downey Mildew (Pathotype 3) resistant sorghum lines for germplasm release (resistant to Apron-resistant P3 Pathotype near El Campo, TX in 2003 and 2004).

		Pericarp color/[1]
Designation	Pedigree	plant color
82BDM 499	(SC173*SC414)	W,P
86PL2120	((SC748*SC650)*SC414)	R,P
92BD1016	(R5646*(SC414*SC326-6))	W,T
90CW8147	(82BDM499*87EO366)-HF8	W,T
91BD1319	(Sureno*82BDM499)BD18	W,T
92BD1982-4	(86PL2120*87EO366)-BD6	R,T
90EO328	(Sureno*82BDM499)-HD5	W,T
96CD635	(SRN39*90EO328)-HF4	W,T
98CD187	(87EO366*90EO328)-HF6	W,T
96CD677	(87EO366*90EO328)-HF3	W,T
95ED509	(86PL2120*87BH8606)-BD19	R,P
95ED508	(86PL2120*87BH8606)-BD19	R,P
--	(86PL2120*87BH8606)-BD5	R,P
--	(TAM428*SC502)/03B/R906(w,ch)	W,P(ch)
--	(TAM428*SC502)/03B/R918(w,tr)	W,P
--	(SC173*SC414)	W,P
--	(SC414*TAM428)	W,P
--	(SC23*QL3(I))	R,P
--	(R4317*SC425(uc)	R,P(uc)
--	(R4317*SC425(nouc)	R,P
--	(Tx432*SC38)	W,P
--	(BTx625*SC33)-BD5	R,P
--	(TP24R*SC33)-4B	W,T
--	(R4317*SC418)-4	R,P
--	(82BDM499*SC574)-WE6	W,P(uc)
--	(Tx430*DurDoc)?Ped(w,tn)	W,T
--	(SRN39*90EO328)-HF3	W,T
--	(SRN39*90EO328)-HF5	W,T
--	KS/(87EO366*90EO328)-HF6-ED5	W,T
--	(87ED366*90EO328)-HF6-ED6	W,T
--	(87ED366*90EO328)-LD30	W,T
--	(87ED366*90EO328)-HF14-BD1	W,T
--	(87ED366*90EO328)-HF14-BD2	W,T
--	(87ED366*(Sureno*82BDM499))-HD40	W,T
--	(87ED366*90EO328)-LD31	W,T
--	(87ED366*90EO328)-HF1	W,T
--	(87ED366*90EO328)-HD8	W,T
--	(87EO366*Tx2891)-BD2	W,T
--	(Sureno*Tx2891)-HF17-BE5	W,T
--	(Sureno*82BD499)-HD9	W,T
--	(Sureno*82BEM499)-14B	W,T
--	(Malisor84-7*90EO328)-HF14	W,T
--	(Malisor84-7*90EO328)-HF9	W,T
--	(CE151*82BEM499)-LD17	W,P
--	(90EO328*CE151)-LD11	W,T
--	(90EO328*CE151)-LA49	W,T
--	(90EO328*CE151)-LA37	W,T
--	(90EO328*CE151)-BD18	W,T
--	(90EO328*CE151)-LA59	W,T
--	(86PL2120*M50069)	W,T
--	(88BE2668*82BD499)-HD14	R,P
--	(90EO328*Kuyuma)-BE7	W,T
B-Lines		
--	((BTx623*QL3(I))*B.HF13)-HL3	W,T
--	((BTx623*QL3(I))*B.HF13)-HL7	W,T
--	((BTx623*QL3(I))*B.HF13)-HL14-BD2	W,T
--	((BTx623*QL3(I))*B.HF13)-HL15	W,T
03L-B/R614	((BTx623*QL3(I))*B.HF14)-HL13	W,T(ch)
03L-B/R/615	((BTx623*QL3(I))*B.HF14)-HL13	W,T
--	((BTx623*QL3(I)*(B1*B9501)-HL14	R,P
--	((BTx623*QL3(I)*(B1*B9501)-HL30	W,P

[1] Pericarp color: W = white, R = red
Plant color: T = tan; P = purple
(ch) = chalky (thick) pericarp
(uc) = undercoat (testa) present

New disease resistant breeding materials were developed, screened, and selected along with advanced generation breeding materials for improved agronomic types with high levels of, and/or multiple, disease resistance. Screening and selection was done primarily in large disease screening nurseries, mostly in south Texas. Major diseases involved were downy mildew, head smut, anthracnose, grain mold/weathering, and charcoal rot.

Approximately 30 A-B pairs and R lines developed cooperatively with L.E. Clark in the cooperative drought-breeding program have been identified for possible release. These lines contain many traits with emphasis on stay green and lodging resistance. Several are white-seeded tan plant lines and some show enhanced weathering resistance. These will be proposed for release mostly as germplasm stocks. Another set of advanced generation potential germplasm releases containing various desirable traits, including resistance to downy mildew, head smut, grain mold/weathering, anthracnose, charcoal rot, both pre- and post-flowering drought resistance, food type grain quality, and lodging resistance have been identified. See Table 1 in the 2003 INTSORMIL Annual Report for a listing of several breeding lines for potential release.

Forty-nine new fully converted lines and 71 partially converted bulks from the cooperative TAMU-TAES/USDA-ARS sorghum conversion program were released.

Sureño, a white-seeded, tan-plant cultivar, with excellent food grain quality, released in the Honduras-INTSORMIL collaborative program was officially released in El Salvador as an open-pollinated sorghum cultivar named SV3.

Near isogenic lines (NILs) developed (BC6 of (B35*Tx7000)) to do fine mapping of stay green QTLs and to do functional genomics and stress physiology research in cooperation with scientists in Australia were evaluated for stay green in Texas and Australia. In another project, advanced backcross populations and hybrids were generated and evaluated to identify QTLs for yield and heterosis in exotic germplasm. One donor parent, Lian Tang Ai, a Chinese landrace cultivar appeared to enhance both grain yield and earliness in hybrids and could be useful in enhancing yield in hybrids.

Several new tan-plant N'Tenimissa derivative guinea type breeding lines looked promising in Mali in 2001, showing less stalk breakage, and better head bug resistance than N'Tenimissa. Six new N'Tenimissa breeding derivative tan-plant guinea lines were released and named in Mali, along with one intermediate caudatum-guinea line (Table 2). Also, some new, shorter N'Tenimissa derivative F_4 and F_5 lines showed real promise. Selection also continued among non-guinea type, tan-plant breeding lines with improved levels of head bug tolerance and grain mold resistance. Several farmers involved in the large-scale identity preserved production of N'Tenimissa in five villages in 2002 were visited in 2003, and all seemed very interested in contract planting of new cultivars but with different grain/marketing entrepreneurs.

In Nicaragua, several of the breeding lines which have looked outstanding in the Southern Africa region, were evalu-

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

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

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

ated and some performed very well. From a 25 entry observation nursery of African/Central American type breeding lines from TAM222, six agronomically promising lines were selected for further evaluation and potential use as new cultivars. The six selected lines were 02CA4778/(ICSV1089BF*Macia)-HF2; 02CA4624/(Macia*Dorado)-HD12; 02L-SABN1094/(Sepon82*87EO366)-HF38; 02CA4597/(Macia*Dorado)-HD2; 02CA4738/(Macia*Dorado)-LL2; and 02CA4747/9Macia*Dorado)-LL6. Three of the six lines were also identified in the 2002 season as combining high yield with appropriate plant height, maturity and agronomic traits for potential use as new cultivars under mechanized production: LL2, LL6, and HD12.Also, the white, tan cultivar, Macia, introduced by Dr. Gary Odvody from Southern Africa region, has been selected in Nicaragua for release (Africana). Macia was one of several elite African sorghums sent to Central America in 1999 is an INTSORMIL nursery.

Thirty-five selected diverse Malian indigenous sorghums, including some new unique Durras, Durra-Bicolor, Bicolor, and Durra Dochna from northern Mali, along with 30 primarily Guinea-Caudatum sorghums from southern Sudan were evaluated for B/R fertility reaction, hybrid vigor and presence of the dominant B1 gene (gives testa with U.S. females) in Mali and Puerto Rico. Most Malian cultivars were restorers except for a few Guinea types, especially Margaritaferum types. Essentially all the Guinea-Caudatum derivative cultivars from southern Sudan were strong restorers but showed good heterosis and yield potential. The dominant B1 gene was absent in most Durra and Durra-Bicolor Malian lines, and some of these lines showed promising heterosis. There appeared to be rather good differences in hybrid vigor among lines, especially under Mali conditions.

Networking Activities

Workshops/Conferences

Participated in the INTSORMIL West African Regional Conference in Ouagadougou, Burkina Faso, April 16-22, 2004 where the structure of one West African Regional INTSORMIL/host country collaborative program was put in place and future research plans developed.

Participation in the American Seed Trade Association Production and Research Conference at Chicago, IL, December 10-11, 2003, and participated in the Sorghum Germplasm Committee meeting held at the ASTA Conference on December 10.

Mr. Niaba Teme, Mali Ph.D. student, participated in the Annual American Society of Agronomy (ASA) meetings, November 2-6, 2003 at Denver, CO, and presented two poster papers.

Research Investigator Exchanges

Interacted with numerous host country and U.S. INTSORMIL scientists to discuss and plan future collaborative research plans and activities at the West African Regional Conference in Ouagadougou, Burkina Faso, April 16-22, 2004.

Traveled to Senegal, October 4-9, and Mali, October 10-21, 2003 to evaluate INTSORMIL/Host Country collaborative research, plan future activities, and assist in coordinating the INTSORMIL External Evaluation Panel (EEP) review of the INTSORMIL collaborative programs in Senegal and Mali, as well as the Ghana program as presented by two Ghanian INTSORMIL scientists who traveled to Bamako, Mali to be reviewed by the EEP.

Traveled to Purdue University, September 8-9, 2003 to meet with Purdue and Nebraska administration and Bruce Hamaker to plan the April, 2004 West Africa Regional Meeting in Burkina Faso, and discuss strategies for merging the Western Region and Eastern Region of West Africa into one overall West African Region.

Traveled to Manhattan and Hesston, Kansas in late August 2003 to visit with Dr. Mitch Tuinstra and evaluate sorghum breeding plots at the two locations.

Participated in the Sorghum Germplasm Committee meeting at Chicago, IL, December 10, 2003 and discussed sorghum germplasm issues and concerns with most of the public and private sorghum researchers in the USA, and the USDA/ARS sorghum germplasm workers and administrators.

Traveled (with Niaba Teme) to College Station, TX, January 5-8, 2004 to develop 2004 research plans and discuss the closing out of my TAES sorghum breeding program as well as INTSORMIL related activities.

Traveled to Washington, DC, February 1-4, 2004 to receive the BIFAD International Research Award and meet BIFAD and USAID Administrators.

Traveled to Corpus Christi and College Station, TX June 28-July 1, 2004 to participate in the INTSORMIL EEP Review of the Texas A&M Projects as well as my INTSORMIL Project.

Organized and led sorghum field days at Corpus Christi, July 10, and at Lubbock, September 15, 2003 where private and public sorghum workers were invited to observe and evaluate my 500 B/R-Line Observation Nursery (possible releases) for interest in requesting and obtaining seed of any of the material through a pre-release distribution MTA (Material Transfer Agreement).

Traveled to Tampico, Mexico, March 3-5, 2004 as a member of the Texas Seed Trade Association Advisory Committee to read sorghum hybrid purity growouts, and interacted with several private seed company breeders.

Coordinated the training of Mr. Niaba Teme, Malian sorghum scientist who is currently working on his Ph.D. in sorghum breeding at Texas Tech University, cooperative with Texas A&M.

Hosted R.E. Schaffert, EMBRAPA sorghum research director from Brazil and Banjerd Boonsue, Thailand sorghum consultant in September 2003 where they toured plots and discussed sorghum breeding and germplasm research.

Germplasm and Research Information Exchange

Germplasm Conservation and Use

Continued the coordination of the work with the Mali Sorghum Collection. The Collection has been evaluated, characterization completed, and a tentative working collection identified. After the seed sent to Experiment Georgia has been processed, seed of the entire collection will be sent to NSSL at Ft. Collins, Colorado and will be distributed as appropriate to ICRISAT, ORSTOM (now IRD), and IER. The complete set of data on the over 40 grain, glume, and plant characterizations has been complied by Jeff Dahlberg and sent to the USDA-ARS for entry into the GRIN system.

Selected indigenous sorghums from the Mali Working Collection (35) and the Sudan Working Collection (30) were evaluated for B/R reaction and hybrid vigor in Mali and Puerto Rico.

Forty-nine new fully converted exotic cultivars from the cooperative TAMU-TAES/USDA-ARS Sorghum Conversion Program were released along with 71 partially converted lines and are in the process of being distributed. Twenty-five Mali entries, including some new, diverse types from northern Mali, were selected as candidates for entry into the Sorghum Conversion Program.

A large number of advanced generation breeding lines from my sorghum breeding program of potential use in host countries and/or U.S. were increased for storage and made available to U.S. collaborating scientists for future distribution and/or use. Selected elite breeding lines were assembled and distributed to host country scientists in South Africa, Zambia, Botswana, Nicaragua, Mali, Ghana, Senegal, and Niger.

Seed Production and Distribution

A large number of sorghum breeding and germplasm lines, from early to advanced generation progeny, A, B, and R lines, converted lines, and experimental hybrids were increased and distributed to international and domestic collaborators. These contained sources of desirable traits such as resistance to downy mildew, anthracnose, sooty stripe, leaf blight, rust, and charcoal rot, pre- and post-flowering drought resistance, grain mold and weathering resistance, and lodging resistance.

Seed of many basic A/B and R-line breeding stocks, RIL populations, photoperiod insensitive introductions, and all the fully converted released lines from the Sorghum Conversion Program were increased in preparation for closing my breeding project.

Assistance Given

Joint evaluation of germplasm and nursery and test entry decisions was done collaboratively with national scientists. Training on disease and drought breeding methodology, as well as information on sources of new useful germplasm and sources of desirable traits, was provided to several visitors. Pollinating bags, coin envelopes, and other breeding supplies were provided to the Mali breeding program. Purchases included computers for Ghana, Senegal, and Mali, and other miscellaneous supplies for Mali.

Other Collaborating/Cooperating Scientists

Cooperation or collaboration with the following scientists in addition to the collaborating scientists previously listed was important to the activities and achievements of Project TAM 222.

Dr. Zenbaba Gutema, Sorghum Breeder, EARO, Nazareth, Ethiopia

Dr. Fred Rattunde, Sorghum Breeder, ICRISAT, Bamako, Mali

Dr. Eva Weltzien Rattunde, Sorghum Breeder, ICRISAT, Bamako, Mali

Dr. Paul Marley, Pathologist, IAR, Ahmadu Bello University, Samaru, Zaria, Nigeria

Dr. Adama Neya, Pathologist, INERA, Farako-Ba Station, Bobo Dioulasso, Burkina-Faso

Dr. Mamaurou Diourte, Pathologist, IER, Sotuba Station, Bamako, Mali

Dr. Demba Farba M'baye, Pathologist, CRZ-Kolda, Kolda, Senegal

Dr. Cleve Franks, Geneticist, USDA/ARS, Plant Stress Laboratory, Lubbock, TX 79415

Dr. John Erpelding, Sorghum Curator, USDA/ARS, Tropical Agriculture Research Station, Mayaguez, Puerto Rico.

Dr. Jeff Dahlberg, Research Director, National Grain Sorghum Producers Association, Lubbock, TX.

Dr. Bob Henzell, Sorghum Breeder, QDPI, Warwick, QLD, Australia

Dr. David Jordan, Sorghum Breeder, QDPI, Warwick, QLD, Australia

Dr. Andrew Borrell, Physiologist, QDPI, Warwick, QLD, Australia.

Dr. Henry T. Nguyen, Molecular Biologist, University of Missouri, Columbus, MO

Dr. John Mullet, Molecular Biology, Department of Biochemistry, Texas A&M University, College Station, TX 77843.

Dr. Robert Wright, Molecular Biology, Department of Plant and Soil Sciences, Texas Tech University, Lubbock, TX 79409.

Dr. Paxton Peyton, Molecular Biology, USDA-ARS, Plant Stress Lab, Lubbock, TX 79415.

Dr. Robert Klein, Molecular Biology, USDA-ARS, College Station, TX 77843.

Dr. Patricia Klein, Molecular Biology, Crop Biotech Center, College Station, TX 77843.

Dr. William Payne, Plant Physiologist, Texas A&M Research Center, Amarillo, TX 79106.

Publications and Presentations

Abstracts

Teme, N., D.T. Rosenow, G.C. Peterson, W. Xu, C.A. Woodfin, H.T. Nguyen, A. Herring, and R.J. Wright. 2003. Backcross method for heterosis enhancement in grain sorghum. Annual American Society of Agronomy Abstracts. CD-ROM. November 2-6, 2003. Denver, CO.

Teme, N., D.T. Rosenow, G.C. Peterson, C.A. Woodfin, and R.J. Wright. 2003. Exotic germplasm use in grain sorghum harvest index improvement. Annual American Society of Agronomy Abstracts. CD-ROM. November 2-6, 2003. Denver, CO.

Presentations

Rosenow, D.T. 2004. Breeding sorghum for biotic and abiotic stress tolerance. Southwestern Branch of Entomology Society of America, February 24, 2004. Lubbock, TX.

Rosenow, D.T. 2004. History of INTSORMIL activities and collaboration in West Africa. INTSORMIL West African Regional Conference, April 18-21, 2004. Ouagadougou, Burkina Faso.

Rosenow, D.T. 2004. TAM-222 sorghum breeding research update. INTSORMIL West African Regional Conference, April 18-21, 2004. Ouagadougou, Burkina Faso.

Theses/Dissertations

Teme, Niaba. 2002. Heterosis, backcross analysis, and breeding potential of one exotic cultivar for grain yield in sorghum (Sorghum bicolor (L.) Moench). Texas Tech University. MS Thesis.

Coulibaly, Sidi Bekaye. 2002. Evaluation of backcross progress and recombinant inbred line populations of sorghum (Sorghum bicolor (L.) Moench). Texas Tech University. Ph.D. Dissertation

Germplasm Enhancement for Resistance to Insects and Improved Efficiency for Sustainable Agriculture Systems

Project TAM 223

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Summary

Increase Yield and Promote Economic Growth

Research activity has emphasized the breeding for resistance to insects component of the Texas Agricultural Experiment Station sorghum improvement program. Primary objectives are to identify, characterize and utilize the genetic diversity of grain sorghum to develop improved cultivars, germplasm, or parental lines resistant to selected biotic and abiotic stresses. Primary insect pests are the greenbug (*Schizaphis graminum*), sorghum midge (*Stenodiplosis sorghicola*), and sugarcane aphid (*Melanaphis sacchari*). Segregating populations are concurrently selected for resistance to economically important diseases including but not limited to: sorghum downy mildew (caused by *Peronosclerospora sorghi* (Westan and Uppal) Shaw), head smut (caused by (*Sphacelotheca reiliana* (Kuhn) Clinton), and anthracnose (caused by *Colletotrichum graminicola* (Cesati) Wilson). Selections are also made for resistance to zonate leaf spot (caused by (*Gloeocercospora sorghi* Bain and Edgerton), bacterial leaf streak (caused by *Xanthomonas holcicola* (Elliot) Star and Burkholder), bacterial leaf stripe (caused by *Pseudomonas andropogoni* (E.F. Smith) Stapp), and charcoal rot (caused by *Macrophomina phaseolina* (Tassi) Goid). Project emphasis is evolving with increased research on drought resistance and food type sorghums and a smaller resistance to insects component. Research activities use primarily conventional methodology. Populations with diverse parents are evaluated to identify superior lines with wide adaptation, resistance to specific diseases, and biotype I greenbug resistance. Relevant populations are also evaluated for drought resistance, primarily stay-green (post-flowering drought tolerance).

A primary research objective has been to develop sorghum midge-resistant hybrid parental lines. Primary research emphasis was to incorporate pest resistance into lines with high grain yield under high pest density, acceptable yield with the pest absent, and incorporate other traits including adaptation, disease resistance, etc. Although significant progress has been achieved the best midge-resistant hybrids produce 10-15% less grain than the best susceptible hybrids when sorghum midge

are absent at anthesis. When sorghum midge are present at anthesis, or when planting occurs two weeks later than normal, resistant hybrids produce significantly more grain than susceptible hybrids. With a shift in project emphasis research on sorghum midge resistant hybrids for the U.S. has decreased with increased emphasis placed on sorghum midge resistant varieties for use in developing country production systems.

Increase Yield, Promote Economic Growth, Improve Nutrition

Eighteen biotype I greenbug resistant and 19 biotype C greenbug/disease resistant lines are in final line evaluation and hybrid yield testing. Most of the biotype C resistant lines also express wide adaptation and resistance to several diseases. Within the group is a diverse array of plant and grain color combinations including tan plant, white grain and tan plant, red grain. Tan plant red or white grain sorghum hybrids with multiple stress resistance and high yield potential may help increase utilization of sorghum in new or non-traditional uses. Multiple stress resistant widely adapted sorghums will be used by private industry in hybrid development programs.

Improve Institutional Capacity

The principal investigator serves on the graduate committee of one Ph.D. student (from Mali) at Texas Tech University and two M.S. students (from Zimbabwe and Mozambique respectively) at Texas A&M University. Mr. Niabe Teme (Mali) will complete requirement for the Ph.D. degree in mid-to-late 2006. Mr. Leo Mpofu (Zimbabwe) and Mr. Joaquim Mutiliano (Mozambique) should complete their M.S. degrees in mid-2005. Mr. Mpofu is a non-INTSORMIL supported student.

Objectives, Production and Utilization Constraints

Objectives

- Obtain and evaluate germplasm for resistance to arthropod pests and other stresses including drought and selected diseases.
- Develop and release high-yielding, agronomically improved sorghums resistant to selected insects and other biotic or abiotic stresses.
- Develop and release high grain yield sorghums with multiple stress resistance and improved grain quality traits.
- Utilize molecular biology to increase understanding of plant traits for stress resistance.

Sorghum Production Constraints

Grain sorghum yield stability and production is constrained by biotic (insects and diseases) and abiotic (drought) stresses. Insects pose a risk in all sorghum production areas with damage depending on the insect and ambient environment. To reduce stress impact sorghums with enhanced environmental fitness are needed. In farmer production stress occurs concurrently and genetic resistance to multiple stresses reduces environmental risk and enhances productivity. This becomes especially important as production ecosystems change with the natural balance between the crop and biotic stresses experiencing change.

Farmers use hybrids or cultivars with improved genetics for adaptation, stress resistance, and quality to meet the demands of increased food production in economically profitable, environmentally sustainable production systems. This requires a multi-disciplinary research program to integrate resistant genotypes into the management system. Varieties or hybrids with genetic resistance to stress readily integrate with other required inputs as part of an integrated, ecologically sound production and stress control strategy with large potential benefits in subsistence and mechanized agriculture. Host plant resistance to insects is a continual effort in response to a dynamic evolving production agroecosystem.

Research Approach and Project Output

Research Methods

Collaborative LDC research is supported through graduate education, germplasm exchange and evaluation, site visits, and research at nursery locations in Texas. Activity is conducted in two regional programs - Southern Africa and Central America. Southern Africa research is primarily focused on incorporating resistance to sugarcane aphid into adapted cultivars. Additional selection criteria include disease resistance, adaptation, and end-use traits. Activity in Nicaragua and El Salvador involves research on sorghum midge, drought resistance, disease resistance, adaptation, and end-use traits. In the United States, sorghum midge and greenbug-resistant sources have been identified and used to develop elite resistant sorghums. Through collaborative ties with other projects genetic inheritance, resistance mechanisms, molecular mapping, and marker-assisted selection research has been conducted. Appropriate selection methodology is used to concurrently select for other biotic or abiotic stress resistance to develop germplasm with wide adaptation, multiple stress resistance, and improved end-use traits.

Germplasm is evaluated for resistance to economically important insects in field nurseries or greenhouse facilities depending on the insect. Sources of germplasm for evaluation are introductions from other programs (domestically and internationally), exotic lines, and partially or fully converted exotic lines from the sorghum conversion program. Introduced germplasm is crossed to elite resistant germplasm, and to germplasm with superior trait(s). Although a primary selection criteria is insect resistance, additional significant selection criteria include wide adaptation, resistance to diseases, drought resistance, weathering resistance and improved end-use traits. Based on phenotypic evaluation and data analysis crosses are

made among elite lines to produce germplasm for subsequent evaluation. The goal is to combine resistance genes for multiple stresses into a single high grain yield genotype. For insects important in LDC's but not in the U.S., germplasm is selected for adaptation, grain yield potential, and disease resistance in nurseries in the Texas Coastal Bend (Corpus Christi and/or Beeville). The germplasm is provided to the LDC cooperator in replicated trials for evaluation for resistance to the specific insect under the local production system (fertilizer, tillage, plant population, etc.) and agronomic and yield data collected if possible.

Research Findings

Sorghum Midge Resistance

Primary emphasis has been directed to identify new superior A- or R-lines. The lines should exhibit a high level of sorghum midge resistance, superior agronomic traits, and high grain yield potential. Grain yield potential of elite breeding lines in hybrid combination was evaluated at Corpus Christi. The midge hybrid test (30 entries x three replications) was evaluated in a late planting (about four weeks after farmer planted sorghum) date. The growing season was characterized by moderate rainfall from planting through maturity. Results are shown in Table 1. Sorghum midge population density at anthesis was low with test mean of 2.9 (rated on a scale of 1 = 0-10% damaged kernels, 2 = 11-21%, up to 9 = 80-100% damaged kernels). The standard resistant check is ATx2755*Tx2882 and the standard susceptible check is ATx2752*RTx430. Grain yield was moderately low with test mean of 2714 kg/ha^{-1} due to the harsh environmental conditions during the growing season. The standard susceptible check, ATx2752*RTx430, produced the most grain in the test (4947 kg/ha^{-1}). This was significantly more grain than all other entries in the test except the experimental resistant hybrid A8PR1011*Tx2882 (4324 kg/ha^{-1}).

Table 1. Mean grain yield, midge damage rating, insecticide phytotoxicity rating, and desirability of entries in midge hybrid test at Corpus Christi, TX, 2003.

HYBRID	DESIGNATION	GRAIN YIELD	MIDGE DAMAGE RATING†	INSECTICIDE PHYTOTOXICITY‡	DESIRABILITY§
		kg/ha^{-1}			
ATx2752*RTx430	s-ck¶	4947	2.0	2.4	2.5
A8PR1011*Tx2882		4324	1.0	2.2	1.9
A8PR1013*MB108B		4163	1.5	2.2	2.2
A8PR1011*9MLT176		4074	1.0	2.8	2.5
A8PR1013*9MLT157		4040	1.0	2.5	2.3
A8PR1013*Tx2880		3941	1.0	2.6	2.4
ATx2755*Tx2880		3779	1.0	2.6	2.5
ATx399*RTx430	s-ck	3637	2.5	2.0	2.5
A0PR13*Tx2882		3634	1.0	2.4	2.4
A8PR1011*9MLT181		3377	1.5	2.2	2.3
ATx2755*97M17		3341	1.0	2.8	2.4
A8PR1011*9MLT157		3240	1.5	2.5	2.4
ATx2755*Tx2882	r-ck	3135	1.0	2.8	2.4
A8PR1013*9MLT181		3058	1.5	2.0	2.3
A8PR1011*MB108B		3055	3.0	2.4	2.1
A0PR13*Tx2880		2771	1.5	2.3	2.5
ATx2755*MB108B		2748	3.0	2.4	2.1
A8PR1011*9MLT180		2714	2.0	1.8	2.5
ATx2755*97M13		2648	3.0	3.0	2.5
A1*Tx430	s-ck	2410	3.5	2.4	2.4
ATx640*RTx430	r-ck	2385	1.5	2.6	2.5
A8PR1013*Tx2767		2114	2.0	2.5	2.5
ATx2752*Tx2862	s-ck	1803	4.5	2.5	2.4
A35*RTx430	s-ck	1678	4.5	2.5	2.4
A8PR1013*Tx2882		1557	3.0	2.5	2.6
A807*Tx2783	s-ck	970	4.5	2.4	2.5
A807*Tx2862	s-ck	729	7.5	2.2	2.4
ATx640*MB108B		714	7.5	2.3	2.7
A35*Tx2862	s-ck	289	8.5	2.3	2.4
A35*Tx2783	s-ck	148	9.0	2.3	2.5
MEAN		2714	2.9	2.4	2.4
LSD.05		773	2.0	0.5	0.4

†Rated on a scale of 1 = 0 to 10% aborted kernels up to 9 = 81=100% aborted kernels.

‡Rated on a scale of 1 = no insecticide phytotoxicity up to 5 = 100% insecticide phytotoxicity.

§Rated on a scale of 1 = most desirable up to 5 = least desirable.

¶s-ck = Susceptible check, r-check = Resistant check.

Most resistant hybrids were at least equal to the other susceptible checks with eight of the 10 hybrids with the highest grain yield being resistant hybrids. Of the 10 hybrids producing the least amount of grain six were susceptible checks. The six susceptible checks produced significantly less grain than most experimental resistant entries. Results confirm previous observations that with a late planting date and few sorghum midge present at anthesis most resistant hybrids will produce significantly more grain than susceptible hybrids. However, for many environments a grain yield difference will exist between resistant and susceptible hybrids.

There is concern that it will not be possible to develop sorghum midge resistant hybrids for use in the United States. The primary constraint to widespread use of currently potentially available resistant hybrids is the lower grain yield potential (averaging 10-15%) of resistant than susceptible hybrids in a normal planting. However, for production delayed at plant-

Table 2. Mean grain yield and selected agronomic characteristics in the biotype I greenbug resistance hybrid test at Lubbock, TX, 2003.

PEDIGREE	DESIGNATION	YIELD	DAYS TO 50% ANTHESIS	HEIGHT	EXSERTION
		kg/ha		cm	cm
ATx645*RTx430	s-ck†	3803	62	44	2
ATx643*LI1/8LI182		3605	65	38	1
ATx643*LI4/8LI178		3587	63	44	2
A8PR1059*LG35		3556	65	43	0
ATx645*LG53/8LI155		3538	62	41	1
ATx642*LI1/8LI188		3432	65	46	1
ATx642*LI1/8LI182		3389	64	44	0
A0PR51*RTx430		3297	61	46	1
ATx642*LI4/8LI178		3266	69	44	1
A8PR1051*RTx430		3260	61	44	1
ATx631*LI4/8LI178		3235	61	44	1
ATx642*LG53/8LI156		3229	62	47	1
ATx645*LG70/8LI170		3204	62	46	1
ATx643*LG70/8LI170		3185	62	44	1
A8PR1053*Tx436		3142	62	47	1
A8PR1053*RTx430		3124	61	40	1
ATx631*RTx430	s-ck	3111	62	47	2
ATx399*RTx430	s-ck	3099	61	38	1
ATx631*Tx436	s-ck	3086	63	47	1
ATx642*LG35/8LI158		3074	63	44	2
ATx645*LG70/8LI172		3068	61	48	1
ATx643*PR8/8LI233		3037	65	40	1
ATx642*LG70/8LI170		2982	63	37	1
ATx642*LG41/8LI163		2976	68	45	1
ATx643*LG41/8LI163		2926	62	47	1
A0PR51*Tx436		2908	61	39	1
ATx642*LG35		2902	69	41	1
ATx645*LI1/8LI188		2889	63	40	1
ATx642*LG70/8LI172		2877	66	37	1
ATx642*LG53/8LI148		2840	63	43	1
ATx642*LG53/8LI155		2840	63	41	1
A0PR59*LG35		2828	62	44	1
A8PR1049*LI4/8LI178		2815	63	44	1
ATx643*RTx430	s-ck	2803	63	44	1
ATx643*LG53/8LI148		2797	64	38	1
ATx645*LG70/8LI173		2797	62	44	1
ATx645*LG53/8LI156		2784	59	46	1
ATx643*LI3/8LI174		2772	61	43	1
A8PR1053*LG35		2754	63	39	0
ATx642*PR8/8LI233		2722	68	42	1
ATx643*LG53/8LI150		2692	64	47	1
ATx645*PR8/8LI233		2655	63	36	1
ATx643*LG70/8LI172		2649	64	43	1
ATx645*LI1/8LI182		2617	62	42	1
A0PR55*LG35		2636	62	47	1
Mean		2463	63	41	1
LSD.05		1230	3	7	1

†s-ck = Biotype I greenbug susceptible check.

ing two weeks or more resistant hybrids will generally out-yield susceptibly hybrids without insecticide application. With increasing environmental concern regarding pesticide application a reduction in availability of insecticides to control sorghum midge could significantly increase interest in and potential use of resistant hybrids. The research focus of sorghum-midge resistance program is changing to reduce hybrid development activity and increase sorghum midge resistant variety development for use in developing country production. While some hybrid development research will continue more resources will be devoted to tan plant and white grain sorghum midge resistant varieties.

Greenbug Resistance

Selections to develop germplasm resistant to biotype I were made. The primary resistance sources are PI550607 and PI550610. Both sources are used in developing R-lines, and PI550610 is used in B-line development. Screening against the greenbug biotypes identified genotypes that express moderate resistance. Biotype resistance is conditioned by several genes and a moderate level of resistance is desired. Crosses to introgress resistance gene(s) into other germplasm were made.

New biotype I resistant R-lines resistant to biotype I were evaluated in a replicated yield trial (94 entries x 3 replications) at Lubbock under moderate drought stress. Partial results are shown in Table 2. The greenbug susceptible hybrid ATx645*RTx430 produced the most grain with 3803kg ha^{-1}. This hybrid did not produce significantly more grain than many experimental resistant hybrids. Fourteen of the to 15 hybrids with the highest grain yield are resistant to biotype I greenbug. The lines represent a range of plant types including tan plant, white pericarp and tan plant, red pericarp. New tan plant, red grain biotype E resistant A-lines were included in the hybrid test. The A-lines A8PR1059, A0PR51, and A8PR1051 produced the fourth, eighth, and tenth, respectively highest yielding hybrids. In addition to excellent grain yield potential many of the entries possess wide adaptation and resistance to several diseases.

New parental lines (either R- or A-lines) resistant to biotype E greenbug and many with excellent disease resistance and grain weathering resistant characteristics were evaluated in a replicated yield trial (46 entries x three replication). The trial was grown under moderate drought stress and limited irrigation at Lubbock, TX. The parental lines have been selected for diversity of plant type, wide adaptation, foliar disease resistance, and increased grain yield potential. This germplasm will be useful as sources of improved traits for other breeding programs, and selected germplasm might have potential as varieties in specific production systems. Test mean was 3266kg ha^{-1} (LSD.05 = 1303kg ha^{-1}). Sixteen experimental produced more grain than the test mean with two hybrids (ATx642*5BRON151 and ATx642*5BRON131) producing significantly more grain at 4635kg ha^{-1} and 4570kg ha^{-1}, respectively. The parental R-line designated 5BRON151 produced the second, eighth, and eleventh highest yielding hybrid when crossed with to ATx642, ATx643, and ATx2752, respectively. It is anticipated that the remaining data required to propose lines for release will be collected in the 2004 growing season and a release proposal will be developed in late-2004 or early-2005.

A replicated yield trial (80 entries x three replications) was grown at the INTA station near Managua, Nicaragua . Data on the 43 entries that produced more train than the test mean (2.1kg ha^{-1}) are listed in Table 3. Superior experimental hybrids produced at least as much grain as standard commercial checks. The highest yielding experimental, ATx635*5BRON139, produced as much grain (4.3kg ha^{-1}) as the best check, ATx631*RTx430. Most of the hybrids expressed acceptable maturity, plant height, and foliar disease resistance. Several of the parental lines including 5BRON139, two derivatives of LG35, 9BRON125, 5 BRON154, and 5BRON155, appear to have potential for use in the regional although additional evaluation is required.

Sugarcane Aphid Resistance

The sugarcane aphid (*Melanaphis sacchari*) is an insect pest of sorghum throughout Southern Africa. Collaborative research between TAM 223, the Botswana College of Agriculture (BCA), the South African Agricultural Research Corporation - Grain Crops Research Institute, and WTU 200 is directed at developing improved varieties with aphid resistance and other acceptable characteristics (maturity, height, grain yield, grain quality, disease resistance) for use in low input, small farmer areas of South Africa and the region. Resistance sources including TAM428, CE151, WM#177, Sima (IS23250), SDSL89426, FGYQ336 have been crossed to locally adapted cultivars (include Segeolane, Marupantse, Macia, Town, SV1, and A964) and to elite lines from the Texas program to develop a range of populations. The segregating populations are planted at Corpus Christi and Lubbock, Texas for evaluation and selection in semi-tropical south Texas. Important selection criteria include plant height, foliar disease resistance, head smut resistance, grain yield potential, and lodging resistance. Evaluation for sugarcane aphid resistance and adaptation to local environments is done at Potchefstroom and the Haxyview Research Station near Burgershall, South Africa or Gaborone, Botswana.

The sugarcane aphid resistance test contains 100 entries. In South Africa, spreader rows of susceptible sorghum were planted two weeks prior to the sugarcane aphid resistance test to ensure presence of aphids. Aphid damage was evaluated when the majority of entries were in the milk stage. Severity of infestation is evaluated using a 1 to 5 scale, where 1 = no aphids present on plants, 2 = light infestation with aphids present on a few leaves (no dead leaves), 3 = moderate infestation with many aphids present of two to three leaves (one or two dead leaves may be present), 4 = high infestation with many aphids on nearly all leaves (many dead leaves) and 5 = majority of plants in plot dying. Plants with a rating of 1 or 2 were considered to be resistant, while a rating of 3 indicated an intermediate level of

Table 3. Grain yield and other agronomic traits of hybrids grown at Managua, Nicaragua, 2003.

HYBRID	GRAIN WEIGHT	DAYS TO 50% ANTHESIS	FOLIAR DISEASE[†]	PLANT HEIGHT	PANICLE EXSERTION	PANICLE LENGTH
	k/ha^{-1}			cm	cm	cm
ATx631*RTx430	4.3	58	2.0	167	3	34
ATx635*5BRON139	4.3	64	1.5	170	12	34
ATx631*LG35/8LI161	3.7	62	1.5	155	3	38
ATx631*LG35/8LI160	3.3	62	1.5	148	4	41
A8PR1059*9BRON125	3.2	61	2.0	150	6	31
ATx635*5BRON154	3.1	62	1.5	175	9	35
ATx635*5BRON155	3.1	62	1.5	166	10	31
ATx645*PR8/8LI233	3.1	62	2.5	137	2	35
ATx645*LG53/8LI148	3.0	58	3.5	145	13	36
ATx643*LI1/8LI182	2.9	62	3.0	147	4	29
ATx631*6OBS124	2.8	65	1.5	158	3	39
A8PR1051*9BRON125	2.8	60	1.5	153	9	36
ATx643*LG70/8LI173	2.8	64	2.0	137	11	36
ATx645*LI1/8LI182	2.8	62	3.0	150	5	30
ATx643*5BRON156	2.7	60	2.0	145	4	33
ATx631*6BRON167	2.7	62	1.5	160	22	34
ATx643*LG53/8LI148	2.7	58	2.5	148	12	29
ATx643*LG70/8LI172	2.7	62	2.0	151	15	32
ATx643*RTx430	2.6	56	2.0	160	9	27
ATx631*Tx436	2.6	58	2.0	165	9	32
ATx399*RTx430	2.6	51	3.0	145	17	27
ATx645*5BRON135	2.5	63	2.0	155	12	39
A8PR1059*6OBS124	2.5	63	1.5	142	11	33
A8PR1057*9BRON125	2.5	62	3.0	145	6	33
ATx643*LG70/8LI171	2.5	61	2.5	152	10	34
ATx645*LG70/8LI173	2.5	65	2.0	142	3	37
ATx399*RTx430	2.4	51	2.0	146	19	29
ATx643*LI4/8LI178	2.4	58	2.0	138	5	38
A8PR1049*LI4/8LI178	2.4	60	1.5	141	9	36
ATx643*LI1/8LI188	2.4	60	3.0	142	20	33
ATx643*6OBS167	2.3	68	2.0	142	3	40
ATx631*8BRON122	2.3	65	1.5	147	5	37
ATx645*LG53/8LI156	2.3	58	3.5	141	9	34
A8PR1057*LI4/8LI178	2.3	59	2.0	145	7	39
ATx631*R88B828	2.2	63	2.0	163	3	33
ATx643*6OBS124	2.2	62	2.0	153	11	34
ATx643*LG53/8LI156	2.2	58	3.0	140	8	38
ATx645*LG70/8LI172	2.2	63	3.0	136	4	30
ATx635*LI4/8LI178	2.2	55	2.0	190	14	39
A8PR1013*Tx2882	2.1	61	3.0	131	3	34
ATx643*5BRON139	2.1	65	2.0	138	3	36
A8PR1049*5BRON154	2.1	68	2.0	118	0	29
A8PR1053*6OBS124	2.1	60	2.0	140	9	32
Mean	2.1	63	2.2	142	8	34

[†]Rated on a scale of 1 = no foliar disease present up to 5 = leaves killed by foliar disease.

resistance. Plants with a rating of 4 or 5 were considered susceptible. Additionally, the percent of plants infested with aphids is estimated as a measure of resistance. Results of the trials are presented in Table 4.

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

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

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

Table 4. Mean sugarcane aphid damage rating, percent ergot infection, percent of plants infested with stem borers, termites, and sugarcane aphids, and number of coccinellids/plant at Potchefstroom and Burgershall, South Africa, and Gaborone, Botswana, 2004.

PEDIGREE	SCA DAMAGE[†]		Ergot[‡]	% infested plants per plot - Botswana			
	Potch	Burger	%	Stem Borers	Termites	Sugarcane aphids	# coccinellids /plot
((6BRON126/87BH8606-14*GR107-90M46)*CE151)-LG2-CG1-BG2-BG3	1.0	1.0	23.5	22.1	21.7	6.7	0.3
(6BRON126/5BRON154/(87BH8606-14*GR107-90M46)*EPSON2-40/E#14/SADC)-LG2-LG1-BG2	1.0	1.0	6.0	36.7	59.5	8.1	0.7
(6BRON161/(7EO366*Tx2783)*EPSON2040/E#15/SADC)-CG2-BG2-BGBK	1.0	1.0	1.0	42.2	19.0	0.0	0.7
(6OB124/(GR134B-LG56)*WM#177)-LG7-CG2-BGBK-CCBK	1.0	1.0	70.0	50.5	37.8	10.4	0.7
(6OB128/(Tx2862*6EO361)*CE151)-LG19-CCBK-CCBK	1.0	1.0	27.5	50.0	11.1	0.0	0.3
(6OB128/(Tx2862*6EO361)*CE151)-LG25-CG1-BG2-BG2	1.0	1.0	84.0	33.6	53.8	11.4	0.0
(6OB128/(Tx2862*6EO361)*CE151)-LG25-CG1-BGBK-CCBK	1.0	1.0	85.0	29.3	12.3	11.1	0.0
(96AD34/6BRON116/5BRON131/(80C2241*GR108-90M30)-HG46-*WM#177)-CG2-BG1-LG1	1.0	1.0	40.0	51.7	12.5	4.2	0.7
(A964*FGYQ336)-LG4-LG2-BG1-BG3	1.0	1.0	56.5	35.1	33.3	12.5	0.0
(CE151*TAM428)-CG1-BG1-BG3	1.0	1.0	3.0	45.4	25.4	5.1	0.3
(CE151*TAM428)-CG1-BGBK-CCBK	1.0	1.0	27.5	34.8	24.1	21.0	0.3
(CE151*TAM428)-LG1-BGBK-CCBK	1.0	1.0	30.0	38.9	38.0	26.2	0.3
(EPSON2-40/E#15/SADC*A964)-LG2-CG1-BG1-BG2	1.0	1.0	37.5	25.5	26.6	10.8	0.3
(EPSON2-40/E#15/SADC*TAM428)-CG1-BGBK-CCBK	1.0	1.0	2.5	35.8	5.1	11.1	0.7
(EPSON2-40/E#15-SADC*TAM428)-CG1-BG1-BG2	1.0	1.0	4.0	42.4	44.4	3.0	0.3
(EPSON2-40/E#15-SADC*TAM428)-LG3-BG1-BG1	1.0	1.0	72.5	22.3	24.4	6.7	1.7
(Macia*TAM428)-LL9	1.0	1.0	37.5	36.1	46.3	25.4	0.0
(SDSL89426*6OB124/GR134B-)-LG5-CCBK-CCBK	1.0	1.0	21.5	61.5	22.2	4.2	1.0
(Segaolane*WM#322)-CG1-BGBK-CCBK	1.0	1.0	42.5	32.2	34.1	16.7	0.0
(SV1*Sima/IS23250)-LG15-CG1-BG2-BGBK	1.0	1.0	6.0	19.2	34.1	3.3	0.0
(Tx430*Sima/IS23250)-LG18-LG2-BG2-BG2-CG2	1.0	1.0	6.0	40.8	15.0	21.0	0.0
PRGC/E#222878	1.0	1.0	12.0	18.5	6.7	5.6	1.3
PRGC/E#69414	1.0	1.0	1.0	13.7	33.3	7.1	0.3
Sima (IS23250)	1.0	1.0	2.5	55.6	14.4	5.0	0.0
WM#177	1.0	1.0	8.5	0.0	25.0	13.3	0.3
WM#322	1.0	1.0	19.5	37.0	20.2	21.0	0.0
(6BRON161/((7EO366*Tx2783)-HG54)*CE151)-CG3-BGBK-CCBK	1.0	1.3	45.0	30.8	23.6	4.2	0.0
(6BRON161/(7EO366*Tx2783)-HG54-*EPSON2-40/E#15/SADC)-LG1-BG2-BG2	1.0	1.3	1.5	47.0	40.5	13.3	0.3
(6OBS124/94CE81-3/GR134B-LG56-*WM#177)-LG1-LG1-BG3-BGBK	1.0	1.3	3.0	3.3	35.3	13.3	0.0
(BRON161/(7EO366*Tx2783)*EPSON2-40/E#15/SADC)-LG5-CC2-BG1-BGBK	1.0	1.3	5.0	34.5	14.8	11.4	0.3
(CE151*(6BRON119/(6EO361*GR107der)*CE151))-CG5-BG1-BG2-CG1	1.0	1.3	60.0	22.2	8.3	3.7	0.0
(Macia*GR128-92M12)-HM16-CM1-CG1	1.0	1.3	50.0	21.3	29.3	7.4	0.3
(Macia*GR128-92M12)-HM20-CA2-CG1	1.0	1.3	9.0	50.4	16.7	12.5	1.0
(Segeolane*WM#322)-LG2-LG2-BG1-LG1	1.0	1.3	30.0	72.8	38.2	8.3	0.0

Table 4. Cont'd - Mean sugarcane aphid damage rating, percent ergot infection, percent of plants infested with stem borers, termites, and sugarcane aphids, and number of coccinellids/plant at Potchefstroom and Burgershall, South Africa, and Gaborone, Botswana, 2004.

PRGC/E#222879	1.0	1.3	3.5	29.7	30.4	21.8	0.0
SDSL89426	1.0	1.3	27.5	55.1	52.8	33.3	0.0
(6BRON126/5BRON154/(87BH8606-14*GR107-90M46)*EPSON2-40/E#14/SADC)-LG3-CG1-BG1	1.0	1.7	37.5	30.4	30.0	17.2	0.7
(6BRON161/(7EO366*Tx2783)*CE151)-LG2-CG3-BG2-BGBK	1.0	1.7	12.5	37.1	31.7	6.7	1.0
(6BRON161/(7EO366*Tx2783)*CE151)-LG5-CG2-BG1-BG2	1.0	1.7	40.0	20.6	17.3	19.4	1.3
(6BRON161/(7EO366*Tx2783)*EPSON2-40/E#15/SADC)-LG4-CG1-BG1-LG2	1.0	1.7	5.0	40.0	4.8	4.8	0.0
(6OB128/(Tx2862*6EO361)*CE151)-LG27-LG1-BG1-LG1	1.0	1.7	30.0	30.6	44.4	34.8	0.7
(6OB128/(Tx2862*6EO361)*CE151)-LG27-LG1-BGBK-CCBK	1.0	1.7	35.0	36.6	49.6	12.2	0.7
(6OBS128/94CE88-3/(Tx2862*6EO361)*EPSON2-40/E#15/SADC)-LG15-CG2-BG2-BGBK	1.0	1.7	27.5	20.7	30.9	7.3	0.3
(CE151*TAM428)-LG2-CG1-BG1	1.0	1.7	1.5	30.6	26.2	0.0	0.7
(Tx430*Sima/IS23250)-LG5-CCBK-CCBK	1.0	1.7	40.0	33.3	8.3	11.1	0.0
(6BRON126/((87BH8606-14*GR107-90M46)-HG10)*CE151)-CG1-BGBK-CCBK	1.0	2.0	4.5	32.1	49.3	0.0	0.7
(96AD34/6BRON116/5BRON131/(80C2241*GR108-90M30)-HG46-*WM#177)-LG2-BG1-LG2	1.0	2.0	51.0	42.4	46.6	18.3	0.0
(Macia*GR128-92M12)-LG1-LG1	1.0	2.0	52.5	0.0	41.2	5.6	0.3
(Town*FGYQ336)-CG1-BG1-LG2	1.0	2.0	27.5	66.7	25.0	3.3	1.3
(6BRON161/((7EO366*Tx2783)-HG54)*CE151)-LG1-BGBK-CCBK	1.3	1.0	14.5	27.8	26.8	0.0	0.7
(6BRON161/(7EO366*Tx2783)-HG54-*CE151)-CG4-BG1-BG1	1.3	1.0	27.5	11.6	35.9	7.1	0.3
CE151	1.3	1.0	2.0	41.0	34.3	17.6	0.3
FGYQ336	1.3	1.0	15.0	4.7	36.5	5.6	0.7
FGYQ353	1.3	1.0	27.5	13.3	48.9	3.3	0.0
(6BRON126/(87BH8606-14*GR107-90M46)*EPSON2-40/E#15/SADC)-LG3-CG1-BGBK-CCBK	1.3	1.3	25.0	62.5	20.8	0.0	0.3
(Macia*TAM428)-LL2	1.3	1.3	14.0	6.7	23.3	6.7	0.0
(6BRON161/(7EO366*Tx2783)-HG54-*CE151)-CG3-BG2-BG2	1.3	1.7	40.0	20.7	24.6	0.0	0.3
(EPSON2-40/E#15/SADC*A964)-CG3-BGBK-CCBK	1.3	2.0	17.0	28.9	32.2	0.0	1.0
Kuyuma	1.7	1.0	0.5	63.3	45.5	11.4	0.3
TAM428	1.7	1.0	17.5	34.2	16.7	18.1	0.7
(Segaolane*FGYQ336)-CG5-BGBK-CCBK	1.7	2.3	20.0	11.1	31.9	16.9	1.0
(Town*EPSON2-40/E#15/SADC)-LG1-BGBK-CCBK	2.0	3.3	14.0	25.9	9.2	11.1	0.0
(Macia*(Tx2882*SRN39))-HM5-CA2	2.3	3.0	82.5	60.0	24.8	0.0	0.0
(Macia*(MR112-90M5*87EO366))-HM8-CA1-CG1	2.3	3.3	32.5	16.7	47.4	0.0	0.3
(Macia*GR128-92M12)-LG33-LG1-CG2	2.7	4.3	37.5	41.7	41.7	0.0	0.7
((6BRON126/(87BH8606-14*GR107-90M46))*CE151)-LG2-CG1-BG2-BGBK	3.0	4.7	4.5	35.2	17.1	0.0	0.0
(Macia*GR128-92M12)-HM14-CM1-CG2	3.7	4.7	49.0	13.3	34.1	0.0	0.0
Macia	4.0	5.0	16.5	21.0	13.3	30.6	0.3
Segaolane	4.7	5.0	1.5	53.6	23.8	0.0	0.3
MEAN	1.5	1.9	17.6	33.9	29.2	10.6	0.4
LSD	0.7	0.9	21.7				

†Rated on a scale of 1 = no damage to 5 = 100% plant damage. Potch = Potchefstroom, Burger = Hazyview Research Station near Burgershall.
‡Rated as a percent of ergot infection.

West Africa (Mali) Graduate Education

Mr. Niaba Teme, a Ph.D. graduate student at Texas Tech University from IER in Mali continued his graduate education. Mr. Teme is in the second year of his Ph.D. program. Research activities were in two major areas. First, collection of phenotypic data of the SC170-14E derived hybrid population for the third year grown at Lubbock and Halfway. Data was collected for grain yield, plant height, panicle length, panicle exertion, number of panicles harvested, thousand-kernel weight, and agronomic desirability. This was the last year the hybrid trial will be grown in the field. Molecular analysis of the 200 entries in the SC170-14E derived population and the parental checks (Tx2783 and SC170-14E continues. Leaf tissue samples from all parental line entries was collected, DNA extracted using the potassium acetate method, and DNA was stored at -20^{0}C. In the next year restriction fragment length polymorphism (RFLP) analysis will be conducted to identify QTLs from the population that influence grain yield and grain yield components. It is anticipated that Mr. Teme will complete requirements for the Ph.D. in the fall of 2006. Following completion of the degree he will return to IER in Mali.

Networking Activities

Workshops and Meetings

Planned and coordinated the INTSORMIL External Evaluation Panel (EEP) review of the Southern Africa regional program 2-12 March 2004 in Lusaka, Zambia and Hilton, Cape Town, and Pretoria, South Africa.

Participated in INTSORMIL Technical Committee meeting 6-7 May 2004, Kansas City, MO.

Participated and was on-site host for the INTSORMIL Board of Directors meeting 13-14 May 2004, Lubbock, TX

Participated in External Evaluation Panel Review of the Texas A&M Univ. sorghum improvement program 29 June - 2 July 2004 in Corpus Christi and College Station, TX.

Research Investigator Exchanges

Interacted with private seed company scientists and Texas Grain Sorghum Association representatives on several occasions. Participated in a Sorghum Field Day at the Texas Agricultural Experiment Station, Lubbock, September 2004.

Zambia, Botswana, Namibia, and South Africa - 8-22 November 2003. In Zambia met with Ministry of Agriculture, Department of Agricultural Research scientists to discuss national and regional sorghum and millet research. Met with the Executive Director of the Golden Valley Agricultural Research Trust to discuss future collaboration between Golden Valley and INTSORMIL. In Botswana met with Department of Agricultural Research and Botswana College of Agriculture scientists and administrators to discuss the status of research in Botswana. In Namibia met with the Deputy Director, Food Production, Ministry of Agriculture, Water and Natural Research to discuss the status of the national pearl millet breeding program. In South Africa met with ARC and Potchefstroom Univ. collaborators to discuss the on-going research program. Met with representatives of the University of Free State to discuss the status of the Ph.D. program of an INTSORMIL sponsored student. Discussed the External Evaluation Panel review with collaborators at all locations to plan the review and associated logistics.

Mozambique, Zambia, and South Africa - 21 February - 12 March 2004. In Mozambique evaluated the status of sorghum research at Sussundenga, Namiolo, and Nampula. Met with INTA scientists to discuss their sorghum activity and evaluated on-farm trials. Met with the INTA Director General to discuss the findings and present recommendations regarding establishing INTA/INTSORMIL collaboration when the Mozambique training grant students return to INTA. In Zambia and South Africa participated in the External Evaluation Panel review of regional activity. In Zambia the review was conducted at Lusaka, Golden Valley, Mount Makulu, and Livingstone with scientists from Zambia, Namibia, and Botswana present. In South Africa the review was conducted at Hilton, Cape Town, and Pretoria with scientists from South Africa and Botswana present.

Germplasm and Research Information Exchange

Germplasm Conservation Use

- Germplasm was distributed to private companies as requested and to the following countries, including but not limited to: Mali, Senegal, Ghana, Nicaragua, El Salvador, South Africa, Botswana, and Zambia. Entries in the All Disease and Insect Nursery (ADIN) were evaluated at many locations domestically and internationally.
- Germplasm previously developed and released by this project is used by commercial seed companies in hybrid production.
- Co-chair of Ph.D. committee for R. Gorena (USA) at Texas A&M University. Served on M.S. committees of N. Teme (Mali) at Texas Tech University and L. Mpofu (Zimbabwe) and J. Mutiliano (Mozambique) at Texas A&M University.

Other Cooperators

Collaboration with the following scientists was important in the activities of TAM 223:

Mr. Leo Mpofu, Department of Research and Specialist Service, Matopos Research Station, P.O. K5137, Bulawayo, Zimbabwe (Currently graduate research assistant at Texas A&M University)

Dr. R. D. Waniska, Cereal Chemistry, Dep. of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843

Dr. G.N. Odvody, Plant Pathology, Texas Agricultural Experiment Station, Texas A&M University Agricultural Research and Extension Center, Route 2 Box 589, Corpus Christi, TX 78406-9704

Dr. Roy Parker, Extension Plant Pathologist, Texas Cooperative Extension, Texas A&M University Agricultural Research and Extension Center, Route 2 Box 589, Corpus Christi, TX 78406-9704

Dr. John Byrd, USDA-ARS, Plant Science and Water Conservation Research Lab., 1301 N. Western Road, Stillwater, OK 74075

Dr. R.G. Henzell, Sorghum Breeding, Hermitage Research Station, via Warwick, QLD 4370, Australia

Publications and Presentations

Abstracts

Coulibaly, S.B., G.C. Peterson, D.T. Rosenow, H.T. Nguyen, W. Xu, V. Chamarek, M.S. Pathan, and P.K. Subudhi. 2003. Expression of grain yield QTLs in sorghum under stress and non-stress environments. *In* Proc. of the 23rd Biennial Sorghum Industry Conference. Albuquerque, N.M., Feb. 17-18, 2003. (CD-ROM, no page numbers).

Teme, N., D.T. Rosenow, G.C. Peterson, W.Xu, C.A. Woodfin, H.T. Nguyen, and A. Herring. 2003. Heterosis and breeding potential of a Chinese cultivar for grain yield in sorghum. *In* Proc. of the 23rd Biennial Sorghum Industry Conference. Albuquerque, N.M., Feb. 17-18, 2003. (CD-ROM, no page numbers).

Books, Book Chapters and Proceedings

Peterson, G.C., B.B. Pendleton, and G.L. Teetes. 2003. PROFIT - Productive Rotations On Farms In Texas: A New Paradigm for Sorghum Research and Information Delivery.

Pp.365-370. *In* Sorghum and Millet Diseases. Edited by John F. Leslie. Iowa State Press.

Dissertations and Thesis

Gorena, R.L. 2004. Characterization of *Schizaphis graminum* (Rondani)(Homoptera: Aphididae) biotype evolution via virulence and fitness on *Sorghum bicolor* (L.) Moench and *Sorghum halepense* (L.) Persoon

Miscellaneous Publications

Rosenow, D.T., L.E. Clark, J.A. Dahlberg, R.A. Frederiksen, G.N. Odvody, G.C. Peterson, F.R. Miller, C.A. Woodfin, K. Schaefer, S.D. Collins, J.W. Jones, and A.J. Hamburger. 2002. Release of four A/B sorghum parental lines ATx642 through ATx645. International Sorghum and Millets Newsletter 43:24-30.