Germplasm Enhancement and Conservation

Breeding Pearl Millet with Improved Performance and Stability

Project ARS-204
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Summary

This project was initiated in January 2000. Population hybrids among West African land races were made in 1999 and in the greenhouse during the 1999-2000 winter. Cooperators were identified in Niger, Mali, Senegal, Zambia and Nigeria for testing and evaluation of pearl millet population hybrids among land races. Seeds were sent to all cooperators. Population hybrids were crosses among West African land races, but the hybrids did not out-yield the local genotypes, indicating a need to produce hybrids among locally adapted and desired types or at least where one parent is from this group. SOSAT-C88 was identified as a parent with good general combining ability that tended to produce the highest yielding grain hybrids. Significant variation existed among the population hybrids for grain yield. Only small differences for grain yields were observed for the various cycles of the population hybrids. However, forage yields of cycles 2 and 3 were significantly lower than for cycle 1. Significant differences were observed for downy mildew resistance among the population hybrids. The population hybrids appear to have potential for improving grain yields in West Africa. One population hybrid, WA13, produced more grain and fodder in Niger than the best local genotype.

Plans are to release a dwarf grain hybrid, TifGrain 102, developed in the Georgia program.

Objectives, Production and Utilization Constraints

Objectives

West Africa

- Improve the productivity and stability of pearl millet cultivars.
- Provide short- and long-term training for pearl millet breeders.

U.S.

- Use West African germplasm to improve germplasm and productivity of U.S. Hybrids.

Constraints

Constraints in West Africa include moisture, availability of fertilizers, resources to purchase fertilizer and other inputs, pest damage (insects, diseases, weeds, and birds), low yields, unstable markets, etc. Plant breeding can help to provide genetic resistance to pest, improve yields, and improve stability of yields. These genetic improvements due to plant breeding can have long-term recurring benefits.

Research Approach and Project Output

Land races from West Africa were assembled and grown under quarantine. Land races were intercrossed by collecting pollen from about 300 plants of one land race, bulking the pollen and using the bulked pollen to pollinate 300 plants of another land race. These crosses are cycle 1 and are referred to as population hybrids (Tables 1 and 2). The same procedure was used to produce cycles 2 and 3, except that the pollen collection and crossing were conducted on 300 random plants within each cycle1 population hybrid. An open-pollinated (random mating) population of cycle 1 was also grown in 2001 for the Exbornu × Ugandi(WA31) and Exbornu × Mansori (WA32) crosses. These population hybrids were evaluated for grain yield in Niger, Nigeria, Senegal, Mali, and Zambia in replicated trials. The hybrids were evaluated for forage production as part of a 9 x 9 lattice trial

Table 1. Yields of population hybrids grown in Nigeria, Senegal, Mali and Zambia during 2001.

		Grain weight/plot		Grain/plot	Grain yield	Dry matter yields	Downy mildew[2]		
2001 Number	Pedigree	Nigeria g	Senegal g	Zambia kg	Mali kg ha^{-1}	Georgia kg ha^{-1}	Nigeria	Mali	Niger
WA 8	99-Ex-Borno Ugandi (C2)	1167	2125	0.478	1030	8410	5.0	6.3	8.4
WA 9	Ex-Borno × Mansori (C2)	917	2300	0.428	865	7607	3.7	9.1	13.9
WA 10	Ex-Borno × Iniari	800		1.023	925	7709	8.3	10.8	8.4
WA 11	Ex-Borno × P3Kolo	1133			1275	8989	3.3	3.4	7.0
WA 12	Ex-Borno × Ugandi	750	2613	0.955	1090	6573	1.3	12.5	22.2
WA 13	Ex-Borno × Mansori	950	2488	0.818	835	10291	5.0	17.1	16.7
WA 14	Ex-Borno × Iniari	1050		0.868	1045	9188	4.3	4.6	7.0
WA 15	P3Kolo × Ugandi	1133		0.885	910	7554	2.7	10.2	18.1
WA 16	P3Kolo × Mansori	967		0.890	1485	10285	6.3	2.9	9.7
WA 17	P3Kolo × Iniari	1067		0.750	1140	9143	3.3	4.6	16.7
WA 18	Ugandi × Mansori	983		0.993	1105	8805	5.3	17.6	7.01
WA 19	Ugandi × Iniari	667		0.715	820	8314	0.7	5.1	13.9
WA 20	Iniari × Mansori	650		0.725	1060	9538	2.3	7.4	5.6
WA 21	2000-Ex-Borno SOSAT-C88	1050	4200	1.093	1120	8570	1.0	8.0	4.2
WA 22	Mansori × SOSAT-C88	1150	3838	0.858	1120	10438	2.3	8.0	1.4
WA 23	SOSAT-C88 × Ankountess	1500	4488	1.298	1665	11571	3.3	1.2	1.4
WA 24	SOSAT-C88 × HKP-GMS	1483		0.863	1150	10515	0.0	9.7	11.1
WA 25	SOSAT × GR-P1	1600		1.095	1545	10669	2.3	2.8	2.8
WA 26	Ugandi × SoSat-C88	1200	3650	1.400	1215	8465	1.0	12.5	2.8
WA 27	Ex-Borno × Ugandi (C2)	617	2275	0.538	850	7398	8.7	11.4	11.1
WA 28	Ex-Borno × Mansori (C2)	683	2512	0.653	1075	7496	6.3	19.3	18.1
WA 29	Ex-Borno × Ugandi (C3)	983	2188	0.698	1065	7507	6.0	7.9	7.0
WA 30	Ex-Borno × Mansori (C3)	567	1881	0.998	850	6942	3.0	13.6	19.5
WA 31	Ex-Borno × Ugandi (C1-op)	967		1.138	1015	8402	6.7	11.4	13.9
WA 32	Ex-Borno × Mansori (C1-op)	917		1.243	950	9566	6.3	9.1	11.1
Check	Souna3		3350						
Check	SoSat				1575			8.0	
Check	SoSat-C88	867					2.7		
Check	Ex-Borno	1283					3.7		
Check	Toroniou C1				2620			12.5	
Check	Boboni				2305			24.4	
Check	Lubasi			0.880					
Check	CIVT								12.5
Check	CT6								11.1
Check	57007BR/W op			0.120					
Check	NCD2-HE op			0.703					
Check	Okahana-1			0.768					
Check	Kuomboka			1.270					
Check	Kataba Local			0.610					
Check	Tifleaf 3					13530			
CV %		32	20	29	28	17	75		
5 % LSD		520	645	.502	476[1]	2127	4.6	7.5	11.0

All WAs are cycle 1 population hybrids except as indicated,
WA 8, WA 9, WA 10, WA 27 and WA 28 are cycle 2
WA 29 and WA 30 are cycle 3
WA 31 and WA 32 are open-pollinated cycle 1.
[1]PPDS
[2]Number of plants per plot in Nigeria and % plants per plot in Mali and Niger.

Table 2. Performance of various cycles of the population hybrids in 2001.

		Dry matter		Country			
Cross	Cycle	Yield kg ha^{-1}	%	Senegal g/plot	Nigeria g/plot	Zambia g/plot	Mali g/plot
Exbornu × Ugandi							
WA 12	1	6573	16.6	1844	750	955	1090
WA 31	1 op	8409	14.6		967	1138	4015
WA 08	2	8410	14.1	1537	1167	478	1030
WA 29	3	7507	14.4	1537	983	698	1065
Exbornu × Mansori							
WA 13	1	10291	14.4	1737	950	818	835
WA 32	1 op	9566	14.2		917	1243	950
WA 09	2	7607	13.5	1575	917	428	865
WA 30	3	6942	14.9	1881	567	998	850
Exbornu × Iniari							
WA 14	1	9188	14.6		1050	868	1045
WA 10	2	7709	14.1		800	1023	925
LSD - 5%		2127	2.0	645	520	502	476

in Georgia. Population hybrids with SOSAT-C88 as a parent tended to perform better at almost all locations (Table 1). For example, hybrids WA 23 and WA26 were in the top four grain producers group at all locations. WA25 was in the top four at three of the four locations. A common parent of these hybrids was SOSAT-C88. It is interesting to note that WA 23 and WA25 also produced the most forage dry matter of the population hybrids. No population hybrid out-yielded the best local genotypes at any location except in Senegal where WA21 and WA23 produced significantly more grain. Performance of the various cycles of the population hybrids is summarized in Table 2. At most locations there were only small differences for grain yield among the various cycles indicating that hybrid vigor could be maintained in these population hybrids. An unexpected response was the grain yield of WA31 and WA32 in Zambia where these two open-pollinated progenies of cycle 1 tended to produce the most grain. This was not observed in either Nigeria or Mali and we have no explanation for this response. Forage yields were somewhat different for the cycles of the population hybrids. No significant differences were observed for cycles of the Exbornu × Ugandi and the Exbornu × Iniari crosses, but cycles 2 and 3 of the Exbornu × Mansori cross produced less dry matter than cycle 1 indicating genotype responses for yield stability in these population hybrids. Significant differences were recorded for downy mildew resistance among the population hybrids, both at a specific location and among locations. The least amount of variations and the lowest incidence of downy mildew was observed in Nigeria. Hybrids such as WA23 showed a low incidence of downy mildew at all three locations, whereas WA26 showed a low incidence in Nigeria but a higher level in Mali. This variation could be due to different races of the disease in the various countries. The population hybrids could make a contribution to improving grain yields of pearl millet in West Africa. However, it appears that crosses need to be made between specific types (maturity, height, grain color and size, head length, etc.) with local adaptation. Genotypes such as SOSAT-C88 with good general combing ability could be effectively used to enhance yield. Crosses between SOSAT-C88 and Souna3, Kuomboka, Toroniou C1 should be evaluated for grain production in Senegal, Zambia and Mali, respectively. The grain and fodder yields of WA-13 were evaluated at two fertility levels in Burkina Faso, Mali, and Niger in a cooperative study with project UNL-213. WA-13 appeared to be adapted to Niger conditions and performed much better than the local cultivar at both locations. WA13 also was one of the best forage producers in the Tifton, GA test. This part of the project is discussed further in the UNL-213 report. We have been working on a disease (mainly rust) resistant dwarf (1.5 m tall) pearl millet grain hybrid for about eight years. Plans are to release an advanced hybrid, TifGrain 102, at the end of 2002. TifGrain 102 yielded from 4300 to 5700 kg ha^{-1} for May and June plantings in 2001. Row widths of 35 to 52 cm appear to produce the most grain. The hybrid flowers in 45 days and grain can be combine harvested in 85 days.

Networking Activities

Sent 21 population hybrids to Nigeria and 13 population hybrids to Senegal.

Ferdinand Muuka, pearl millet breeder in Zambia spent three weeks in the Tifton,GA program.

Jurgens Hoffman from Namibia spent two days in Tifton, GA.

Other cooperating scientists

Ouendeba Botorou, ROCAFREMI Coordinator, ICRISAT Sahelian Center, Niamey, Niger.

Publications and Presentations

Journal Article

Sanogo, M.D. and W. W. Hanna. 2002. Effects of drying time and method on viability of stored pollen of pearl millet. International Sorghum and Millets Newsletter (accepted).

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 the last four years, research efforts in PRF-207 have focused on a selected core of constraints that limit the productivity and utilization of the sorghum crop. We conducted specific studies in attempting to understand the genetic and physiologic basis of drought tolerance using a mix of both traditional and molecular approaches. We also conducted several studies in elucidating the basis of grain mold resistance in low and high tannin sorghums. Specific studies were undertaken in determining the role of physical and chemical kernel properties associated with mold resistance, and in assessing the nature of specific phenolic compounds that contribute to grain mold resistance. We also conducted major studies on assessing genetic diversity using both phenotypic characters and molecular markers. The results of many of these experiments have been summarized in our previous reports. In Year 24, we summarized the results of our genetic diversity analysis on the Sudan sorghum collection.

Objectives, Production and Utilization Constraints

Objectives

Research

- Study the inheritance of traits associated with resistance to biotic and abiotic stresses in sorghum and/or millets.
- Elucidate mechanisms of resistance to these stresses in sorghum and/or millets.
- Evaluate and adapt new biotechnological techniques and approaches in addressing sorghum and millet con-

straints for which conventional approaches have not been successful.

Germplasm Development, Conservation, and Diversity

- Develop sorghum varieties and hybrids with improved yield potential and broader environmental adaptation.
- Develop and enhance sorghum germplasm with increased levels of resistance to drought, cold, diseases, and improved grain quality characteristics.
- Assemble unique sorghum germplasm, and to encourage and facilitate free exchange of germplasm between U.S. and LDC scientists and institutions.
- 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

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

Research Approach and Project Output

Research Methods

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. 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.

Research Findings

Analysis of Regional Diversity and Distribution among Sorghums of the Sudan

Sorghum originated in the Northeast quadrant of Africa over 3000 years ago, and slowly dispersed into other parts of Africa, eventually spreading its area of cultivation into Asia and the rest of the world. Diversity of sorghum appears to be highly correlated with duration of domestication and the type of farming practiced in a geographical area. A high level of diversity was reported in sorghums from Ethiopia, a primary center of origin, from India, a secondary center of domestication, as well as from China, another important center of diversity for sorghum.

Sudan is one of the most important centers of sorghum domestication and cultivation. Sorghum is grown in every region of the country where it is possible to raise a crop. Nearly 80% of the total grain production in the country is obtained from sorghum. It is the staff of life for all Sudanese. In many parts of the country the crop is wholly utilized. The grain is used for making *kisra* (unleavened bread from fermented dough), a local porridge, *asida,* a non-alcoholic beverage, *abreih*, and a local beer, *marisa*. The stalks are used as building material and the straw is utilized as animal feed or as source of fuel.

Sorghums from the Sudan have impacted sorghum improvement efforts globally. They have served as germplasm sources for improvements in yield, drought tolerance, stalk strength, insect and disease resistance, as well as nutritional quality. Early introductions of sorghum into the USA were primarily from Sudan. Sudan was probably the place where mutations for height and maturity took place in nature and where 'U.S. type sorghums' originated providing an excellent opportunity for gene transfer between tropical and temperate sorghums. Indeed many varieties such as *hegaris*, *feteritas*, *zerazeras* and *kurgis* have contributed much towards breeding of improved sorghum varieties in both the U.S. and India. In spite of their immense global importance, however, no organized diversity analysis has been reported on sorghums of the Sudan except for a few collection reports describing apparent variability among Sudanese sorghum landraces. The value of these collections is better appreciated if a thorough analysis of the genetic diversity is undertaken. We therefore, undertook an analysis of the Sudan sorghum collection to develop a better understanding of the diversity and distribution of the present collection and to provide a basis for formulating policy for future action.

A total of 2017 Sudanese sorghum landraces in the ICRISAT gene bank were included for this study. Passport information of accessions were designated either by scientists of the institute which transferred the material to ICRISAT, or by local farmers where the germplasm accession was collected. The collection was divided into three groups corresponding to the nature of the material, i.e., breeding lines, advanced selections, (both originating from Sudanese research institutes), or landraces. Only landraces were considered in the present study. Landraces collected from farmers' fields were designated with local names as well as localities and geographical coordinates (latitude, longitude and altitude) of the sampled fields. Accessions from local markets or those donated by individuals were described for passport data with local names occasionally, but primarily by the contributing institute's geographical location.

Upon entry into the gene bank at ICRISAT, international sorghum numbers (IS number) were assigned to each accession. Results from morphologic characterization and agronomic evaluation for each accession were recorded in the ICRISAT database. Morphologic characterization of accessions was conducted at ICRISAT over the last 20 years. Accessions were grown on a vertisol soil at ICRISAT Patancheru, India (17°25'N, 78°E) and characterized during the rainy and the post-rainy seasons. Longer day lengths, lower temperatures, and cloudy and rainy weather often characterize the rainy season. Only plant height (PHTK) and days to flowering (FLK) were recorded during the Kharif, long rainy season. During the Rabi, post-rainy season, data were recorded for eight quantitative characters, namely, plant height (PHTR), days to flowering (FLR), number of basal tillers (BT), panicle exsertion (PEX), panicle length and width (PLG and PWD), kernel size (KRS), and 100-seed weight (SWT). Additional data on 10 qualitative characters, including presence of nodal tillers (NT), plant pigmentation (PIG), glume color (GLC), midrib color (MRC), panicle compactness and shape (PCS), threshability (THR), glume covering (COV), kernel color (KRC), endosperm texture (TEX), and presence of subcoat (SC) were also recorded. Race classification of *Sorghum bicolor*, as proposed by Harlan and de Wet (1972) and defined by five races (Bicolor, Caudatum, Durra, Guinea and Kafir) and their 10 intermediates based on spikelet and panicle shape at maturity, was used to assess racial distribution.

Among the 2017 Sudanese sorghum landraces maintained at ICRISAT, only 45% were geo-referenced in the database with information on province and/or specific locality of origin . Gezira-Gedarif, one of the major irrigation schemes and large-scale mechanized sorghum farming areas of the world , is home to 73% of the geo-referenced landraces. Among landraces collected on-farm, 52.5% were from 20 different localities in the Blue Nile province. Upper Nile included fewer on-farm collections since all of the entries were designated as originating from Tozi, where an old rainland experiment station was located.

All the races except the Guinea-Kafir intermediate were present in the Sudan collection. Four landraces belonging to the subspecies *Sorghum drummondii* (an annual weedy species) were also present. Landraces belonging to the race Kafir, its intermediates Bicolor-Kafir and Durra-Kafir, and the intermediate Bicolor-Guinea were under represented in the Sudan collection. Race distribution in the Sudan collection was heavily skewed (80%) toward the Caudatum race and its intermediate forms.

Racial distribution was markedly different among regions. Sorghums from Gezira-Gedarif included 14 races made up mainly of Caudatum and its intermediate races. Among landraces from the Kassala region, six races were present with Caudatum and Durra equally represented. Race Bicolor represented as high as 16% of the landraces from Kassala. This is much higher than the frequency of the Bicolor sorghums in the total Sudanese collection (4%). In the Blue Nile region, six races of sorghum were included with race Caudatum as the most dominant (49%) followed by its intermediate Caudatum-Guinea (27%). More races were included in landrace sorghums from Upper Nile where there too, 70% of the landraces were classified as Caudatum. The less diverse region, race-wise, was Equatoria, where only 10 Caudatum, 4 Guinea, and 4 Caudatum-Guinea landraces were reported.

Descriptive statistics were performed on the total collection as well as for group of accessions based on area of origin. Geographic partitioning of phenotypic diversity in each of these regions was tested through variance analysis. To avoid redundancy and improve readability, the results of these analyses were presented by grouping related traits together under the general categories of quantitative and qualitative characteristics.

Phenotypic diversity among landraces was high, as expressed by the large range of variation for mean quantitative traits and the high Shannon-Weaver Diversity Index (0.80). Landraces from Gezira-Gedarif tended to be shorter in stature, earlier in maturity and less sensitive to changes in photoperiod. They also appeared to have long, narrow and compact panicles that may result from adaptation to low rainfall and early adoption of mechanized farming practices. In contrast, taller and later maturing plant types characterized sorghums from Equatoria, most of which delayed their flowering in response to increased day-length. These sorghums included many genotypes with small and light kernels, suggesting possible utilization as fodder. Furthermore, sorghums from Equatoria along with those from the Upper Nile tended to have loose panicles with poorly covered kernels that may result from adaptation to high rainfall of the Southern region. Collections from Kassala showed a higher frequency of landraces with yellow midribs, well covered, and colored kernels that were more difficult to thresh. Landraces from Blue Nile tended to have greater agronomic eliteness with mainly compact panicles, white kernels, no subcoat, and easy to thresh. Although distinct distributions of types were represented by geographical origin, a high level of within-region diversity was present among all Sudanese sorghums.

Phenotypic diversity was estimated by using multivariate analyses of several morphological characters. A principal component analysis involving all 10 quantitative characters was performed where factors were retained when their given value exceeded the value of one. The first three axes explained 62% of the observed phenotypic diversity among landraces from the Sudan . The first axis accounted for 33% of the variance and was significantly and positively associated with plant height and days to flowering recorded during both the rainy and post-rainy seasons. The second axis explained 17% of the variance and was associated with kernel size and 100-seed weight. A third axis, explaining 11% of the variance was associated with panicle length. Plotting the accessions on the first two axes as well as on the first and third factors (not shown) graphically demonstrated that landraces from different regions cover the factorial space unequally. For instance, sorghums from Gezira-Gedarif, despite covering the greatest space, were more densely represented on the factorial space corresponding only to the shortest and earliest plants. On the other hand, accessions from Upper Nile that are largely and evenly distributed on the first axis, had more landraces represented in the factorial space where large and heavy seeded sorghums were plotted. Sorghums from Blue Nile were mainly represented by small and light seeded landraces. The tallest and latest flowering plants of accessions from Blue Nile had the largest and heaviest seeds. Similar observation could be made for sorghums from Kassala, although the distribution in the factorial space was more compact in this group. Landraces from Equatoria, however, were neatly plotted away from landraces from other regions. It was apparent that Equatoria sorghums were small-seeded, tall in stature and among the latest flowering in maturity.

Diversity was also estimated using the Shannon-Weaver diversity index calculated from frequency distribution of multiple morphological traits. Estimates were based on phenotypic variability of the landraces, only considering the qualitative characters. High global index of diversity (H'=0.80) was found in the total collection. Within region, however, the range of index of diversity varied from H'=0.60 for accessions from Equatoria, to H'=0.79 for sorghums from Gezira-Gedarif. Pair-wise comparison of the indices using the *t*-test revealed significant differences (at $p<0.05$ probability-level) between the diversity indices obtained from Blue Nile (H'=0.67) and the total collection (H'=0.80) as well as between Blue Nile and Gezira-Gedarif (H'=0.79).

Networking Activities

Workshop and Program Reviews

Participated in the evaluation of a Food Security Project for the Amhara Region in Ethiopia at the invitation of USAID/Ethiopia, May 5-12, 2001, Addis Ababa, Ethiopia.

Participated in a study on survey of available technologies for use in development of drought tolerant crops in Eastern Africa for the Inter-Governmental Agency for Development, May 12-18, 2001, Nairobi, Kenya.

Attended and chaired two sessions at the 7th International Parasitic Weed Conference, 6-8 June, 2001, Nantes, France.

Attended International Conference on Contemporary Development Issues in Ethiopia, 16-18 August 2001.

Organized a stakeholders conference to discuss findings of regional study on state of technologies for drought tolerant crops in East Africa, 27-31 October 2001, Nairobi, Kenya.

Traveled to Ethiopia to initiate a program on community-based improved sorghum seed multiplication and integrated *Striga* management program for Ethiopia and Eritrea, 10-22 December, 2001.

Research Investigator Exchange

Visited University of Paris and the Tropical Agricultural Research Centre (CIRAD) and held discussions with staff at both institutions regarding collaborative research on sorghum *Striga* resistance, 10-12 June 2001, France.

Hosted international visitors from Ethiopia, Tanzania, Zimbabwe, and Australia.

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 25 countries in 1996, 15 countries in 1997, 10 countries in 1998, and 7 countries in 1999.

Three new *Striga* resistant varieties of sorghum from our program in 2001 were recommend for commercial cultivation in two African countries, one in Tanzania and two in Ethiopia.

Publications

Refereed Papers

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Conference Proceedings

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Grenier, C., P. Rich, A. Mohamed, A. Ellicott, C. Shaner, and G. Ejeta. 2001. Independent inheritance of *lgs* and *IR* genes in sorghum. pp. 220-224. *In*: Fer et al. (eds.) Seventh International Parasitic Weed Symposium. 5-8 June, Nantes, France.

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Published Abstracts

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Invited Research Lectures

Ejeta, G. 2001. Introgression of genes from landraces and wild relatives of sorghum. Presented at the American Seed Trade Association Annual Conference. 6-8 December, Chicago, Illinois.

Ejeta, G. 2001. Exploiting global genetic variation in sorghum improvement. Presented at Kansas State University, Invited seminar, Department of Agronomy. 5 September, Manhattan, Kansas.

Ejeta, G. 2001. The State of Agricultural Research in Sub-Saharan Africa. A keynote address, presented at the International Conference on Contemporary Development Issues in Africa. 16 August, Western Michigan University, Kalamazoo, Michigan.

Ejeta, G. 2001. An African Success Story: the control of a noxious weed. Presented at the Wabash Area Center for Lifetime Learning, 6 November, W. Lafayette, IN.

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. Four A/B female parental lines, A/BTx642 - Tx645, previously known as A/B35, 1, 803, and 807, were released. They possess drought resistance (pre and post-flowering and lodging resistance). Forty-eight new fully converted exotic lines and 70 partially converted lines from the cooperative TAMU-TAES/USDA-ARS Sorghum Conversion Program were identified for release.

Data and characterization on the Mali Sorghum collection of indigenous sorghum cultivars was completed and entered into the USDA-ARS GRIN system. Several very unique and promising new Durra and Durra-Dochna type cultivars from the dry northern part of Mali were identified in the Collection, and hold promise in sorghum improvement in the drought prone areas of Africa and the U.S. Twenty-five sorghums from the Mali Collection were selected for entry into the Sorghum Conversion Program.

Breeding progeny developed in TAM-222 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. 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 Mozam-

bique) derivative lines looked especially promising and also offer potential 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.

Flour made from the IER/INTSORMIL developed tan plant guinea cultivar, N'Tenimissa, was successfully used in Mali by a private bakery (GAM) to produce and market a new cookie, DeliKen, made with 20% sorghum flour being substituted for wheat flour. A private entrepreneur was successful in organizing the production of 13,800 kg of N'Tenimissa in 2001 and had initiated new markets in addition to the GAM bakery. This demonstrates 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 show good promise to be even superior to N'Tenimissa for production and grain quality. One of the new cultivars, 97-SB-F5DT-63, N'Tenimissa* Tiemarfing, has been released and called Wasa.

Collaborative INTSORMIL activities were initiated in Senegal and Ghana in the areas of sorghum breeding, disease resistance, and Striga, as well as in entomology and agronomy research. MOU's are currently in place with both countries.

Objectives, Production and Utilization Constraints

Objectives

U.S.

- Develop and release agronomically improved disease and drought resistant lines and germplasm and identify new genetic sources of desirable traits. Select for drought resistance with molecular markers. Evaluate new germplasm and introgress useful traits into useable lines or germplasm.

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 indigenous Mali origin Sorghum Collection and evaluate for useful traits and breeding potential, introduce into U.S., and place in storage in U.S., ICRISAT, and ORSTOM.

- Initiate collaboration with scientists in Ghana and Senegal including breeding, pathology, entomology, agronomy, and *Striga* research.

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 semi-arid 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 nonguineense 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 where 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.

There is a constant need in both host countries and 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. lines or elite 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. Molecular markers for the stay green trait are being used in a marker assisted selection program. 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), they 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. Growouts 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

Breeding, selection, and screening for drought resistance continued, using major field screening nurseries at Lubbock, Halfway, Chillicothe, Corpus Christi and Beeville. Extreme stress at Chillicothe and Lubbock resulted in severe pre-flowering stress and the loss of most of the Lubbock dryland plots. The "stay green" line, B35, continues to be an excellent source of post-flowering drought resistance and lodging resistance in breeding progeny. Breeding derivatives of the parental line, 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.

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. Resistance to other foliage diseases such as rust, zonate, and gray leaf spot was also selected in some nurseries.

Four advanced generation female parental A/B lines known as A/B35, A/B1, A/B803, and A/B807 were officially released by the Texas Agricultural Experiment Station in June 2002. These lines were released as A/B Tx642, Tx643, Tx644, and Tx645, respectively. ATx642 and 643 possess good post-flowering drought tolerance (stay green) and good lodging resistance (Table 1). The hybrids of ATx642 (A35) are outstanding in their stay green reaction and have excellent charcoal rot resistance and stress-type lodging resistance. Hybrids with ATx643 are not as stay green, depending on the male parent, but usually have quite good pre-flowering drought tolerance. Hybrids with ATx644 and ATx645 show good pre-flowering drought tolerance, and ATx645 hybrids possess an improved level of grain weathering resistance.

Table 1. Agronomic characteristics and disease ratings of BTx642-BTx645 sorghum parental lines and hybrids in various sites throughout Texas.

Location/Destination		Days to anthesis	Plant height in	Panicle exertion in	Agronomic* desirability rating	LPD*** rating	Stalk lodging %	Grain weight gms/1000
							%	
Lubbock	BTx642	71	38	5	2.2	1.4	0	28.4
	BTx643	65	36	1	2.0	1.7	5	30.1
	BTx644	58	35	4	2.5	1.5	7	23.8
	BTx645	62	40	3	2.2	2.2	13	30.4
	BTx378	70	37	3	2.8	2.7	20	31.4
	BTx623	64	40	2	2.6	2.8	50	30.6
Corpus Christi	BTx642	80	38	6	2.9	2.6	0	-
	BTx643	78	38	2	1.9	2.6	0	-
	BTx644	78	36	5	1.9	2.7	2	-
	BTx645	77	38	4	2.1	3.3	10	-
	BTx378	75	39	5	2.4	3.2	15	-
	BTx623	78	42	3	2.1	3.5	20	-

*1 = very good to 5 = very poor; ** = Leaf and plant death rating: 1 = all green, 3 = 50% of leaf area dead, 5 = entire plant dead;
BTx642 = B35; BTx643 = B1; BTx644 = B803; BTx645 = B807

Designation	Head Smut (%)	Downy mildew (%)	Anthracnose rating	Fusarium head blight rating	Chemical Insecticide burn rating	Pre-flowering drought rating	Post-flowering drought rating
BTx642	0	10	4.8	1.0	3.5	4.0	2.6
BTx643	30	0	4.0	1.0	1.0	2.5	2.6
BTx644	5	0	3.0	2.5	1.0	3.1	2.7
BTx645	10	0	4.0	3.0	1.0	2.1	3.3
BTx378	3	2	1.0	3.5	3.0	2.7	3.4
BTx623	30	0	5.0	2.5	1.0	3.3	3.5

All ratings were taken at Corpus Christi except Anthracnose (College Station) and Fusarium head blight (Lubbock).
Disease and burn ratings 1 = resistant through 5 = death.
Drought rating 1 = very good through 5 = very poor.

Hybrid/Pedigree	LPD[1] rating	LPD[1] rating	Lodging[2] percent (%)
	1993	1994	1994
ATx642*Tx430	2.6	2.7	2
ATx643*Tx430	3.8	3.9	31
ATx642*Tx436	2.6	2.7	1
ATx643*Tx436	3.5	4.1	7
ATx642*BE2668	2.6	2.7	4
ATx643*BE2668	3.3	4.0	22
ATx644*BE2668	-	3.1	6
ATx645*BE2668	-	4.1	26
ATx642*86EON361	2.9	2.9	3
ATx643*86EON361	4.0	4.5	68
ATx642*P37-3	3.2	2.5	3
ATx643*P37-3	4.3	4.7	62
ATx642*89CC443	-	-	-
ATx399*Tx430 (check)	-	4.2	41
ATx2752*Tx430 (check)	-	4.0	27
ATx378*Tx430 (check)	-	4.3	55
DK 46 (check)	-	3.2	8

[1]Leaf and plant death rating: 1 = all green; 3 = 50% of leaf area dead; 5 = entire plant dead. Ratings are mean of Lubbock and Halfway.
[2]Primarily moisture stress type lodging, Lubbock

Approximately 30 A-B pairs and 8 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 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 was tentatively identified.

Forty-eight new fully converted lines are now ready for final release preparation and distribution. Data was obtained on a set of 27 and the other set of 21 was selected from seed increase and purification plots. These are cooperative TAMU-TAES/USDA-ARS releases from the sorghum conversion program. In addition, 71 partially converted bulks are ready for release writeup and distribution.

Molecular analysis using RFLP markers, collection of field drought data, and manuscript preparation continued on 100 F_8 recombinant inbred lines (RILs) each of (B35*Tx430) and (B35*Tx7000). Of the five QTL's identified for the stay green trait in the cross (B35*Tx7000) two (Sg2 and Sg3) appearing to be the most important. In the cross (B35*Tx430), the same QTL's were identified for stay green along with two others, and five QTL's were identified for yield. Two hundred progenies each from two other populations, B35*Tx7000 and SC56*Tx7000, were also evaluated for drought and lodging. Several QTLs were identified for pre- and post-flowering drought resistance and lodging resistance. Two of the QTLs for stay green in the SC56 population were the same as those previously identified from B35. All the above research was in cooperation with Henry Nguyen of Texas Tech/TAES. Near isogenic lines (NILs) were developed (BC6) to do fine mapping of stay green QTLs and to do functional genomics and stress physiology research in cooperation with scientists in Australia. In another project, advanced backcross populations and hybrids were generated and evaluated to identify QTLs for yield and heterosis in exotic germplasm.

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. One line, 97-SB-F5DT-63, N'Tenimissa* Tiemarfing, has been released and is called Uassa. 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. A local private entrepreneur successfully organized the production of a large quantity of grain of N'Tenimissa in 2001 in the Bamako area and has initiated new market for the flour.

DeliKen, a locally produced cookie, made partially using flour from the recently developed tan plant Guinea-type sorghum variety, N'Tenimissa, was marketed successfully in the Bamako, Mali area by GAM, the largest local bakery of bread and cookies in Bamako. It was favorably received and was strongly promoted by the Mali government.

From the evaluation of lines and hybrids in Nicaragua, several Texas A&M developed materials look excellent and seed was requested for evaluation again in 2002 (Table 2).

Table 2. Sorghum cultivars and hybrids with the best agronomic potential selected from 2001 nurseries in Nicaragua for further evaluation in 2002. All are white seeded, tan plant unless indicated.

Designation/Pedigree/Source	
(Cultivars)	
96CD635/(SRN39*90EON328)-HF4	
98CD187/(87EON366*90EON328)-HF6	
99GWO92/86EON361*90EON343)-HD12	Red, Tan
(SRN39*90EON328)-HF4..CA2/OOCA4295	
(Macia*Dorado)-HP4..CA2/OOCA4834	
(Macia*Dorado)-HD12/OOCA4846,7	
(Macia*Dorado)-LL2/OOCA5129,34	
(Macia*Dorado)-LL6/OOCA5146,7	
(Macia*Dorado)-LL7/OOCA5159	
(Macia*Dorado)-HD12/OOCA4842,3,5	
(ICSV1089BF*Macia)-HF9/OOCA5189,93	
(ICSV1089BF*Macia)-HF11/OOCA5194,5	
ICSV1089VF*Macia)-HF2/OOCA5169	
(Hybrids)	
ATx631*86EON361	
A.HF14*86EON361	
A.HF8*86EON361	
A.V26*86EON361	
A.V57*86EON361	
A.LD6non*86EON361	
A.HF4(3d)*86EON361	
A.DLO357*86EON361	Red, Purple
ATx631*Tx436	
A.LD6non*Tx436	
A.V57*Tx436	
A.HF4(3d)*91BE7414	
A.HF14*R.9113	Red, Tan
A.HF14*CA4205	Red, Tan
A.LD6non*BRON299(EO361*Macia)	
A.LD6non*GR134/GCPOB124	Red, Tan
A.LD6wxy*GR134/GCPOB124	Red, Tan
A.DLO357*Tx2783	Red, Purple
A.DLO357*88BE2668	Red, Purple

Several breeding progeny from crosses generated for Host Country use, as well as U.S. use, looked very good in several locations, especially in Zambia and South Africa. Some show excellent yield potential as well as good disease resistance. Some progenies also show good drought resistance combined with yield potential. Many Macia and Dorado derivatives looked excellent. Other lines giving good progeny included 86EON361, 87EON366, 90EON328, Sureno, SRN39, TAM428, ICSV1089BF, WSV387, CE151, and MP531.

Leaf blight and ergot were especially severe in Cedara, South Africa in the 2001-2002 season on the ADIN and SABN with excellent ratings obtained (Tables 3 and 4). Agronomic expression was excellent under rather dry conditions at Golden Valley, Zambia and selected progenies with the best ratings are presented in Table 4.

In southern Zambia at Lusitu under extremely severe drought, the lines given below from the Drought Line Test showed excellent drought resistance and produced meaningful quantities of grain, when most other sorghum entries and farmer production was zero. Lines from the DLT with excellent drought resistance included Tx7078, Tx7000, Ajabsido, El Mota, P954035, SC1154-14E, SC1017-14E, SC701-14E, SC265-14E, CE151-262-A1, Macia, Kuyuma, CSM63, 82BDM499, and 88V1080.

Networking Activities

Workshops/Conferences

Participated in the Central America INTSORMIL Research Reporting and Planning Conference, February 26 - March 1, 2002, Managua, Nicaragua.

Participated in and presented plans for new release at the Texas Seed Trade Association (TSTA) Research Conference, February 4-5, 2001, Dallas, Texas.

Participated in the Annual ASTA (American Seed Trade Association) Sorghum and Corn Research Conference, December 5-7, 2001, Chicago, Illinois.

Table 3. Disease and agronomic performance of selected ADIN entries, Cedara, South Africa, 2001-02.

Designation	Desirability[1/] rating	Leaf[2/] blight	Ergot[3/] rating
R9120	2.5	1.0	15.0
SC414-12E	3.0	1.3	38.5
Tx430	3.5	1.0	36.0
Tx2911	3.2	1.8	34.0
BTx631	2.3	0.8	19.0
BTx635	3.0	0.5	26.5
BTx623	2.8	4.0	22.0
SRN39	2.6	3.0	9.5
Tx2783	3.0	2.8	21.5
Tegemao	2.2	3.0	3.5
B35	2.8	0.8	10.0
Tx7078	3.3	2.0	19.5
Tx436	2.2	0.2	11.0
Malisor 84-7	2.0	0.5	18.5
Sureno	2.2	0.3	24.5
SC630-11E	2.5	0.0	29.5
BTx378	3.5	0.5	10.0
SC326-6	3.4	0.0	38.5
86EON361	2.0	0.0	19.0
91BE7414	1.5	0.0	8.0
90EON328	2.0	1.5	6.5
R9618	2.0	0.5	20.0
88BE2668	2.2	1.5	5.5
R9603	1.2	0.5	4.5
MB108B	2.0	3.0	9.0
CA5986	2.0	1.0	7.5
BRON155	2.2	0.3	16.5
BD1982-4	2.2	3.8	9.0
98CD187	1.5	2.8	7.5
96CD635	3.0	1.8	11.5
GCPOBS160	2.0	0.3	13.5
R9519	2.0	0.5	9.0

[1/] Rating 1 = very good to 5 = very poor. By D.T. Rosenow.
[2/] Rating where 0 = completely resistant to 5 = severe disease. By N. McLaren.
[3/] Rating done as mean percentage infected florets. By N. McLaren.

Table 4. Disease and agronomic ratings on selected SABN (Southern Africa Breeding Nursery) entries, Golden Valley, Zambia, and Cedara, South Africa, 2001-2002.

Designation/Pedigree	Desirability[1/] rating G. Valley	Desirability[1/] rating Cedara	Leaf[2/] blight Cedara	Ergot[3/] rating Cedara
(CE151*MP531)-LD12	1.2	1.5	1.3	0
ZSV15	1.5	2.8	2.2	0
ICSV1089BF	1.5	2.2	2.2	7.5
(87EON366*WSV387)-HD27	1.5	2.8	2.5	0
(87EON366*WSV387)-HF14	1.5	2.0	2.0	0
(M84-7*WSV387)-HD7	1.5	3.0	1.5	9.0
(Macia*Dorado)-HD12—CA1	1.5	3.0	2.0	2.5
(Macia*Dorado)-LL1-CA1	1.5	2.9	1.5	0
(Macia*Sureno)-HF19	1.5	3.0	0.8	2.5
(90EO328*CE151)-LD11	1.5	1.8	0.8	2.5
96CA5986 (Sureno*EO366)	1.8	2.5	1.0	9.0
98CA4598(361*343)-HD12	1.8	3.2	3.0	14.5
(SRN39*EO366)-LD39	1.8	2.4	3.3	9.5
(EO366*WSV387)-HD27	1.8	2.7	2.8	5.0
(Macia*Dorado)-HD12—CA3	1.8	2.8	1.5	0.0
(Macia*Dorado)-HD2—CA1	1.8	3.2	2.0	0.0
(Macia*Dorado)-LL2	1.8	3.0	3.0	1.0
(Macia*Dorado)-LL5	1.8	2.5	1.0	9.5
(Macia*Dorado)-LL7	1.8	2.5	1.3	1.0
(ICSV1087BF*Macia)	1.8	3.2	1.0	11.0
Sureno	2.0	3.0	2.0	4.0
86EON361	2.0	2.0	1.0	8.5
Macia	2.0	2.5	2.0	0.0
Kuyuma	2.0	3.0	2.0	0.0
Tegemao	2.0	2.8	2.8	2.5
90EON328	2.0	3.0	2.4	0.0
B.PDLT157	2.0	3.0	4.3	6.0
96CD635	2.0	3.0	2.3	2.5
(EO366*EO328)-HF9	2.0	2.2	2.8	2.5
(Sureno*SRN39)-LD2	2.0	3.2	2.8	23.0
(EO366*WSV387)-HF24	2.0	2.0	0.8	25.0
(EO361*Macia)-HD15	2.0	2.3	0.5	10.0
(EO361*Macia)-HD19	2.0	3.2	2.0	3.5
(Macia*Dorado)-LL1-CA3	2.0	3.2	1.5	0.0
(Macia*Dorado)-LL6	2.0	3.2	2.0	3.5
(Macia*TAM428)-LL14	2.0	2.0	1.5	1.0
(ICSV1089BF*Macia)-HF2(BE1)	2.0	1.5	1.3	3.5
(CE151*MP531)-LD47	2.0	2.2	1.0	0.0
(Sepon82*EO366)-HF38	2.0	2.0	1.5	2.5
(Macia*TAM428)-LL3	2.2	2.5	1.0	1.5
Sima/WSV187	2.5	3.0	1.0	1.1
82BDM499	2.5	2.2	2.2	2.0
TAM428	2.5	3.0	3.8	1.5
Dorado	2.5	3.4	2.3	4.0
98CD187-2	2.5	2.5	0.5	0.0
R2241 der.	2.5	2.3	0.3	5.0
87EON366	2.8	2.6	2.8	22.0
CE151-262-A1	2.8	2.2	2.2	1.0
SRN39	2.8	3.2	3.0	6.5
91BE7414	2.8	2.0	0.0	5.0
(Sureno*EO362)-HF9	2.8	2.0	0.8	0.0
(EO366*TAM428)-HF15	2.8	2.0	2.0	3.0
(ICSV1089BF*Macia)-HF11	2.8	2.0	0.8	2.5
(87EO366*WSV387)-HF3	—	2.0	1.8	2.5
90EL328 der.	—	2.0	2.0	5.0
(CE151*Macia)-BE22	—	2.0	0.8	5.0

1/ Rating 1 = very good to 5 = very poor. By D.T. Rosenow.
2/ Rating where 0 = completely resistant to 5 = severe disease. By N. McLaren.
3/ Rating done as mean percentage infected florets. By N. McLaren.

Serving on Planning committee for the INTSORMIL P.I. Conference in Ethiopia, November 2002.

Research Investigator Exchanges

Traveled to Managua, Nicaragua Feb. 25 - March 1, 2002 to review and plan collaborative INTSORMIL research in Central America with scientists from Nicaragua, El Salvador, and the U.S.

Traveled to Southern Africa region March 31 - April 15, 2002 to evaluate INTSORMIL collaborative sorghum research and plan future activities with scientists from Botswana, Zambia, Zimbabwe, and South Africa; Botswana - April 2-4, Dr. Peter Setimela, sorghum breeder, and others; Zambia - April 4-7, Dr. Medson Chisi, sorghum breeder, and Leo Mpofu, sorghum breeder from Zimbabwe; South Africa - Dr. Neal McLaren, pathologist, Dr. Johnie van den Berg, entomologist, and Prof. John Taylor, Cereal Scientist.

Hosted Dr. Janos Berenji, Sorghum Breeder from Yugoslavia and viewed sorghum research and discussed sorghum breeding and germplasm at Corpus Christ, TX, July 27-28, 2001.

Visited with Rafael Obando, Rene Clara, and Hector Deras at Corpus Christi July 30 and 31, 2001 and evaluated sorghum breeding nurseries and tests.

Arranged travel and hosted Dr. Ibrahim Atokple, Ghana Sorghum Breeder at Lubbock August 13 - September 29, 2001 for breeding training and evaluation of diverse germplasm and advanced breeding material.

Arranged the travel of Mr. Kissima Traore, Sorghum Breeding Technician from Cinzana, Mali for short-term breeding training at Lubbock, TX, September 2 - October 6, 2001.

Visited with Dr. Grame Hammer, Sorghum agronomist and sorghum plant stress modeling expert from Queensland, Australia, November 14, 2001 at Lubbock, TX.

Visited with Dr. Peter Esele, Pathologist from Uganda, November 29-30, 2001, Lubbock, TX, and discussed INTSORMIL research in Uganda and the Horn of Africa Region.

Hosted Dr. Andrew Borrell, Sorghum Stress Physiologist, and Dr. David Jordon, Sorghum Breeder, Queensland, Australia, at Lubbock, TX January 17-29, 2002 and discussed future collaborative physiology and molecular collaborative research on stay green, a post-flowering drought resistant trait in a cooperative research program involving Texas A&M, Texas Tech, and Queensland.

Interacted with INTSORMIL and Host Country scientists at the TC Meetings, November 29-30, 2001 at Kansas City and at the Host Country Coordinators Meeting, P.I. Conference Planning Committee Meeting, and TC meeting April 29-May 3, Lincoln, NE.

Coordinated the training of Mr. Niaba Teme, former sorghum technician with IER, Mali who is nearing completion of his M.S. degree at Texas Tech University, cooperative with TAES at Lubbock.

Interacted with several private seed company scientists at various times, such as at the TSTA Research Conference, ASTA Corn and Sorghum Research Conference, and at the Sorghum Advisory Committee Growouts at Tampico, Mexico, Feb. 20-22, 2002, as well as in individual scientist visits to the TAES research station at Lubbock.

Hosted Dr. Ed Clark, retied TAES Sorghum Breeder and Agronomist, December 13-14, 2001, to evaluate potential releases and develop plans for release of several sorghum drought and lodging resistant sorghum lines developed cooperatively with Dr. Clark.

Germplasm and Research Information Exchange

Germplasm Conservation and Use

Continued the coordination of the work with the Mali Sorghum Collection with the completion of the data and characterization and entry into the USDA/ARS GRIN system. The mid-maturity group of about 1000 items was grown there the winter of 2000-2001. The Collection was evaluated, characterization completed, and a tentative working collection identified in cooperation with Drs. Aboubacar Toure, Jeff Dahlberg, and John Erpelding, and Mr. Niaba Teme. After the seed was sent to Experiment, Georgia and 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, and IER. The complete set of data on the over 40 grain, glume, and plant characterizations was complied by Jeff Dahlberg and sent to the USDA-ARS for entry into the GRIN system.

Nineteen new sorghum breeding lines from IER, Mali were introduced into the U.S. These included some Durras from northern Mali and white-seeded, tan-plant, good food quality guinea derivative and non-guinea types. The 35 lines introduced from Mali in 1999 were evaluated (all were photoperiod sensitive) and were increased in '00-'01 Puerto Rico and evaluated for B/R fertility restorer reaction.

Two sets of new fully converted exotic lines (27 and 21 items) from the cooperative TAMU-TAES/USDA-ARS Sorghum Conversion Program were selected for release and are being prepared for release along with 70 partially converted lines.

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 was increased and many sets of standard replicated trials containing elite germplasm and source lines were packaged and distributed in the U.S. and internationally. These include the ADIN (All Disease and Insect Nursery), GWT (Grain Weathering Test), DLT (Drought Line Test), DHT (Drought Hybrid Test), and the UHSN (Uniform Head Smut Nursery). Also, special drought trials and elite germplasm nurseries were assembled and distributed. Countries to which large numbers of germplasm items were distributed include Mali, Niger, Ghana, Senegal, Nigeria, Burkina Faso, Zimbabwe, Botswana, Zambia, South Africa, Ethiopia, Guatemala, El Salvador, Nicaragua, and Mexico.

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 and Mali, a fax machine for Mali, and other miscellaneous supplies for Mali.

Other Collaborators

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. Issoufou Kapran, Sorghum Breeder, INRAN, Niamey, Niger.

Dr. Aberra Debelo, Ethiopian Country Cooridnator, EARO, Addis Ababa, Ethiopia.

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

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

Dr. Inoussa Akintayo, WCASRN Coordinator, WCASRN, ICRISAT, Bamako, Mali.

Dr. Peter Setimela, Sorghum Breeder, University of Botswana, Gabarone, Botswana.

Mr. Leo Mpofu, Sorghum Breeder, Plant Breeding Institute, c/o SADC/ICRISAT , Bulawayo, Zimbabwe.

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

Dr. Mitch Tuinstra, Sorghum Breeder, Kansas State University, Manhattan, KS 66506.

Dr. Ken Kofoid, Sorghum Breeder, Ft. Hays Branch Station, KSU, Hays, KS.

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

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

Publications and Presentations

Journal Articles

H. Kebede, P.K. Subudhi, D.T. Rosenow, and H.T. Nguyen. 2001. Quantitative trait loci: influencing drought tolerance in grain sorghum (*Sorghum bicolor* L. Moench). Theor Appl. Genet. 103:266-276.

Sanchez, A.C., P.K. Subudhi, D.T. Rosenow, and H.T. Nguyen. 2002. Mapping QTLs associated with drought resistance in sorghum (*Sorghum bicolor* L. Moench). Plant Molecular Biology 48:713-726.

Books, Book Chapters, and Proceedings

Subudhi, P.K., H.T. Nguyen, M.L. Gilbert, and D.T. Rosenow. 2002. Sorghum Improvement: Past Achievements and Future Prospects. In Manjit S. Kang (Ed.) Crop Breeding: Challenges in the Twenty-First Century. Food Products Press. Pp.109-159.

Abstracts

Rodriguez-Ballesteros, O.R., A.S.B. Mansuetus, R.D. Waniska, R.A. Frederiksen, G.N. Odvody, and D.T. Rosenow. 2000. Free and bound phenolic acids in mature sorghum caryopses as affected by inoculation with Fusarium thapsinum. In Proc. of Global 2000: Sorghum and Pearl Millet Diseases III. September 23-30, 2000. Guanajuata, Mexico (in press).

Greneir, C., G. Ejeta, P. Bromel, J. Dahlberg, A.El Ahmadi, M. Mahmoud, G. Peterson, and D. Rosenow. 2001. Sorghums of the Sudan; Importance and Diversity. American Society of Agronomy Abstracts. CD-ROM. October 21-25, 2001, Charlotte, North Carolina.

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

Project TAM-223
Gary C. Peterson
Texas A&M University

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Collaborating Scientists

Dr. J. van den Berg, Entomology, ARC - Grain Crops Institute, Private Bag X1251, Potchefstroom 2520, Republic of South Africa
Ing. Rafael Obando, Sorghum Breeding, Instituto Nicaragense de Tecnolog, Edificio Mar, Apdo.1247, Managua, Nicaragua
Ing. Rene Clara, Sorghum Breeding, CENTA, Apartado Postal 885, San Salvador, El Salvador
Dr. Medson Chisi, Sorghum Breeding, Golden Valley Research Station, Box 54, Fringila, Zambia
Dr. Pharoah Mosupi, Entomology, Department of Agricultural Research, Private Bag 0033, Gaborone, Botswana
Dr. Neal McLaren, ARC-Grain Crops Institute, Private Bag X1251, Potchefstroom 2520, Republic of South Africa
Dr. Aboubacar Toure, Sorghum Breeding, IER, Sotuba, B.P. 438, Bamako, Mali
Mr. Sidi B. Coulibaly, Agronomy/Physiology, IER, Sotuba, B.P. 438, Bamako, Mali (currently Graduate Research Assistant, Texas A&M University Agricultural Research and Extension Center, Rt. 3 Box 219, Lubbock, TX 79403-9803)
Dr. Bonnie B. Pendleton, Entomology, Division of Agriculture, West Texas A&M University, Canyon, TX 79016 (WTU-200)
Dr. W.L. Rooney, Sorghum Breeding, Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843 (TAM-220C)
Dr. Lloyd Rooney, Cereal Chemistry, Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843 (TAM-226)
Dr. D.T. Rosenow, Sorghum Breeding, Texas Agricultural Experiment Station, Texas A&M University Agricultural Research and Extension Center, Rt. 3 Box 219, Lubbock, TX 79403-9803 (TAM-222)

Summary

Increase Yield and Promote Economic Growth

Primary research emphasis of this project is the breeding for resistance to insects component of the integrated Texas A&M University sorghum improvement program. Project 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. Insect pests receiving major emphasis are the sorghum midge (*Stenodiplosis sorghicola*), greenbug (*Schizaphis graminum*), and sugarcane aphid (*Melanaphis sacchari*). Segregating populations are also 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), anthracnose (caused by *(Colletotrichum graminicola* (Cesati) Wilson). Other diseases for which resistant genotypes are selected include 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).

Breeding and selection activities primarily use conventional methodology. Collaborative molecular biology research has mapped genes for resistance to greenbug biotypes and molecular markers are being used to concurrently select for greenbug resistance and stay green (post-flowering drought tolerance). Numerous lines from different populations are being evaluated to identify superior lines resistant to greenbug biotype I with excellent stay green and wide adaptation.

A primary research objective is to develop sorghum midge resistant hybrid parental lines. In addition to pest re-

sistance, the lines should produce excellent grain yield under high pest density, acceptable yield with the pest absent, and contain other favorable traits including adaptation, disease resistance, etc. The best midge-resistant lines currently available in the breeding program in hybrid combination produce 10-15% grain yield than the best susceptible hybrids when sorghum midge are absent at anthesis. When sorghum midge are present at anthesis the resistant hybrids produce significantly more grain than susceptible hybrids. Research is on-going to select for improved grain yield potential.

Increase Yield, Promote Economic Growth, Improve Nutrition

The greenbug resistance program has lines in advanced yield testing with excellent resistance. Many of the lines possess wide adaptation and resistance to several diseases. Included is an array of plant and grain color combinations including tan plant, white grain and tan plant, and red grain. Breeding lines with multiple stress resistance and tan plant with white or red grain may help increase utilization of sorghum in new or non-traditional uses. The multiple stress resistance, wide adaptation, diverse plant types will contribute to utilization by private industry after release.

Improve Institutional Capacity

The principal investigator serves on the graduate committee of one M.S. student (from Mali), and two Ph.D. students (co-chair of Malian student at Texas Tech and U.S. student at Texas A&M University). The principal investigator coordinated the short-term training of collaborators from El Salvador and Nicaragua, and initiated the process of providing short-term training opportunity to a Southern Africa collaborator. The principal investigator presented a seminar at the Botswana College of Agriculture on INTSORMIL objectives and goals, and on TAM-223 research.

Objectives, Production and Utilization Constraints

Objectives

- Obtain and evaluate germplasm for resistance to arthropod pests.
- Determine the inheritance of insect resistance, and the resistance source or mechanisms most useful to sorghum improvement.
- Develop and release high yielding, agronomically improved sorghums resistant to selected insects.
- Utilize molecular biology to increase understanding of the genetics of plant resistance traits.
- Develop and release high grain yield sorghums with multiple stress resistance and improved grain quality traits.

Constraints

Sorghum production and yield stability is constrained by biotic and abiotic stresses including insects, diseases and drought. Insects pose a risk in all sorghum production areas with damage depending on the insect and local environment. To reduce stress impact sorghum cultivars with enhanced environmental fitness suitable for use in sustainable production systems are needed. Cultivars experience stress concurrently or sequentially and genetic resistance to multiple stresses will reduce environmental risk and enhance productivity. This is especially important as production ecosystems change due to technology improvements with the natural balance between cultivars and biotic stresses changing and insect damage becoming increasingly severe.

Genetic resistance may be utilized at no additional producer cost 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 three regional programs - Southern Africa, Central America, and West Africa (Mali). Project resources previously directed to Mali have been reallocated to other sites with current activity primarily to support a Ph.D. student. Southern Africa research is directed at incorporating resistance to sugarcane aphid into adapted cultivars, and includes disease resistance, adaptation, and end-use traits. Nicaragua and El Salvador provide additional research on sorghum midge (the most important biotic production constraint in Nicaragua), drought resistance, disease resistance, adaptation, and end-use traits. In the United States, sorghum midge and greenbug-resistant sources have been identified and used in developing elite resistant sorghums. Primary emphasis is on biotype I greenbug resistance. 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 mode of infestation. Sources of germplasm for evaluation are introductions from other programs (including ICRISAT), exotic lines, and partially or fully converted exotic lines from the sorghum conversion program. New resistance sources are crossed to elite resistant germplasm, and to other germplasms with superior trait(s). Although a primary selection criteria is insect resistance, selection criteria include wide adaptation, resistance to specific diseases, drought resistance, weathering resistance and improved end-use traits. Based on data analysis and phenotypic evaluation, crosses are made among elite lines to produce germplasm for subsequent evaluation. The goal is to combine resistance genes for multiple stress into a single high yielding genotype.

For insects important in LDC's but not in the U.S., germplasm is provided to the LDC cooperator. The germplasm is evaluated for resistance to the specific insect under the local production system (fertilizer, tillage, plant population, etc.), and/or greenhouses, and agronomic and yield data collected if possible. The populations are grown in the U.S. and selected for adaptation.

Research Findings

Sorghum Midge Resistance

Research to identify new superior A- or R-lines continued. In 2001, a replicated line test (85 entries x 3 replications) was grown in 7 planting dates and four locations. A replicated hybrid test (60 entries x 3 replications) was grown in 5 planting dates at three locations. Additionally, the midge line test was grown at the INTA research station near Managua, Nicaragua to evaluate for adaptation to local conditions, and at Potchefstroom, South Africa to evaluate for adaptation and resistance to sugarcane aphid. Partial results are reported in Table 1. Sorghum midge density in Texas was abnormally low during the 2001 summer resulting in average midge damage ratings of less than 2.0 (corresponding to less than 20% seed loss) in most planting dates. Many entries were identified with excellent resistance to the low population density. However, these entries may not be resistant under high or moderate population density. Based on agronomic desirability in Texas, 37 entries were selected for additional evaluation. At the INTA station near Managua, Nicaragua, population density was also low. There was generally a good correspondence between sorghum midge resistance in Texas and in Nicaragua. Several entries were identified with generally good midge resistance in Texas and Nicaragua, and good grain yield in Nicaragua.

Grain yield potential of elite breeding lines in hybrid combination was evaluated in 5 environments - Corpus Christi normal (CA), Corpus Christi medium-late (CM), Corpus Christi late (CL), Lubbock (L), and Halfway (H). Partial results are shown in Table 2. Because of environmental conditions few midges were present at anthesis and midge damage ratings are not reported. The standard resistant check is ATx2755*Tx2767 and the standard susceptible checks are ATx2752*RTx430 and ATx399*RTx430. Grain yield was variable due to harsh environmental conditions at Corpus Christi and Halfway. Susceptible hybrids

Table 1. Mean midge line test sorghum midge damage, and grain yield at Managua, Nicaragua and sorghum midge damage at Corpus Christi and College Station, TX, 2001.

	Midge Damage Rating[†]					
	Corpus Christi		College Station		Nicaragua	Grain
Designation	Early	Late	Early	Late		Yield Kg ha^{-1}
(Tx2883*(Tx2880*(GR108-90M24*(Tx2862*(Tx430*(Tx2862*PI550610))))))-PR2-LG4-der	1.0	1.0	1.0	2.5	1.0	6344.00
(MR102-90M2*IS3546C/SC751-14)-SM3-CM3-CM1-SM1-CM1-CMBK	1.3	1.0	1.5	1.0	1.0	5838.00
B8PR1013	3.0	2.0	1.5	2.5	1.0	5322.00
(Tx430*MR112B-92M2)-SM29-	1.3	1.3	1.0	1.0	1.0	5140.00
B9PR2143	1.7	1.3	3.5	4.0	1.0	4780.00
B0PR11	1.0	1.7	1.0	2.0	1.5	4566.00
(PM12713*Tx2882)-CM7-CM1-	1.0	1.0	1.0	2.0	1.5	4470.00
(Tx2880*(86EO361*(Tx2880*PI550607)))-PC1-PR10-LG2-CG2-CM2	1.0	1.0	2.0	6.5	1.5	4462.00
(Tx2882*SRN39)-CM3-SM2-SM2-SM2	1.0	1.0	1.0	1.5	2.0	4373.00
9MLT157	1.0	1.3	1.5	2.0	1.5	4262.00
(MR112B-92M2*Tx2880)-SM3-SM1-	1.0	1.0	1.0	1.0	1.0	4197.00
(Tx2880*(Tx2880*(Tx2864*Tx436*(Tx2864*PI550607)))))-PR3-SM6-CM3-CM4	1.0	1.3	1.0	2.0	3.5	4167.00
(PM12713*Tx2882)-CM3-CM2	1.0	1.0	1.0	1.0	2.0	4164.00
MB108B/P.G.	1.0	1.7	1.5	2.5	2.0	4112.00
(MB110-B92NF3*BTx631)-SM11-SM1-SM1-CM2-CM1	1.3	1.7	1.5	4.0	1.0	4070.00
(BArg34*MB120C-BM5)-SM3-	3.3	1.7	1.5	1.5	1.0	4011.00
(Tx2883*(Tx2880*(GR108-90M24*(Tx2862*(Tx430*(Tx2862*PI550610))))))-PR2-LG4-der	1.0	1.3	1.0	2.5	1.5	3292.00
(Tx2882*SRN39)-CM3-SM2-SM2-CM1	1.0	1.0	1.0	2.0	1.5	3806.00
B8PR1021/MB116C	2.0	1.0	1.5	1.0	2.0	3775.00
Tx2767	1.0	1.3	1.5	1.5	1.0	3775.00
(Tx2883*(Tx2880*(GR108-90M24*(Tx2862*(Tx430*(Tx2862*PI550610))))))-PR2-LG4-der	1.0	1.0	1.0	2.0	1.0	3757.00
(PM12713*Tx2882)-SM8-CM1	1.0	1.0	2.0	1.5	4.0	3748.00
MEAN	1.4	1.5	1.8	3.0	2.0	1.89
LSD	1.0	1.2	1.2	1.5	1.5	0.8

[†] Rated on scale of 1 = 0-10% damaged kernels, 2 = 11-20% damaged kernels, up to 9 = 91-100%.

Table 2. Grain yield and days to 50% anthesis of selected entries in the 2001 Midge Hybrid Test.

Hybrid	Status[1]	Grain Yield				
		Corpus			Lubbock	Halfway
		Late	Medium-Late	Normal		
		lb/ac				
ATx399*Tx430	S-CK	1221	1480	700	1777	439
ATx2755*97M14		1119	1053	669	1797	1392
A8PR1013*MB108B		1074	1189	459	1664	501
ATx2752*Tx2862	S-CK	1069	1247	948	2225	787
A0PR11*Tx2882		1013	1170	967	1589	698
ATx2755*97M9		999	876	778	1467	636
A8PR1011*9MLT180		989	995	792	1620	434
A8PR1013*Tx2882		962	826	398	1729	718
A8PR1013*9MLT164		923	844	410	1841	774
A8PR1011*MB108B		917	1674	873	1667	488
A8PR1019*Tx2882		903	911	740	1569	1270
A8PR1011*Tx2880		897	899	406	1610	864
A8PR2145*Tx2882		897	1253	677	1503	1174
ATx2755*MB108B		881	1466	798	1836	447
A8PR1013*Tx2880		876	999	566	1554	834
A8PR1011*9MLT157		872	879	755	1313	1031
A0PR13*Tx2880		870	1244	1214	1406	1200
A8PR1015*Tx2880		865	1837	1139	2189	1187
A8PR1013*9MLT180		848	1064	656	1466	886
A0PR15*Tx2880		844	1261	1043	1967	592
A35*Tx430	S-CK	839	1901	1125	1273	279
A0PR11*Tx2880		827	1313	938	1815	792
ATx2752*Tx2783	S-CK	821	1292	989	2039	426
A8PR1011*9MLT164		814	853	496	1643	880
A9PR2141*Tx2880		812	873	650	1304	722
ATx2755*97M17		810	1099	625	1396	1116
A8PR1013*9MLT176		806	781	558	1015	704
ATx2755*Tx2882	R-CK	778	891	530	1596	723
ATx2752*Tx430	S-CK	766	567	949	2026	633
A1*Tx430	S-CK	745	967	854	1527	942
A35*Tx2862	S-CK	663	1447	1179	1764	366
ATx2755*Tx2767	R-CK	607	925	515	1863	856
ATx2755*Tx2880	R-CK	596	838	545	1398	1277
A1*Tx2862	S-CK	574	592	786	2120	994
MEAN		1696	2401	1733	3651	1745
LSD .05		556	817	839	1071	925

[1] R = resistant; S = susceptible; Ck = check.

generally produced more grain than resistant hybrids although differences were not consistent. Some resistant experimental hybrids produced grain yield not significantly different than some susceptible hybrids depending on the environment. Results confirm previous observations - most resistant hybrids will not produce grain yield equal to susceptible hybrids in plantings where no or few midges are present. The line designated 8PR1013 has a large open panicle with white grain and possess excellent resistance. It was selected for inclusion in the PROFIT (Productive Rotations On Farms In Texas) hybrid seed project.

Greenbug Resistance

Selections to develop germplasm resistant to biotype I and K greenbug 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 different genes and a moderate level of resistance is desired. Crosses to introgress resistance gene(s) into other germplasm were made.

New R-lines resistant to biotype E and/or I produced excellent hybrids. The lines represent a range of plant types including tan plant, white pericarp and tan plant, and red pericarp. New tan plant, red grain biotype E resistant A-lines were evaluated in hybrid combination. The hybrids expressed excellent grain yield potential, wide adaptation and resistance to several diseases. Based on performance one A-line, 8PR1059, and two restorer lines, 5BRON139 (resistant to biotype E) and LG35 (resistant to biotype E/I/K) were selected for inclusion in the PROFIT hybrid program.

A 120-entry observation of experimental hybrids was provided to INTA, Nicaragua, to evaluate for adaptation. Hybrids represent a range of plant types including different plant color and grain color combinations, and most pollen (male) parents have excellent disease resistance. Many experimental hybrids produced excellent grain yield and appear to be well adapted to the local production system. (partial data Table 3). Additional evaluation will continue in 2002.

Sugarcane Aphid Resistance

The sugarcane aphid (*Melanaphis sacchari*) is an insect pest of sorghum throughout Southern Africa. Previous col-

Table 3. Mean grain yield and selected agronomic of experimental hybrids, Managua, Nicaragua, 2001.

Designation	Days to 50% Anthesis	Height	Excertion	Panicle length	Grain yield
A0PR59*6OBS143	64	143	8	39	9265
ATx635*5BRON156	65	166	15	26	7341
A8PR1053*6BRON167	65	137	5	37	6514
A8PR1053*Tx430	59	161	11	34	6476
A8PR1057*6BRON167	65	137	9	34	6333
A8PR1051*Tx430	59	152	12	38	5892
A8PR1057*Tx2862	65	136	5	31	5889
A0PR51*5BRON131	62	134	11	35	5696
A0PR51*Tx430	61	135	7	35	5646
A8PR1059*Tx430	59	158	6	32	5633
A8PR1057*LG35/8LI161	65	145	8	34	5633
A807*6BRON167	66	130	15	37	5482
ATx631*6BRON167	65	171	14	40	5398
A8PR1059*Tx2862	64	147	9	32	5396
ATx635*5BRON131	65	149	8	34	5284
A8PR1053*Tx436	57	142	12	40	5182
A8PR1059*Tx436	64	160	13	24	5166
A8PR1051*6OBS143	67	149	5	44	4940
A91NF18*Tx2783	66	143	8	26	4918
A91NF18*5BRON151	60	158	8	40	4885
ATx635*5BRON139	64	185	14	36	4864
A8PR1057*5BRON131	59	136	9	31	4845
A8PR1053*98LI159	66	155	9	38	4750
A8PR1045*Tx2862	65	139	10	33	4750
ATx631*6OBS124	60	195	13	34	4672
ATx2752*5BRON151	58	142	12	34	4635
A8PR1045*Tx2783	66	180	13	27	4450
A8PR1051*Tx436	57	145	9	41	4449
A8PR1057*5BRON155	66	147	11	33	4391
A35*5BRON151	61	144	23	34	4293

laborative research between TAM-223, TAM-225 (discontinued), and the Botswana Department of Agricultural Research (DAR), identified several sources of resistance and studied the inheritance of resistance. The program now includes South African (ARC-Potchefstroom) collaborators. Resistance sources including TAM428, CE151, WM#177, Sima (IS23250), SDSL89426, FGYQ336 have been intercrossed, crossed to locally adapted cultivars (include Segeolane, Marupantse, Macia, Town, SV1, and A964), and crossed to elite lines from the Texas program to develop a range of populations. The segregating populations are planted at Beeville and Lubbock, Texas for selection. Evaluation for sugarcane aphid resistance and adaptation to local environments is done at Potchefstroom, South Africa or Gaborone, Botswana.

A 100-entry test for sugarcane aphid resistance was developed and sent to South Africa and Botswana. The test was evaluated for aphid resistance, adaptation, and weathering resistance in replicated tests at the ARC, Potchefstroom, and for aphid resistance and adaptation at the ARC Lowveld Station near Hazyview (Table 4). Thirty experimental entries sustained aphid damage less than or equal to several resistant checks (WM#322, Ent. 62/SADC, FGYQ353, TAM428). Forty-three entries were selected for additional evaluation based on aphid resistance and adaptation. The breeding lines will undergo additional selection in Texas, and screening and agronomic evaluation in Southern Africa. Varieties developed should contain wide adaptation, sugarcane aphid resistance, disease resistance (primarily sooty stripe and anthracnose), and other favorable traits including tan plant, white pericarp, and appropriate height and maturity. Several experimental entries may have potential use as varieties. Additional studies will be conducted to accurately access the yield potential, agronomic acceptability, and food use potential.

The midge line test (and 85-entry test) was also evaluated for resistance to sugarcane aphid. Sorghum midge population density at anthesis was not sufficient to evaluate for midge resistance. However, ratings obtained in Texas give an accurate measure of the sorghum midge resistance level. Experimental entries were identified with sugarcane aphid damage less than the test mean and sorghum midge damage (in Texas) of 20% or less.

Greenbug Resistance/Stay-green Study

Marker-assisted selection research for greenbug resistance and stay green (post-flowering drought tolerance) continued. This is a collaborative research activity between this project, TAM-222, and the molecular biology laboratory of Dr. Henry Nguyen (formerly at Texas Tech University and now at the University of Missouri). Mr. Sidi

Table 4. Mean sugarcane aphid damage ratings and weathering resistance, 2002.

Pedigree	Damage rating†		Weathering‡
	Potchefstroom	Hazyview	
(MR112B-92M2*Tx2880)-SM3-SM1-ML52	0.0	1.3	-
(6BRON161/((7EO366*Tx2783)-HG54)*CE151)-CG3-BGBK	1.0	1.0	3.0
(CE151*BDM499)-LD17-BE1	1.0	1.7	3.0
TAM428	1.0	2.0	3.0
(Macia*TAM428)-LL2	1.0	1.0	3.0
(6BRON161/(7EO366*Tx2783)*CE151)-LG2-CG3-BG2	1.3	1.0	2.5
(CE151*BDM499)-LD17-BE2	1.3	1.0	1.0
(SV1*Sima/IS23250)-LG15-CG1-BG2	1.3	1.0	2.5
WM#322	1.3	1.0	3.0
(5BRON131/((80C2241*GR108-90M30)-HG46)*WM#177)-LG1-BGBK	1.3	1.0	2.5
(6BRON126/(87BH8606-14*GR107-90M46)*EPSON-40/E#15/SADC)-LG1-LG1-BGBK	1.3	1.0	1.5
(EPSON2-40/E#15/SADC*TAM428)-CG1-BGBK	1.3	1.0	2.0
FGYQ336	1.3	1.0	2.5
(Segaolane*WM#322)-CG1-BGBK	1.3	1.0	2.5
(6OB124/(GR134B-LG56)*WM#177)-LG7-CG2-BGBK	1.3	1.0	2.0
(6OB128/(Tx2862*6EO361)*CE151)-LG27-LG1-BGBK	1.3	1.3	1.0
GR128-92M12	1.7	1.3	2.5
(CE151*TAM428)-LG15-LG1-BG1	1.7	1.0	2.0
(6BRON161/((7EO366*Tx2783)-HG54)*CE151)-LG1-BGBK	1.7	1.0	
(6OB128/Tx2862*6EO361)*CE151)-LG4-CG1-BGBK	1.7	1.0	1.0
(Macia*TAM428)-HD1	1.7	2.0	2.5
Sima(IS23250)	1.7	1.0	2.5
(Macia*TAM428)-LL9	1.7	1.0	2.0
(CE151*TAM428)-CG1-BGBK	1.7	1.3	2.0
(CE151*TAM428)-LG1-BGBK	1.7	1.0	2.5
(87EO366*TAM428)-HF2	1.7	1.0	2.0
(6OB128/(Tx2862*6EO361)*CE151)-LG19-CCBK	1.7	1.0	3.5
Ent.62/SADC	1.7	1.0	0.5
PRGC/E#222878	1.7	1.0	2.0
(EPSON2-40/E#15/SADC*6OBS124/94CE81-3/GR134B-LG56-)-LG1-CG1-BG1	2.0	1.0	1.0
FGYQ353	2.0	1.0	2.0
CE151	2.0	1.0	2.0
(6BRON161/(7EO366*Tx2783)*EPSON2040/e#15/SADC)-CG2-BG2	2.0	1.3	2.5
(6BRON126/((87BH8606-14*GR107-90M46)-HG10*CE151)-CG1-BGBK	2.0	1.3	2.5
(6OBS128/94CE88-3/(Tx2862*6EO361)*EPSON2-40/E#15/SADC)-LG1-CG2-BG2	2.0	1.0	0.5
(EPSON2-40/E#15/SADC*TAM428)-LG3-CG1-BGBK	2.0	1.3	2.0
(6OB124/94CE81-3/GR134B-LG56-*WM#177)-LG1-LG1-BG3	2.0	1.0	2.0
SDSL89426	2.0	1.0	2.5
(EPSON2-40/E#15/SADC*A964)-CG3-BGBK	2.3	1.0	1.0
(6OB124/94CE81-3/GR134B-LG56-*WM#177)-CG3-BG1	2.3	1.0	1.0
(Tx2883*(Tx2880*(GR108-90M24*(Tx2862*(Tx430*(Tx2862*PI550607))))))-PR2-CCBK	2.3	2.3	3.5
(Macia*TAM428)-CG2-BGBK	2.3	1.3	3.0
(Segaolane*FGYQ336)-CG5-BGBK	2.3	1.0	2.5
((6BRON126/(87BH8606-14*GR107-90M46))*CE151)-LG2-CG1-BG2	2.3	1.3	2.5
(6OB128/(Tx2862*6EO361)*CE151)-LG3-LG1-BGBK	2.3	1.0	2.0
PRGC/E#222879	2.3	1.0	2.5
((6BRON126/(87BH8606-14*GR107-90M46))*CE151)-LG1-LG1-BG2	2.3	1.3	1.0
(6BRON161/(7EO366*Tx2783)*CE151)-LG4-CG2-BG2	2.3	1.7	1.5
(6BRON126/(87BH8606-14*GR107-90M46)*EPSON2-40/E#15/SADC)-LG1-LG1-BGBK	2.3	1.7	1.5
Mean	2.6	1.5	
LSD .05	1.0	1.1	

[1] Rated on scale of 1 = no damage, 2 = light damage, 3 = medium damage, 4 = heavy damage, 5 = dead plant.
[2] Rated on scale of 0 = no weathering up to 5 = severe weathering.

Bekaye Coulibaly (Mali) is conducting this Ph.D. research to compare the efficiency of marker-assisted selection versus traditional selection methodology. Mr. Coulibaly is completing the dissertation and should return to Mali by October 1, 2002.

Networking Activities

Workshops and Meetings

INTSORMIL Central America Region Research Planning Workshop - 27 to 28 February 2002, Managua, Nicaragua

Participated in the 2002 Sorghum Industry Conference, 17-19 February 2002, San Francisco, CA

Research Investigator Exchanges

Coordinated training program of Ing. Rene Clara (El Salvador), Ing. Hector Deras (El Salvador), and Ing. Rafael Obando (Nicaragua), July-August, 2001.

Interacted with private seed company scientists and Texas Grain Sorghum Association representatives on several occasions as part of the Texas Agricultural Experiment Station (TAES) Sorghum Advisory Committee.

Interacted with sorghum farmers and Texas Grain Sorghum Association representatives on several occasions as TAES PROFIT (Productive Rotations On Farms In Texas) coordinator.

Participated in Sorghum Germplasm Committee meeting, 18 February 2002, San Francisco, CA. Interacted with private scientists and USDA scientists and administrators on issues related to germplasm.

Botswana, Zambia, and South Africa - 31 March to 14 April 2001. In Botswana met with Department of Agricultural Research scientists to plan future research activity. Met with Botswana College of Agriculture administrators and scientists to discuss initiating additional collaborative research in plant breeding and entomology, and potential in other disciplines. In Zambia met with Ministry of Agriculture, Department of Agricultural Research scientists to discuss sorghum and pearl millet research. Evaluated sorghum research plots at Golden Valley and Siavonga region. Discussed INTSORMIL Southern Africa activity with USAID/Zambia representatives. In South Africa, met with collaborators at the ARC, Potchefstroom, to evaluate collaborative activity and plan future research. Evaluated sorghum research plots at the Cedera Research Station near Hilton, the ARC at Potchefstroom, and the Lowveld Station near Hazyview. Also met with Dr. John Taylor at the University of Pretoria to discuss sorghum and pearl millet grain quality research.

Arranged the travel of Mr. Leo Mpofu to Zambia to interact with regional scientists and the visiting INTSORMIL team, 4-12 April 2002.

Participated in the Crop Germplasm Committee Chairs meeting, 4-5 June 2002, Beltsville, MD. Discussed germplasm issues with crop curators, Regional Station Directors, NSSL personnel, and USDA-ARS administrators.

Germplasm and research information exchange

Germplasm Conservation and 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, Zimbabwe, and Zambia. Entries in the All Disease and Insect Nursery (ADIN) were evaluated at many locations domestically and internationally.

The following TAM-223 developed experimental lines were used as hybrid seed parents in the summer of 2001: sorghum midge resistant: Tx2880 and A8PR1013; biotype E greenbug resistant: 5BRON139, A8PR1059, biotype E/I greenbug resistant: LG35. Seed was provided to a private seed company to produce hybrids for wide area testing in 2002 as part of the PROFIT (Productive Rotations On Farms In Texas) initiative.

Germplasm previously developed and released by this project is used by commercial seed companies in hybrid production.

Participated in short- or long-term training of collaborators from Mali, Nicaragua and El Salvador. Serving on M.S. committee of N. Teme (Mali), and co-chair of S.B. Coulibaly (Mali). Coordinated training program of Ing. Rene Clara (El Salvador), Ing. Hector Deras (El Salvador), and Ing. Rafael Obando (Nicaragua), July-August, 2001.

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

Dr. R. D. Waniska, Cereal Chemistry, Department 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. R.G. Henzell, Sorghum Breeding, Hermitage Research Station, via Warwick, QLD 4370, Australia

Publications and Presentations

Abstracts

Rosenow, D.T., N. Teme, C.A. Woodfin, G.N. Odvody, and G.C. Peterson. 2000. Relationship of stay-green with charcoal rot and lodging in sorghum. *In* Proc. of Global 2000: Sorghum and Pearl Millet Diseases III. Guanajuato, Mexico, Sep. 23-30, 2000. (In Press).

Presentations

Peterson, G.C., B.B. Pendleton, and G.L. Teetes. 2000. PROFIT - Productive Rotations On Farms In Texas: A New Paradigm for Sorghum Research and Information Delivery. *In* Proc. of Global 2000: Sorghum and Pearl Millet Diseases III. Guanajuato, Mexico, Sep. 23-30, 2000. (In Press).

Refereed Journal

Katsar, C.S., A.H. Paterson, G.L. Teetes, and G.C. Peterson. 2002. Molecular analysis of sorghum resistance to the greenbug significantly involved in conceptualizing and implementing the extension process, and participated in the grant presentation that resulted in a five-year extension of INTSORMIL.