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

Darrell T. Rosenow
Texas A&M University

Regional Coordinators

Dr. Aboubacar Touré, Sorghum Breeder, Regional Coordinator, IER, Sotuba Research Station, B.P. 262, Bamako, Mali
Dr. Darrell T. Rosenow, Sorghum Breeder, U.S. Regional Coordinator, Texas A&M University, Texas Ag Experiment Station, Route 3, Box 219, Lubbock, TX
Dr. Ndiaga Cissé, Sorghum Breeder, Co-Country Coordinator, ISRA/CNRA, Bambey, Senegal
Dr. Demba Farba M'Baye, Pathologist, Co-Country Coordinator, ISRA/CRZ, Kolda, Senegal
Dr. Samuel Saaka Buah, Agronomy, Co-Country Coordinator, SARI, Wa Station, Ghana
Dr. Ibrahim D.K. Atokple, Sorghum Breeder, Co-Country Coordinator, SARI, Tamale, Ghana

Collaborating Scientists

Dr. Minamba Bagayoko, Agronomist, IER, Niono Center, Segou
Ms. Fatim Cisse, Cereal Scientist, IER, Sotuba Station, Bamako, Mali
Dr. Niamoye Yaro Diarisso, Entomologist, IER, Sotuba Station, Bamako, Mali
Dr. Mamadou Doumbia, Soil Scientist, IER, Sotuba Station, Bamako, Mali
Dr. Yocouba Doumbia, Entomologist, IER., Sotuba Station, Bamako, Mali
Dr. Mamourou Diourté, Pathologist, IER, Sotuba Station, Bamako, Mali
Dr. Mountaga Kayentao, *Striga* (Weed Science), Sotuba Station, Bamako, Mali
Mr. Mamadou N'Diaye, Entomologist, IER, Cinzana Station, Segou, Mali
Mr. Moussa Sanogo, Millet Breeder, IER, Cinzana Station, Segou, Mali
Mr. Abdoul Wahab Touré, Agronomist, IER, Sotuba Station, Bamako, Mali
Dr. Samba Traoré, Agronomist, IER, Cinzana Station, Segou, Mali
Mr. Amadou Fofana, Millet Breeder, ISRA/CRZ, Kolda, Senegal
Mr. Mamadou Balde, Entomologist, ISRA/CNRA, Bambey, Senegal
Mr. Djibril Badiane, Entomologist, ISRA/CRZ, Kolda, Senegal
Mr. Moctar Wade, Weed Scientist (Striga), ISRA/CNRA, Bambey, Senegal
Dr. Steven K. Nutsugah, Pathologist, SARI, Tamale, Ghana
Dr. Paul B. Tanzubil, Entomologist, SARI, Manga Station, Ghana
Mr. Luke N. Abatania, Economist, SARI, Wa Station, Ghana
Mr. David A. Afribeh, Millet Breeder, SARI, Manga Station, Ghana
Dr. Gebisa Ejeta, Sorghum Breeder/Striga, Purdue University, West Lafayette, IN 47907
Dr. John Leslie, Pathologist, Kansas State University, Manhattan, KS 66506
Dr. Clint Magill, Pathologist/Molecular Genetics, Texas A&M University, College Station 77843
Dr. Stephen Mason, Agronomist, University of Nebraska, Lincoln, NE 68583-0915
Dr. Bonnie Pendleton, Entomologist, West Texas A&M University, Canyon, TX 79016
Dr. Gary Peterson, Sorghum Breeder, Texas A&M University, Lubbock, TX 79403
Dr. Lloyd Rooney, Cereal Scientist, Texas A&M University, College Station, TX 77843
Dr. John Sanders, Economist, Purdue University, West Lafayettte, IN 47907
Dr. Jeffrey Wilson, Millet Breeder, Pathologist, USDA-ARS, University of Georgia, Tifton, GA

Collaborative Program

The initial INTSORMIL collaborative program in this area was established in Mali which has a large multidisciplinary research program. The program centers around Malian scientists and each Malian scientist develops research plans cooperatively with a U.S. counterpart which provides for effective research planning, communication, and coordination. Each year INTSORMIL collaborators travel to Mali as appropriate to observe field trials, consult, review progress and plan future activities with Malian scientists. Occasionally, IER scientists also travel to the US for research review, planning, and coordination. The planned project activities then become part of the annual Amendment to the MOA between INTSORMIL and IER.

The program includes all aspects of sorghum/millet improvement with major emphasis on breeding or germplasm enhancement, utilization and quality, nutrient use efficiency, soil management, insect pests, disease control strategies, and *Striga* control.

A new thrust to the program previously centered in Mali began in 2000-2001 with the initiation of collaborative INTSORMIL research in Ghana and Senegal. A MOU between INTSORMIL and ISRA (Institute of Agricultural Research) in Senegal was signed in early 2001. An existing MOU with SARI (Savanna Agricultural Research Institute) in Ghana which involved agronomic research between Dr. S.S. Buah and Dr. J.W. Maranville was utilized to include the new collaborative efforts in Ghana. In 2002 a new MOU was signed between INTSORMIL and ITA (Institut de Technologic Alimentaire) in Dakar, Senegal which deals with commercialization of grain in Senegal.

Collaborative research was initiated in the 2001 crop season in both countries in breeding, pathology, entomology, and *Striga*, and also in agronomy in Ghana, continuing some of the research initiated in collaboration with Dr. Maranville. Breeding, disease, insect, drought, and *Striga* trials were developed collaboratively with Malian and U.S. INTSORMIL scientists and grown in Ghana and Senegal as well as in Mali. Some of these were also offered to scientists in Niger, Burkina Faso, and Nigeria, and scientists there requested seed of specific nurseries according to their interests and needs. Also, an elite sorghum germplasm nursery from worldwide sources was sent to Ghana and Senegal to broaden the genetic base of their breeding program. The mechanism for developing collaborative research plans is evolving as new INTSORMIL PIs initiate their programs, and PIs are able to interact and/or travel to these new countries. The PI Conference in Ethiopia in November, 2002 served as the initial broad based planning conference for collaborative research efforts among Mali, Ghana, and Senegal as well as with the Eastern Region (Niger, Nigeria, and Burkina Faso) scientists.

Other Collaboration

Collaboration involving germplasm exchange, workshops, monitoring tours, and specific research projects continued with the regional networks ROCARS (WACSRN), and ROCAFREMI as well as with ICRISAT at Samanko outside Bamako, Mali. Unfortunately, ROCARFEMI ceased operation prior to the 2002 crop season, and ROCARS funding for the 2002 crop season was ended, effectively ceasing operation. There also was cooperation with NGOs such as World Vision, Winrock, AMEDD, FDS, and GRADECOM in evaluation of potential new cultivars as well as with the Soil Management CRSP and the SYNGENTA Foundation.

Financial Input

The USAID Mission has in the past provided significant financial support to IER research program through the SPARC Project which ended in June 1997. In addition to the Malian Government, the Syngenta Foundation and World Bank support the IER research program.

Sorghum/Millet Constraints Researched

Plant Production Constraints

Grain yield level and stability in sorghum and millet production is of major importance in all the countries. Drought is a serious constraint to production over much of the area. Diseases, insect infestations and *Striga* significantly affect both sorghum and millet production. Head bugs and associated grain molds adversely affect sorghum yield and grain quality of sorghum. Anthracnose is a very severe sorghum disease in the more humid areas and long smut is severe in the drier regions. Sooty stripe can be a severe leaf disease problem. *Striga* is a major constraint for both sorghum and millet. Downey mildew is a serious problem on pearl millet.

Land Production Constraints

Low soil fertility combined with the low yield and unstable yields of local cultivars affect sorghum and millet production. Major soil related constraints to production are phosphorus and nitrogen deficiency, and water stress.

Technological and Socioeconomic Constraints

There is a lack of farm credit policy which would encourage adoption of improved sorghum and millet new cultivars. In addition, the prices of these two cereals are low and unstable. New shelf-stable foods, industrial sorghum and millet based products, and enhanced use for animal feed are needed to encourage production.

Research Methods

The collaborative program in the Western Region of West Africa emphasis research in breeding (germplasm enhancement), entomology, pathology, agronomy (soil, water, fertility relationships), weed science (*Striga*), cereal technology (quality and utilization), marketing, and technology transfer. An effort to develop new food products from sorghum and millet is emphasized in Mali along with new cultivars with improved food quality traits. Major breeding activities involve the use of new genetic materials to develop cultivars to increase or stabilize yields of grain with enhanced food quality traits. Research methods appropriate for each of these are used in this research program.

Research Results

Details of some of the research in the area are presented in individual PI project reports in this publication. This Regional Annual Report will emphasize research done by IER in Mali, SARI in Ghana, and ISRA in Senegal.

Sorghum Breeding

The sorghum breeding program in IER in Mali is a large and diverse program. The program utilizes extensive crossing and intercrossing among elite introductions, improved non-guinea and guinea derived breeding lines, and elite local cultivars. It utilizes genetically diverse germplasm from around the world resulting in much genetic diversity in the breeding program. Extensive use is made of previously developed ICRISAT lines and elite lines from the U.S. Emphasis in the program centers on developing tan-plant true guinea cultivars, and on improving the head bug/grain mold resistance of high yielding tan-plant non-guinea breeding lines and guinea by non-guinea intergrades. Essentially 100% of the breeding effort is directed toward white-seeded, tan-plant genotypes. Breeding for the dry northern areas also involves crosses with local Durras and good yielding Bicolor derivatives from the area and early Caudatum derivatives from Senegal.

A standard system of moving progenies along at the different locations is in place and understood by the technicians. After the F_2 progenies are separated into early, medium, and late maturing groups and then selected and advanced at appropriate sites. Early materials are selected at the lower rainfall, more northern sites of Bema and Cinzana, while medium maturity materials are grown at Sotuba, Kolombada, and Cinzana. Late maturing progenies are evaluated mainly in the more southern, high rainfall sites of Farako (Sikasso), Finkolo, and Kita. Yield trials of advanced breeding lines also are divided into these three general maturity groups and corresponding sites.

New breeding crosses are made annually to assure the gradual improvement of new breeding materials through recombination of the best materials. In the 2002 rainy season, 60 new crosses were made at Sotuba, and the F_1's grown during the 2002-03 off-season nursery to get F_2 seeds.

From the multilocation evaluation of 108 F_2 families in the 2002 rainy season, 491 single-plant selections were made at Samanko, 254 at Cinzana and 112 at Finkolo. These selections will be advanced by the pedigree method. We evaluated 778 F_3 progenies mostly derived from tan guinea cultivars. The F3 families were grown at Samanko, Cinzana, Finkolo and Bema and we selected, 203 single heads at Sotuba, 89 at Cinzana and 85 at Béma. The F_4 and F_5 generations were evaluated according to the maturity group. The early and medium F_4 progenies were evaluated at Kolombada, Béma and Cinzana. We selected 139 panicles at Béma, 64 panicles at Kolombada and 147 panicles at Cinzana. The late F_4 progenies were evaluated at Finkolo and Kita with 18 and 65 panicles selected, respectively, at Kita and Finkolo. In the early F_5's we selected 15 lines at Béma and 18 at Cinzana. The medium F_5 progenies were evaluated and we selected 43 lines (28 at Sotuba and 15 at Kolombada). A total of 19 lines were selected for F_5 progenies at Finkolo and Kita. The F_5 selections move to the off-season for seed increase for entry into Group I yield trials the following year.

Yield trials of improved varieties in 2002 were divided into three maturity groups, Early, Medium, and Late with three groups (GI, GII, GIII) within each maturity corresponding to the years in tests (I - first year, II - second year, III - third year). Evaluation was for maturity, yield, agronomic desirability, and food quality.

Advanced Early Variety Trials

We evaluated our three advanced elite early variety group trials (GI, GII and GIII) at two locations, Bema and Cinzana. In GI (first year evaluation) with 46 entries at Cinzana and at Bema there were significant differences among entries for grain yield, plant height and flowering date. At Bema the highest yielding varieties were 01-CZ-F5P-244 and 01-BE-F5P-288 with 2000 kg ha^{-1} while the yield of local check was 1555 kg ha^{-1}. At Cinzana the variety 01-CZ-F5P-244 and the local had the same yield. In GII (two year evaluation) at Cinzana and Bema with 26 entries there were no significant differences among lines for the three variables studied.

After three years of evaluation, of 18 entries at two locations (GIII), four lines 99-BE-F5P-66 (2246 kg ha^{-1}), 99-BE-F5P-67 with 2046 kg ha^{-1}, 99-BE-F5P-69 (2002 kg ha^{-1}) and 99-BE-F5P-95 (2006 kg ha^{-1}) were retained for grain yield and grain quality and will be in on-farm tests in 2003 (Table 1). The line, 99-BE-F5P-128-1, performed well and was selected by 31 out of 34 farmers. It also appeared to have some tolerance to *Striga* as well as excellent resistance to the head bug (*Eurystylus*).

Advanced Medium Variety Trials

In GI at Sotuba, the variety 01-SB-F5-DT-198 ranked first with 4028 kg/ha followed by 01-SB-F5-DT-221 (3694 kg/ha); 01-SB-F5-DT-23-1 (3528 kg ha^{-1}); 01-SB-F5-DT-203 (3333 kg ha^{-1}); 01-SB-F5-DT-243 (3278 kg ha^{-1}) with a grain yield of 3000 kg ha^{-1} for the local check. At Kolombada the average yield (869 kg ha^{-1}) was lower than at Sotuba with the highest yielding variety, 01-SB-F5-DT-22,1 producing 1972 kg ha^{-1} compared to 987 kg ha^{-1} for the local check.

In GII at Sotuba, among the 26 varieties tested, the highest yielding variety 00-SB-F5-DT-18 gave 4228 kg ha^{-1} against 3583 kg ha^{-1} for the local, with a test mean yield of 2687 kg ha^{-1}. At Kolombada, there was no significant difference among entries for grain yield.

Table 1. Mean performance data on selected improved breeding varieties from sorghum yield trials, Mali, 2000-2002.

Designation	Pedigree	Days to 50% flowering	Plant height (m)	Grain yield (kg/ha^{-1})
Early GIII - (3 years - 2 locations)				
99-BE-F5P-66*	(89-SK-F4-53-2*Naga White)	73	1.7	2246
99-BE-F5P-128-1	(N'Tenimissa*Seguetana-CZ)	75	3	2102
99-BE-F5P-67*	(ICSV1078*89-CZ-CS-F5-21AF)	75	1.8	2046
99-BE-F5P-95*	(E36-1*(N'Tenimissa)	77	1.9	2006
99-BE-F5P-69*	(ISCV1078*89-CZ-CS-F5-21AF)	69	2.3	2002
CSM-63E (check)	Improved Local	66	2.9	2112
Local (check)		71	3.2	1965
(Test Mean)		72	2.5	1905
Medium GIII - (3 years - 2 locations)				
99-SB-F5DT-170-2*	(N'Tenimissa*CSM388)	82	3	2293
99-SB-F5DT-170-1*	(N'Tenimissa*CSM388)	82	2.8	2263
99-SB-F5DT-198*	(N'Tenimissa*Seguentana CZ)	86	3.5	2243
CSM 388 (check)	Improved Local	90	3.6	1683
Local (check)		91	3.4	2315
(Test Mean)		86	3.2	1999

*Entries to be advanced to on-farm trials in 2003.

After three years of evaluation (GIII) at two locations, three varieties, 99-SB-F5DT-170-1, 99-SB-F5DT-170-2, and 99-SB-F5DT-198 were selected for on-farm testing (Table 1). These lines also gave the highest decortication yield, the hardest grain, and the best tô stability.

Advanced Late Variety Trials

In GI with 40 entries at Finkolo and at Kita there were no significant difference among entries for grain yield. The average yield at Finkolo was 2187 kg ha^{-1}.

On-Farm Trials

Six farmers were selected in each of two locations, Cinzana and Sirakorola, where fifteen early maturing new varieties were compared to the local check of the farmer. Each plot consisted of 500 m^2; rows were 0.75 m apart and 5 m long. Varieties were evaluated for maturity, yield, agronomic desirability, and food quality. The analysis showed significant differences among entries for grain yield. Two lines 98-CZ-F5P-84 and 98-CZ-F5P-31-1 showed higher grain yield than the local. while the line 98-CZ-F5P-74-1 had the same grain yield as the local check.

For medium maturity varieties, 6 farmers at Ouéléssébougou and Bancoumana evaluated 9 varieties compared to the local check. The analysis showed significant difference among entries for grain yield at Ouéléssébougou. The variety 98-SB-F5DT-82 and the local check ranked first with more than1400 kg ha^{-1} followed by 98-SB-F5DT-52 (1220 kg ha^{-1}) and 98-SB-F5DT-19-3 (1130 kg ha^{-1}). 98-SB-F5DT-52 was appreciated by farmers for its forage and grain qualities.

In another on-farm test of medium maturity varieties, 6 farmers at Ouéléssébougou and Bancoumana compared to the local check for two years. The results showed the 97-SB-F5DT-150 as the highest yielding variety with more than 1400 kg ha^{-1} against 1100 kg ha^{-1} for the local. In Table 2, the farmer's desirability ratings are presented.

For the late maturity on-farm trial, 6 farmers were selected at Kita and Finkolo to evaluate 4 varieties. The analysis showed significant difference among entries for grain yield at Ouéléssébougou. The analysis showed significant difference among entries for grain yield at Kita. Two (97-KI-F5-22 and 96-CZ-F4P-99) and the local check ranked first with more than1700 kg ha^{-1}.

Seed Multiplication

Listed below are some improved cultivars and new breeding lines for which seed was increased by the Mali IER sorghum breeding program in 2002.

Varieties	Localities	Area (ha)	Quantity (kg)
CSM-63 E	Béma	1/2	500
MALISOR-92-1	Béma	1/2	200
CSM-388	Kolombada	¼	100
N'TENIMISSA	Kolombada	¼	100
97-SB-F5DT-64	Kolombada	¼	100
CSM-388	Tamala and	½	400
Seguetana	Ouélessebougou	½	400
Wassa	Tamala and Ouélessebougou Kafara	¼	200
96-CZ-F4P-98	Kita	¼	200
96-CZ-F4P-99	Kita	¼	200
96-CZ-F4P-98	Kebila	¼	62
96-CZ-F4P-99	Kebila	¼	22
Sakoïka I	Kebila	¼	210

Table 2. Farmer's appreciation of medium maturity on-farm varieties[1/].

Variety	Plant vigor	Maturity	Yield appreciation	Grain quality	Tô quality	Couscous quality	Porridge quality
97-SB-F5DT-74-1	3	2	3	3	2	2	2
97-SB-F5DT-150	1	2	1	1	1	1	1
Tiemaring (check)	3	3	3	3	3	3	3

[1/] 1: excellent, 2: very good, 3: good, 4: average, 5: poor

Senegal

A backcross program to introduce earlier maturity into the varieties CE151-262, CE196-7-2-1, CE 145-66, and CE180-33 for use in the drought prone northern zone. Three sources of earliness in introductions from Russia were used. The four local varieties were also used in crosses with lines from the 2001 observation nurseries. Some of the lines selected from the germplasm nursery are: Ajabsido, MP531, Malisor 84-7, M92-1, S34, ICSV400, ICSV401, Sureno, Dorado, VG153, and ICSV1089BF. From a guinea derivative population selected by ICRISAT for short stature, 95 families at S1, S2, S3, and S5 were grown for observation at Bambey. From INTSORMIL collaborative drought nursery of 35 entries, severe stress was favorable for drought reaction and 14 lines were selected for future evaluation and use. Yield trials in 2002 at Bambey and Sinthiou were all lost due to severe moisture stress and poor stands. The trails at Bambey were with 25 lines selected from the 2001 INTSORMIL collaborative observation nurseries. At Sinthiou in the east, 13 Malian breeding lines were included in the trial.

Ghana

A nation-wide sorghum germplasm collection was embarked upon (October-December, 2002) as a result of duplications and lack of passport data for the sorghum accessions collection by ICRISAT in 1997. So far 187 accessions have been collected from the 4 districts of each of the Upper West, Upper East, and Northern regions. All accessions will undergo agro-morphological evaluation during the 2003 season, to be complemented by molecular markers to help assess the true genetic diversity present as well as determination of their nutritional and functional properties.

Some of the best Striga resistant lines from the 2001 INTSORMIL/West African Striga Trial are being utilized in the breeding program. The drought tolerance trials suffered from shoot fly attack at the seedling stage followed by midge at flowering making drought evaluations impossible.

Hybrid Sorghum - Mali

The coperative IER/ICRISAT hybrid research funded by the Rockefeller Foundation continued with the evaluation of breeding lines and local cultivars for restorer (B/R) reaction, the presence of the B1 gene, and sterilization of B-lines through backcrossing. Several new Malian guinea and guinea/caudatum intergrades were evaluated for their fertility reaction, B gene status, and heterosis potential in Mali, 2002, and Puerto Rico (winter '02-'03). Also evaluated were 35 selected Malian indigenous cultivars representing the diversity in the Mali Sorghum Collection and 30 selected mostly Guinea/Caudatum exotics from Southern Sudan for their potential use in hybrid breeding in the Guinea type sorghum zone of West Africa. See Table 4 in the Annual Report of TAM 222 in this publication for detailed data. Most Malian cultivars were restorers except for a few Guinea types, especially Margaritaferum types. Essentially all the Guinea-Caudatum derivative cultivars from Southern Sudan were strong restorers and were dominant B1 and B2. The dominant B1 gene was absent in most Durra and Durra-Bicolor Malian lines, and some of these lines showed promising heterosis. There appeared to be rather good differences in hybrid vigor among lines, especially as expressed in Mali.

Several elite Mali breeding lines introduced into the U.S. showed good B-line reaction, and were backcrossed for sterilization in Puerto Rico. They are agronomically good, white-seeded, tan-plant cultivars with recessive b1. Their designation and pedigrees are: 99CZ-F5-131 (N'Tenimissa*Segnetana CZ); 99EADT#36/98SB-F5DT-17((M84-7*Tiemarfing)*Tiemarfing); 99 EADT#52/98SB-F5DT-52 (N'Tenimissa*CSM388); and 99SB-F5DT-169 (N'Tenimissa*CSM388).

Millet Breeding

Mali

At Cinzana, seed multiplication of the variety Ankountess*SoSat was carried out. This variety was selected from the 2001 African land race hybrid trial distributed from the ARS millet breeding program at Tifton, GA. The variety showed tolerance to downy mildew, high yield potential, and slight earliness compared to the local check. The variety has been evaluated by farmers at 27 locations in the Segou, San, Tominian, and Koro areas. Other activities included the production of the BC3 of CivarexA49105 and TrombedieR4, and the off season hybrid production of CivarexA49105* TrombedieR4.

At N'Tarla, the first cycle of recombination of the Indiana 05 improved population was done. Harvested plants were selected for downy mildew tolerance, panicle compactness, grain hardness, number of fertile tillers, and similar maturity to the local day length sensitive variety. Also, seed multiplication of the varieties Sanioba and Sanioteli was carried out under isolation, producing 150 kg and 140 kg, respectively.

Senegal

In the Advanced Yield Trial at Bambey, 8 synthetics and 2 checks were evaluted, but very low and erratic rainfall

Table 3. Performances of the inter-population millet hybrids trial at Bambey, Senegal, 2002.

Entrees	Cycle	Days to flowering	Mildew incidence %	Plant height (cm)	Panicle length (cm)	Number panicles/ plant	1000 grain weight (g)	Grain yield (kg/ha-1)
WA 12 Ex-Bornu x Uganda	1	50 cd	1.6	199 abc	24.8 c	120 ab	8.9	1836
WA 21 Ex-Bornu x SoSat C88	1	52 abc	1.6	193 abc	27.7 bc	92 bc	9.2	1915
WA 22 Mansori x SoSat C88	1	52 abc	2.4	208 ab	30.1 bc	80 c	9.7	1412
WA 23 SoSat C88 x Ankoutess	1	53 ab	0.8	191 bc	25 c	81 c	9.3	1719
WA 25 SoSat C88 x GR-P1	1	53 ab	0.8	210 ab	35 b	72 c	8.9	1559
WA 26 Ugandi x SoSat C88	1	48 d	0.8	210 ab	28.4 bc	92 bc	6.9	1759
WA 27 Ex- Bornu x Ugandi	2	49 d	0	182 c	25.1 c	130 a	10.2	1620
WA 28 Ex-Bornu x Mansori	2	50 cd	0.8	180 c	27.3 bc	103 abc	8.5	1182
WA 29 Ex Bornu x Ugandi	3	49 d	0.8	183 c	26.9 bc	117 ab	9.2	1475
WA 30 Ex -Bornu x Mansori	3	51 bcd	0.8	186 c	26.9 bc	114 ab	8.5	1305
WA 31 Ex-Bornu x Ugandi	OP	48 d	0.8	192 abc	27.3 bc	120 ab	9.7	1694
WA 32 Ex-Bornu x Mansori	OP	50 cd	1.6	191 bc	26.8 bc	112 ab	9.5	1596
WA 33 SoSat C88 x Gwagwa	1	53 a	2.3	213 a	30.8 bc	80 c	9.7	1958
Souna 3 (check)	-	52 abc	7.1	200 abc	45.4 a	71 c	6.5	1573
Means	-	51	1.6	195	29.1	99	8.9	1615
Significance	-	HS	-	S	HS	HS	NS	NS
S.E	-	0.66	-	7.98	1.84	7.46	0.77	180
C.V(%)	-	2.6	-	8.2	12.7	15.1	17.2	22.3

Table 4. Performance of selected sorghum varieties in *Striga* infested field at SARI, Ghana, in 2001 and 2002 cropping seasons.

Variety	Days to flower	Height (cm)	*Striga* count 28days		*Striga* count 42 days		*Striga* count at harvest		Panicle weight (kg/ha-1)		Grain weight (kg/ha-1)	
			2001	2002	2001	2002	2001	2002	2001	2002	2001	2002
CMDT-38	86	171	0.00	-	1	8	8	46	1534	1531	568	1014
CMDT-39	88	203	1.00	-	2	11	9	179	1187	1823	578	1138
SEGUETANA	84	192	0.00	-	3	25	9	54	1084	1093	472	444
CMDT-45	85	207	2.00	-	7	57	32	163	1455	1911	711	1156
97-SB-F5DT-63	87	187	0.00	-	5	1	28	7	1768	816	895	429
97-SB-F5DT-64	86	209	0.00	-	1	1	6	40	3284	1484	2232	1013
N'TENIMISSA	87	223	2.00	-	12	20	48	86	1494	1272	474	714
97-SB-F5DT-65	83	193	0.00	-	0	27	3	60	1673	1413	690	653
MALISOR-92-1	76	159	0.00	-	4	32	13	42	1214	922	1011	642
MALISOR-84-1	76	165	0.00	-	0	34	2	66	1333	1461	627	1016
CE-151-202-A1	87	142	0.00	-	0	35	0	58	-*	460	-*	253
SRN 39	78	146	0.00	-	1	4	3	30	1218	1320	362	569
SAMSORG 41	77	149	0.00	-	1	15	18	47	-*	1069	-*	704
SAMSORG 14	89	167	1.00	-	10	8	45	225	2120	1613	733	742
KP33-2	89	102	0.00	-	7	-	14	-	-*	-	-*	-
IS 7777	89	177	1.00	-	7	-	39	-	1459	-	341	-
Grand Mean	84	175	0.31	-	3.48	20	17.0	79	1602	1206	707	692
CV(%)	2.0	2.0	21.0	-	51.8	60.7	26.4	107	73.2	47.1	56.5	52.1
LSD(0.05)	3	6	1.10	-	3.00	43	7.491	141	664	955	673.8	605

* These did not produce any harvestable heads and were not included in the analysis of those parameters.

resulted in poor stands. Grain yield varied between 178 and 1631 kg ha^{-1}, the best performers being ISMI9404, ISMI9501, and ISMI9506, with 1631, 1600, and 1409 kg ha^{-1} respectively compared to the check, IBMV 8402 with 1080 kg ha^{-1}. ISMI9404 had a good overall agronomic rating this season, with moderate panicle length and good exsertion.

In the Inter–Population Hybrid Trial, 14 entries were evaluated (Table 3). Grain yield varied from 1182 to 1958 kg ha^{-1} but were not significantly different.

Two new synthetics, ISMI9301 and ISMI9305, were planted in on-farm sites near Bambey, but were abandoned due to poor plant stand.

At Kolda, seed of the new introduced early variety GB8735 was increased. This variety matures in 65-70 days in the dry northern zone. The seed will be used to disseminate the variety.

Striga

Mali

At Sotuba, 45 early, 37 medium, and 38 late maturing breeding lines selected from the IER breeding program were evaluated for Striga in 2002. Infestation, however, was low with no significant differences among entries in all trials. At Cinzana, unusually high Striga infestations occurred in the Advanced Yield Trials and several new elite breeding lines showed good tolerance compared to the local checks, inlcuding the new IER cultivar, Wassa (97-SB-F5DT-63).

Other *Striga* trials at Cinzana showed excellent infestations and good differential among entries, however, no data is available for this report. Some of the trials were from Purdue University.

Senegal

A screen house test was conducted with lines from the West African regional *Striga* trial distributed in 2001. Pot infestation was made with *Striga* seeds collected from sorghum fields in 2000. The number of *Striga* plants emerged was zero (0) on CMDT-39, Seguetena, 97-SB-F5DT-63 (Wassa), 97-SB-F5DT-65, Malisor 92-1, CE-151-262, SRN-39, Samsorg 41; it was one (1) on CMDT-38, CMDT-45, 97-SB-F5DT-64, Samsorg 14 and KP33-2, two (2) on N'Tenimissa, Malisor 84-1, IS 7777; and 3 on the check F2-20. The low *Striga* plant emergence did not permit conclusive differentiation among test entries but did indicate that differences among entries likely exist. The same lines were included in field tests, but because of poor germination due to drought, the trial was abandoned.

Similarly, 11 advanced millet synthetics were screened against *Striga hermonthica*, in a screen house. The *Striga* seeds were harvested from millet fields near Bambey in 2002. The mean number of emerged *Striga* plants was 1.9 and the most infested were ISMI 8203 with 4 plants emerged followed by Souna 3, ISMI 9404, ISMI 9504 with 3 *Striga* plants emerged. GAM 8203 and ISMI 9301 remained free of the parasite. Screening tests against *Striga* on sorghum and millet need be conducted over several locations and years for an accurate evaluation and for evidence of the possible presence of different races.

Ghana

Remnant seed of the 2001 West African *Striga* trial was planted at the same site in 2002. Table 4 shows data for the two years. The 16 varieties showed varied but high level of *Striga* resistance/tolerance. Generally, the *Striga* infestations were much higher in 2002 than 2001. The late maturity of line, CE-151-202-A1 resulted in severe midge infestations in 2001 and the lowest yield (253 kg ha^{-1}) in 2002 in spite of its high resistance to *Striga* . The line 97-SB-F5DT-64 however, combined high yields (range of 1.0-2.2 t ha^{-1}) with low level *Striga* infestation. Other lines that exhibited consistent high level of *Striga* resistance with appreciable yields over the two years included CMDT-38, 97-SB-F5DT-63 (Wassa), MALISOR 92-1, SRN 39 and SAMSORG 41. SRN 39 was much earlier than the rest of the lines and consequently suffered much bird damage. SAMSORG 14 appeared to be the most susceptible of all the lines evaluated. Considering other traits like grain quality and plant height the farmers had expressed their interest in the cultivars, CMDT-38 and CMDT-39. The sorghum breeding program will also utilize some of these resistance lines as source materials.

Pathology

Mali

For anthracnose, 3 years of screening indicated that six Malian breeding lines screened with inoculation at Sotuba showed good resistance to the disease. These six were: 99-SB-F5DT-51; 99-SB-F5DT-188; 99-SB-F5DT-200; 00-KO-F5DT-80; 98-FA-EART-101; and F2-78. Additionally 3 entries from Texas A&M/INTSORMIL ADIN (All Disease and Insect Nursery) and from the Texas A&M/INTSORMIL GWT (Grain Weathering Test) also were very resistant to anthracnose. These included SC326-6, 92BD1982-4, and BTx378 from the ADIN and SC279-14E, (Malisor 84-7*VG153)/19178, and (VG153*(TAM428*SBIII)-23)-BE2 from the GWT.

Three years results indicate that covered smut (*Sproisorium sorghi*) incidence can be reduced dramatically by treating sorghum seeds with 20 g of (Diro + Nguo + Néré) powder per kg of seed, with a grain yield increase of 56%. This plant pesticide can be used to replace Apron Stars in the future.

Ghana

To identify sources of stable broad-spectrum resistance to sorghum diseases for use in the breeding program, two trials were evaluated in 2002, the WASDON (West African Sorghum Disease Observation Nursery), put together in Mali by IER, and the Texas A&M/INTSORMIL ADIN. Disease and agronomic data on the WASDON is presented in Table 5.

Four entries (SAMSORG 14, SARIASO-01, OUEDZOURE and FOULATIEBA) were infected by grey leaf spot with mean score of 4.0. Sorghum entry SARIASO-02 and Kadaga were attacked by bacterial leaf stripe (*Burkholderia andropogonis*) a quarantine pathogen with mean scores of 4.0 and 5.0, respectively.

The yield potential of the genotypes screened in the 2002 ADIN was higher and ranged up to 2,013 kg ha^{-1}. The field disease reaction of the genotypes was higher in incidence and

Table 5. Performance data and field reactions[1/] of sorghum genotypes (WASDON) to different diseases at Nyankpala, Ghana, 2002.

Entries	Origin	Days to 50% flowering	Plant height (cm)	Grain yield (kg/ha)	Grey leaf spot	Zonate leaf spot	Bacterial leaf stripe
SAMSORG 14	IAR, Samaru	85	246	307	4.0	2.0	1.0
SAMSORG 40	"	87	191	813	2.0	1.0	1.0
SARIASO-01	INERA, Burkina	83	285	1,433	4.0	2.0	1.0
SARIASO-02	"	83	285	880	3.0	1.0	4.0
OUEDZOURE	"	85	346	1,267	4.0	1.0	1.0
SC326-6	Texas, USA	87	94	107	1.0	1.0	1.0
VG 153	"	85	205	1,200	2.0	1.0	1.0
SURENO	"	91	217	607	1.0	1.0	1.0
9GW092	"	93	159	613	2.0	1.0	3.0
90L19178	"	81	203	1,267	2.0	1.0	1.0
98-FA-EART-101	IER, Mali	90	215	787	1.0	1.0	1.0
98-SB-F5-DT-25	"	84	269	693	1.0	1.0	1.0
98-SB-F5-DT-59	"	77	294	933	1.0	1.0	1.0
98-SB-F5-DT-4	"	88	117	900	2.0	1.0	1.0
98-KO-F5-DT-39-2	"	73	333	987	2.0	1.0	1.0
98-KI-F5-T-45	"	83	280	387	2.0	1.0	1.0
98-F2-82	"	80	148	1,467	2.0	1.0	1.0
97-SB-F5-DT-154	"	89	146	387	1.0	1.0	1.0
97-SB-F5-DT-160	"	100	129	200	1.0	1.0	1.0
F2-78	"	79	141	1,533	1.0	1.0	1.0
97-SB-F5-DT-150	"	89	169	607	2.0	1.0	1.0
97-SB-F5-DT-151	"	93	153	947	1.0	1.0	1.0
FOULATIEBA	"	84	326	1,207	4.0	2.0	1.0
KADAGA	SARI, Ghana	76	211	393	3.0	3.0	5.0
A2267-2	ICRISAT, Mali	91	213	613	2.0	1.0	1.0
Mean[2] (25 entries)		83.8	215.0	821.4	2.0	1.2	1.4

[1/] Based on rating scale 1-9: 1 = no disease; 2 = 1-5%; 3 = 6-10%; 4 = 11-20%; 5 = 21-30%; 6 = 31-40%; 7 = 41-50%; 8 = 51-75% and 9 = > 75% of leaf area of the plant or panicle parts damaged by the disease.

severity. A score of 5.0 was recorded for zonate leaf spot on entry R9188. Grey leaf spot was rather prevalent with eleven entries with high scores of 4.0-7.0. Eight entries did not show any sign of shoot fly infestation, 8BPR1013, 96GCPOB143, 8BPR1019, 87EO109, Tx2917/R9120, Tx436, and BTx 631, while five others had less than 10% incidence, 96CA5986, 00CA4654, B8PR1059, R9603, and R9618. The seven top yielding entries were 98CD187 (2013 kg/ha), 96CA5986 (1653 kg ha^{-1}), SC326-6 (1627 kg ha^{-1}), GR108-90M24 (1427 kg ha^{-1}), 95BRON151 (1400 kg ha^{-1}), Malisor 84-7 (1346 kg ha^{-1}), and 88B943 (1333 kg ha^{-1}). Five entries were selected for further evaluation based on their overall agronomic traits and disease/pest tolerance or resistance (88BE 2668, 96GCPOB 124, 94CW 5045, B9307 and Tx2783).

Entomology

Mali

At the Cinzana Station, the sorghum breeding lines in the Advanced Early Maturity Variety Trials (GI, GII, and GIII) were evaluated for resistance or tolerance to the major insect pests, green aphid, sorghum midge, and head bug (*Eurystylus*). Aphid and midge populations were low, with no significant difference among lines. However, head bug pressure was high with significant differences among entries for head bug damage. Head bug damage ratings were made on 5 panicles per plot at maturity, and damage to the grain scored on a 1-9 scale where 1 + <10% damage to 9 = > 80% damage. There were excellent differences among entries for head bug damage with lines in each test showing excellent resistance with data on those plus other selected entries presented in Table 6.

At Sotuba, three large preliminary head bug screening nurseries (93, 113, and 121 entries) and three advanced screening nurseries were evaluated for head bugs (*Eurystalus*) and grain mold. Dry conditions during and after grain maturity resulted in very little grain mold damage, except to a few entries with severe head bug damage. Natural head bug infestation was high and excellent for screening. At heading, 2 panicles were protected with cages and 2 by selfing bags. At the milk stage, 5 unprotected panicles were sampled to determine head bug infestation level. At harvest, visual ratings were made on head bug and grain mold damage to the grain, and a 200 seed weight taken on threshed grain to determine grain weight loss due to head bug damage. In the first preliminary trial, 5 entries plus

Table 6. Performance of selected entries for head bug damage and other traits from the Advanced Early Maturity Variety Yield Trials (GI, GII, and GIII), Cinzana, Mali, 2002.

Designation	Days to flower	Plant height (m)	Head bug[1/] damage rating	Grain yield (kg ha^{-1})
Early GI				
01-CZ-F5P-5	81	2	1	933
01-CZ-F5P-46	87	2.1	1	997
01-CZ-F5P-50	83	3.7	1	749
01-CZ-F5P-123	77	1.9	1	1168
97-SB-F5DT-63 (Wassa)	79	3.4	1	1225
CSM63E	73	2.8	1	1587
Malisor 92-1	72	1.9	6	1206
Local check	76	3.2	1	1473
Early GII				
00-BE-F5P-1	78	2.8	1	900
00-BE-F5P-93	83	1.9	1	967
Malisor 92-1	71	1.9	7	1086
97-SB-F5DT-63 (Wassa)	79	3.6	2	1105
CDM63E	72	2.5	1	581
Local Check	75	2.6	1	810
Early GIII				
99-BE-F5P-66	73	1.6	6	1590
99-BE-F5P-67	74	1.9	6	1471
99-BE-F5P-69	74	2.1	6	905
99-BE-F5P-95	78	1.7	5	1029
99-BE-F5P-120	78	2.7	1	1186
99-BE-F5P-128-1	74	3	1	1710
99-BE-F5P-131-1	73	2.7	1	1348
99-BE-F5P-131-2	71	2.8	1	1243
99-BE-F5P-131-3	71	2.7	1	1233
Malisor 92-1	71	1.8	6	1324
CSM63E	71	2.3	1	1100
Wassa	79	3.1	1	1433
Local Check	73	2.5	1	1414

[1/] Rating scale: 1 = < 10% damage to 9 = > 80% damage.

the check, Malisor 84-7, showed a high level of head bug and grain mold resistance. Data on the 5 resistant lines and other selected susceptible lines for comparison purposes is presented in Table 7. The selfing bags and cages worked equally well in protecting grain from head bug damage. Grain mold damage was minimal overall, but highest in entries with high head bug damage. Seed weight was severely reduced in head bug susceptible lines, but was similar or reduced only slightly for unprotected and protected on resistant entries. Head bug numbers (adults and larva) varied considerably among entries, and were generally higher on susceptible lines but not always. There was no head bug damage on any protected panicles.

In the second preliminary nursery, 17 entries plus Malisor 84-7 shoed excellent head bug resistance with ratings of 1.5 or less: 00-CZ-F5P-23; 00-CZ-F5P-34; 00-BE-F5P-163; 00-BE-F5P-171; 00-BE-F5P-95; 00-KO-F5DT-108; 00-KO-F5DT-149; 00-KO-F5DT-301; 00-SB-F4DT-435; 00-SB-F5DT-247; 00-SB-F5DT-5; 00-SB-F5DT-366; 00-KI-F5T-89; 00-KI-F5T-20; 00-KI-F5T-47; 00-KI-F5T-32-1; and 00-KI-F5T-543. In the third preliminary nursery, 8 lines showed head bug resistance with ratings of 1.2 or less: 01-CZ-F5P-24; 01-CZ-F5P-76; 01-SB-F5DT-45; 01-SB-F5DT-46; 01-SB-F5DT-231; 01-FI-F5T-35; 01-KI-F5T-38; and 01-KI-F57-80.

Table 7. Head bug and grain mold evaluation of selected entries from the first preliminary Entomology nursery, Sotuba, Mali, 2002.

	Head bugs at flowering		Natural infestation			Protected selfing Bag		Protected cage	
Varieties	Adults / 5 pan	Larva / 5 pan	Head bug[1/] rating	Mold[1/] rating	200 Seed weight (g)	Mold[1/] rating	200 Seed weight (g)	Mold[1/] rating	200 Seed weight (g)
99CZ-F5P-136-2	65	0	1.2	1	4.1	1.2	4.4	1	4.5
99CZ-F5P-131-2	128	149	1.2	1	4.3	1	4.4	1.2	4.6
99CD-F5P-67-2	34	52	1.2	1	3.5	1	5	1	3.6
99SB-F5DT-170-1	15	3	1.2	1.2	4.8	1	5.4	1	5.3
99SB-F5DT-49-2	49	40	1.2	1	4	1.2	4.8	1	4.5
99CZ-F5P-104-2	47	9	7.5	1.2	2.6	1.2	4.6	1	4.3
99-CZ-F5P-123-1	70	348	6.7	2.2	4.8	2	6.4	1.5	6.5
99CZ-F5P-12-2	118	217	8.5	3.2	3.9	1	4.9	1	4.7
99-BE-F5P-22	91	133	6	2	4.7	1.5	7.7	2.3	6.5
99-BE-F5P-122	227	632	6	1.7	4.7	1.7	7.9	1	6
99-SB-F5DT-196	49	318	6	1.5	3.3	1.2	4.1	1	3.9
99-FA-F5DT-60	35	15	9	1	2.7	1	4.9	1	4.6
99-CA-F5P-104-1	77	24	6.2	1	3.5	1	5	1	4.8
Malisor 84-7	86	96	1.2	1	3.4	1	3.8	1	4.6

[1/] Rating scale: 1 = no damage to 9 = 90% damage.

In the three advanced screening nurseries at Sotuba, 9, 18, and 21 breeding lines were evaluated for head bug and grain

Table 8. Head bug resistant breeding lines from the three advanced screening nurseries using natural and artificial infestation, Sotuba, Mali, 2002.

	Natural infestation			Infested			Protected
Varieties	Adults at flower/ 5 pan	Head bug[1/] rating	200 seed weight (g)	Head bug adults	Head bug[1/] rating	200 seed weight (g)	200 seed weight (g)
95-EPRS-G-1032	105	1.5	3.8	83	1	4.6	4.7
95-EPRS-G-1055[2/]	182	6.5	2.2	74	1.5	3.3	3.5
PA-F4[2/]	77	7.2	3.5	701	5.2	4.8	6.3
97-SB-F5DT-65	36	1.1	4.9	85	1.4	5.2	5.6
97-SB-F5DT-72-2	27	1	4.5	90	1.2	4.8	4.9
97-SB-F5DT-82	49	1.7	4.2	93	1.2	4.7	4.7
CZ-F5P-37-3	39	1.1	4.3	113	1	3.9	4.4
97-SB-F5DT-64[2/]	16	5.5	2.6	110	2.8	2.8	3.4
97-SB-F5DT-150[2/]	18	4	3.1	94	1.6	3.8	4.5
Malisor 84-7	24	2.1	3.6	71	1.6	3.9	4.1
97-SB-F5DT-74-1	140	1	3.3	103	1	3.4	3.5
98-BE-F5P-14	16	1.6	4.1	93	1.1	4.4	4.5
98-BE-F5P-10[2/]	31	4.1	2.7	107	1.9	3.2	3.6
KO-F5-39-2[2/]	18	4.4	3.6	94	2.4	4.1	3.9

[1/] Rating scale: 1 = no damage to 9 = 90% damage.
[2/] These entries rated as head bug susceptible based on natural infestation.

mold damage using natural infestation and artificial infestation under cages and compared to protected panicles. Several IER breeding lines showed excellent head bug resistance with ratings of less than 2.0 (Table 8). Natural infestation consistently resulted in more severe head bug damage even though the adult and larva numbers were not consistently higher. Adults were generally higher in infested, but larvae were higher under natural. Resistance expressed through low head bug damage ratings on the grain, plus maintenance of grain weight compared to protected, and slightly less grain mold.

Another entomology trial of midge resistant lines from the USA was planted at Samanko and evaluated for midge, head bug, and grain mold. Three entries, O1LI9315, 00LI1331, and O1BG2330 showed little midge damages or grain mold, but were damaged by the head bug. Only one entry, 00LI1316, showed good tolerance to the midge, head bugs, and grain mold.

A trial to test the efficacy of local plant extracts for head bug control was conducted at Samanko in 2002. Treatments included neem tree leaves juice, *Calotropus precera* leaves juice, and the control with varieties Malisor 92-1, same tolerance, and S34, very susceptible to head bugs. Although the two leaf extract treatments reduced the head bugs somewhat, there was not significant differences among treatments. However, the Calotropus juice seemed to be more effective on head bugs than the neem tree juice.

Senegal

The effect of chemicals and botanicals application on the control of sorghum head bugs was tested in Nioro station in the central zone. A synthetic insecticide (Dimethoate) and Neem (*Azadiractha indica*) extract were applied on the variety CE 145-66. Four species of head bugs were observed; (*Creontiades pallidus, Dysdercus völerii, Diploxis floweri*, and *Nezara virudula*). Significant differences were observed between treatments for insect populations, panicle weight and grain per panicle with Neem being effective, but not quite as effective as Dimethoate (Table 9).

Insecticide control of the insect complex at Sinthiou indicated a yield loss of 35% due to insect pests in this eastern station.

Table 9. The effect of head bug control on sorghum performance, Nioro, Senegal, 2002.

Treatment	Number of head bugs/panicle	Panicle weight (g)	Grain weight/panicle (g)
Unsprayed	13.3 a	35.1 a	23.6 a
Neem	5.3 a	41.7 ab	32.7 b
Dimethoate	4.0 b	57.8 b	42.5 c
CV	42.1%	11.6%	8.2

Table 10. Physical-chemical characteristics of grain from lines in the advanced yield trial of medium maturity group (GIII), 2002.

Varieties	Ash %	Flotation %	1000 grains weight g	Tô[1/] stability rating	Vitrosity[2/] rating	Decortication yield (%)
99-SB-F5DT-49-1	1.19	2.67	18.09	1.50	1.17	75.83
99-SB-F5DT-52	0.96	0.67	19.98	1.00	1.37	76.67
99-SB-F5DT-169	1.14	0.67	17.87	1.00	1.43	79.17
99-SB-F5DT-170-1	1.10	0.80	18.06	1.27	1.47	74.17
99-SB-F5DT-170-2	0.94	0.00	18.89	1.50	1.30	79.17
99-SB-F5DT-189	0.79	1.33	20.72	1.00	1.67	72.50
99-SB-F5DT-190	1.00	0.67	22.71	1.00	1.37	84.17
99-SB-F5DT-196	0.95	5.33	18.34	1.00	2.23	71.67
99-SB-F5DT-198	0.80	0.00	23.63	1.00	1.47	82.50
99-SB-F5DT-206	0.83	2.67	21.51	1.50	1.57	75.00
99-SB-F5DT-209-1	1.03	0.67	20.96	1.00	1.73	74.17
99-SB-F5DT-209-2	0.79	0.67	22.99	1.50	1.70	83.33
99-SB-F5DT-213	0.69	2.67	19.51	1.27	1.43	78.33
99-SB-F5DT-228	0.77	2.00	22.98	1.00	1.60	75.83
99-BE-F5P-53	0.83	3.33	21.45	1.00	1.50	68.33
CSM-388 (check)	1.08	1.33	21.00	1.00	1.63	80.83
97-SB-F5DT-74-2	1.07	0.67	20.63	1.00	1.00	83.33
LOCAL	1.10	5.33	21.55	1.00	1.87	64.17
Mean	0.94	2.15	20.6	1.14	1.53	76.62
Significance	**	**	**	**	**	**
CV%	5.03	80.13	1.29	7.56	6.50	3.43

[1/] Rating 1 = very stable to 5 = unstable.
[2/] Grain hardness rating: 1 = hardest to 3 = soft.

Food Technology

Characterization of Sorghum Breeding Lines

Improved breeding lines were analyzed for food quality traits. Most of the lines were resistant to grain molds and head bug damage. In the medium maturity grain yield trial (third year evaluation GIII) most showed vitreous grain (range between 1 and 2.23). The variety 99-SB-F5DT-196 and the local check showed the flouriest grain. The decortication yield of lines was good with a minimum of 75% and a maximum of 88 % and an average of 85%. All the lines studied showed a good tô consistency and acceptable tô color. The physical-chemical characteristics of lines in the yield trial of medium maturity group GIII are presented in Table 10.

Diversification of Sorghum End-Use Products

New products:

Snacks, biscuits and cakes 100% sorghum
Sorbis fortified with dates
Sorbis fortified with coco
Sorbis fortified with peanut
Sorbis fortified with almonds
Sorbis with butter
Cake fortified with dates
Cake fortified with chocolate
Cake fortified with banana
Cake fortified with butter

Non-alcoholic drinks:

Sorghum syrup
Sorghum Malta
In several villages, many women were trained how to make Sorghum Malta

Agronomy

Acid Soil (Sorghum) - Mali

A screening experiment was designed to identify tolerant or susceptible sorghum genotypes to acid soils. Several sorghum exotic genotypes, emerging or promising breeding lines, local cultivars, and improved varieties were tested for tolerance to acid soil condition in Mali at the Cinzana Station in 2002. Each entry was planted in a single row. Planting was performed on the 11th of July, in rows 75 cm apart and within rows, in hills 50 cm apart with three replications planted. The screening was conducted on plot F9 of the toposequence of the Cinzana station with no fertilizer applied. Concentrations of P, Al, and Mn were determined in the shoots of each genotype for the purpose of understanding mechanisms of tolerance. Selected properties of plot F9 are given below:

Selected properties of a Sandy, mixed, hyperthermic Plinthic Paleustalf profile of the Cinzana station (Plot F9).

Parameter	Top-soil	Sub-soil
Depth (cm)	0-20	20-60
Clay (%)	5.0	9.8
Sand (%)	84.9	78.6
pH (H2O)	5.1	4.9
Organic C (%)	0.21	0.16
ECEC [cmol(+) kg-1]	0.91	0.90
Al (%) ‡	37.0	42.0
Bray-1 P (mg kg-1)	4.2	5.0
FCC soil classification	SLdeh	SLdeh

‡ Al saturation in % of ECEC

The results showed local genotypes selected from acid, sandy soils of Niger (El Mota and Bagoba) brought to physiological maturity at least 72% of germinated planting hills (Table 11). Despite variations in their performance from one year to another, these genotypes (including Babadia Fara) have maintained good performance for the last 10 years (Doumbia et al., 1998). Their mechanism of tolerance seems to be related to accumulating acceptable P concentrations (about 2.0 g P/kg) and normal levels of both Al and M (114 to 187 mg/kg).

Improved and exotic genotypes included in this study have different abilities to withstand acid soil conditions through accumulation of low or high concentrations of one or more of the following elements: Mn, P, Si, and Al. These genotypes brought to grain production 39 to 92% of their planting hills (Table 11). The released genotype, N'Tenimissa, performed about 62% better than the susceptible check, Malisor 84-5 (14% survival). N'Tenimissa and similar genotypes accumulate not only low levels of P (just below the deficient level of < 2 g P/Kg), but also low levels of both Al and Mn (200 to 317 mg/kg) under acid soil conditions (low P, but high Al and Mn concentrations).

Table 11. Selected properties of the sorghum genotypes tested in acid soil area, Cinzana station, Mali, 2002.

Sorghum variety	Germinated hills (%)	Hills at Maturity (%)	P content in leaves (g/kg)	Al content in leaves (mg/kg)	Mn content in leaves (mg/kg)
El Mota	100	97	2.1	114	124
Bagoba	100	72	2.2	135	187
Gadiaba	100	69	1.7	185	176
Kenike	100	64	1.4	211	231
Malisor 84-5	100	14	0.7	718	746
IS 3553	100	92	2.0	119	91
IS 6902	100	39	1.2	360	518
IS 8577	100	39	0.7	293	494
MN 4508	100	51	1.5	625	118
97-BE-F5P-4	100	69	1.9	311	291
97-SB-F5-DT-63 (Wassa)	100	44	1.0	301	301
97-SB-F5-DT-74-2	100	56	1.5	279	200
98-SB-F2-78	100	54	1.9	198	208
98-SB-F2-82	100	46	1.7	212	221
98-BE-F5P-84	100	61	1.8	219	311
N'Tenimissa	100	76	2.0	192	317

Exotic genotypes such as IS 3553, IS 6902, and IS 8577 confirmed their known properties in acid soils (Gourley et al., 1991). They showed some tolerance (39 to 92% survival) through accumulations of low or igh concentrations of P, Al or Mn.

In conclusion, El Mota, Bagoba, and Gadiaba/CZ have shown, over years, strong abilities to withstand acid soil conditions. At least 72% of the planting hills of these genotypes were harvested this year for grain. They accumulate acceptable concentrations of P (about 2 g P/kg), but low contents of both Al and Mn (>.200 mg/kg).

Sorghum genotypes emerging from the Mali breeding programs have shown some tolerance to acid soil conditions. These genotypes brought to grain production 44 to 76% of their planting hills. These genotypes accumulate not only low levels of P (just below the deficient level of < 2 g P/Kg), but also low levels of both Al and Mn (200 to 317 mg/kg) under acid soil conditions.

Table 12. Influence of Micro-dose fertilizer treatments on millet and sorghum growth and yields on heavy soil at Cinzana in 2002.

Treatments	Population at harvest (ha)	Number of panicle (ha)	Panicle weight (kg/ha^{-1})	Grain weight (kg/ha^{-1})	Straw weight (kg/ha^{-1})
Millet					
Control (No fertilizer)	44167	32361	639	389	1632
Microdose (2 g of DAP/poquet)	49306	26528	729	444	1875
Microdose + 20 kg/ha^{-1} P	55139	34028	1153	715	2674
Microdose + 40 kg/ha^{-1} P	45972	25556	660	382	1736
Microdose + 30 kg/ha^{-1} N	57778	20278	604	368	2153
Microdose + 60 kg/ha^{-1} N	51528	25694	681	382	1875
Microdose + 20 kg/ha^{-1} P + 30 kg/ha^{-1} N	59306	37222	1077	597	2917
Microdose + 40 kg/ha^{-1} P + 60 kg/ha^{-1} N	68473	31945	1118	542	3334
P>F	0.29	0.782	0.684	0.852	0.032
sed	9790.2	407.2	407.2	266.1	488.2
CV%	25.7	51.2	69.2	78.8	31.2
Sorghum					
Control (No fertilizer)	38889	26111	647	453	1250
Microdose (2 g of DAP/poquet)	54444	29583	570	344	2014
Microdose + 20 kg/ha^{-1} P	41806	25139	472	240	1493
Microdose + 40 kg/ha^{-1} P	50139	53889	1306	796	2465
Microdose + 30 kg/ha^{-1} N	58195	46111	1118	701	2813
Microdose + 60 kg/ha^{-1} N	52500	30000	715	563	2361
Microdose + 20 kg/ha^{-1} P + 30 kg/ha^{-1} N	73611	60278	1741	1064	2743
Microdose + 40 kg/ha^{-1} P + 60 kg/ha^{-1} N	53611	26111	604	347	2570
P>F	0.138	0.014	0.014	0.035	0.032
sed	11147.9	10791.4	341.9	236.2	488.2
CV%	29.8	41.1	53.9	59.3	31.2

Table 13. Grain yield data of millet in the micro dose tests at Kounè, Kamba and Kolodougoukoro.

		Grain yield (kg ha^{-1})		
Village/Collaborators	Soil type	Micro dose	Control	% yield of control
Kounè				
Abdoulaye Traoré	Sandy	1719	944	182
Balkassoum Diarra	Sandy	1294	925	140
Oumar Diarra	Loam y	1550	1669	93
Moustapha Coulibaly	Sandy	1863	1225	152
Kamba				
Ali Binkè Sacko	Sandy	1250	625	200
Mamoutou Sacko	Sandy	750	375	200
Binkègninè Sacko	Sandy	1875	1625	115
Kobé Kaba	Sandy	2500	1875	133
Moussa Cissé	Sandy	875	625	140
Kolodougoukoro				
Bakaye Coulibaly	Sandy	813	525	155
Ali Coulibaly	Sandy	1225	625	196

Mali - Cinzana

On-Station Trials

Micro-dose fertilizer treatment effects on millet and sorghum growth and yields were investigated at Cinzana research station in 2001 and 2002. The 2001 results indicated that micro dose application may significantly increase crop yield, but soil type and rainfall conditions can severely limit crop response (Table 12). On light soil, micro-dose and recommended fertilizer treatment significantly increased millet plant population and panicle numbers, panicle weight, grain weight and stover weight at harvest. However on heavy soil, no significant differences were observed between treatments for both millet and sorghum. In 2002, millet and sorghum were grown only on the heavier loamy soil at the Cinzana research station. Similar to 2001, rainfall distribution in 2002 at Cinzana research station was erratic.

As in 2001, micro-dose treatment effects on millet growth and yields on heavy soil were not significantly different from the control for all parameters except the total straw weight. Addition of N or P alone did not significantly affect yields. However, combination of N and P fertilizers increased total plant biomass yield.

For sorghum, in contrast to the 2001 results, sorghum growth and yield were significantly affected by fertility treatments. Although differences were not perceptible with panicle and grain yields, total plant biomass was increased by almost 40% with micro dose treatment alone. The results were characterized, however, by large variability with CVs ranging from 30 to 59%.

The present results confirmed those of 2001, where millet responded better to fertility treatments on light soil than on heavy soil. As in 2001, plants on heavy soil suffered from moisture stress, which occurred when millet plants were at flowering stage. This severely affected plants with fertility treatments and decreased their yields compared to those of control plots. Sorghum on heavy soil had better growth compared to millet. Plant height (data not shown) and stover yield tended to increase both with recommended and micro dose fertilizer applications. The results of these experiments indicated that micro dose application may significantly increase crop yield, but soil type and rainfall conditions can severely limit crop response.

On-Farm Trials

On-farm experiments with millet were conducted in three villages around Ségou. The objective was to determine the performance of micro dose fertilizer treatment compared to farmer's practice. Two treatments were studied: T1 = farmer's practice; T2 = 4 T ha^{-1} manure + micro dose (2g per seeding hole).

The experiment sites were characterized by low organic matter content, low pH and low nutrient status. At the planting time, some difficulties related to plant germination were observed. For both grain yield and straw yield, crop response to micro dose treatments also depended on soil type. On heavy soil, no response was observed while on sandy soil, the percent yield increase due to micro dose varied from 40% to 82% a

KounP, from 15% to 100% at Kamba and from 55 to 96% at Kolodougoukoro (Table 13).

Mali - Sorghum

To study the effect of planting date, plant population, and the interactions on two tan-plant sorghum varieties (97-SB-DT-154 and Malisor 92-1), three planting dates, seven plant populations with varying row width and hill sparings, and three fertilizer levels (Kebila only) were evaluated at Sotuba and Kebila. At Sotuba, for both grain and biomass yield, the earliest planting date (June 20) was the best, while at Kebila, the middle planting date (July 5) was superior for both grain yield and biomass. There was no significant interactions of planting date x population or with cultivar. However, significant differences due to plant population were observed at both Sotuba and Kebila with the highest plant populatio (0.75 m x 0.25 m, with 53,000 hills/ha, and 2 plants per hill) giving the highest yield. At Kebila, the highest fertilizer rate (92-92-0) gave higher yields than (41-46-0) or (0-0-0), but there was no interaction with planting date or plant population. The conclusion from the 2002 results indicated a need to increase plant population up to 100,000 plants per ha to realize the yield potential of these two cultivars.

Ghana - Sorghum

The major objective of this long-term experiment at the Wa Station was to determine if fertilizer Phosphorus (P) rates (0, 30, 60 and 90 kg P/ha) applied to one crop (direct for current crop and residual for succeeding crop) or to both crops (cumulative) would enhance soil P availability enough to maintain both sorghum and cowpea yields when grown in rotation.

Sorghum yield response to frequency of P application was not significant in 2000, but in 2001 and 2002, fresh (direct and cumulative) application of P to sorghum produced significantly greater kernel number and grain yields than its application to previous cowpea crop. Grain yields with fresh P applications were significantly increased by an average of 23% (508 kg ha^{-1}) in 2002 (Table 14). Over the years, added fertilizer P consistently increased kernel numbers and grain production in a linear manner. Additionally, grain yield was often more correlated with seed number than seed weight. Grain yield was linearly related to P rates (Y = 1908.44 + 13.97P, R^2 =0.38) when averaged across frequency of P application in 2002. Sorghum yields were not increased significantly beyond the 30 kg P/ha level in 2001 and 2002. Frequency of P application did not influence cowpea yield and yield components in 2000 through 2002.

Table 14. Sorghum grain yield and yield components as affected by added fertilizer P, Wa, Ghana, 2002.

Frequency of P application	Days to 50% flowering	100-seed weight g	Kernels m^{-2} no	Grain yield kg ha^{-1}
Cumulative	68	2.35	9681	2692
Direct	68	2.32	9938	2721
Residual	68	2.27	8467	2199
LSD (0.05)	NS	NS	962	406
P rate kg/ha^{-1})				
0	69	2.15	7048	1760
30	68	2.26	9666	2543
60	68	2.40	9856	2763
90	67	2.45	10878	3084
P linear	**	NS	**	**
P quadratic	NS	NS	*	NS
CV %	2.2	14.7	12.0	18.6

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

In another agronomy trial at the Wa Station the effect of previous-crop (sorghum, groundnut, cowpea, and soybean) on grain sorghum growth and response to four N fertilizer rates (0, 40, 80 and 120 kg ha^{-1}) was studied. The experiment was initiated in 2000 and rotation effects were determined in 2001 and 2002. During both years, the effects of previous crops and the rates of nitrogen applied to the sorghum did not interact significantly. In 2002, apart from stover production, agronomic and physiological traits of sorghum measured or calculated in this experiment were not influenced by the previous crops. However, on average, sorghum following groundnut tended to have the greatest grain yields (2151 kg ha^{-1}) and numerically the most kernels, followed by sorghum following cowpea (1954 kg/ha) or soybean (1721 kg ha^{-1}), while the least grain yield and fewest kernels were recorded after a previous crop of sorghum (1627 kg ha^{-1}). Similar results were obtained in 2001. The results support the need for enhancing biological nitrogen fixation of grain legumes to furnish some of the N requirements of non-legumes in rotation cropping systems.

In a third agronomy trial at Wa, the effects of fertilizer use and crop residue management on soil organic matter content, extractable nutrient concentration and production of maize and sorghum in the savanna zone were studied.

Results indicate that crop residue return rate did not influence parameters measured or calculated for sorghum in 2001 and 2002. When averaged across residue return rates, fertilized sorghum flowered 4 days earlier than did unfertilized sorghum. However, added fertilizer increased plant height, seed number, stover and ultimate grain yields. A yield advantage of 113% (732 kg ha^{-1}) was obtained from fertilized sorghum when compared with unfertilized plants averaged over crop residue rates. The results obtained for the two seasons reveal that fertilizer application regardless of crop residue can increase sorghum grain yields on a savanna soil low in plant available nutrients.

Economic Analysis/ Ghana Agronomy

Economic analyses suggest that when cowpea is grown in rotation with sorghum, P fertilizer should be applied directly to sorghum at the rate of 90 kg P/ha (the maximum net benefit is obtained with the rate and frequency of application). For four cropping seasons the results indicate that when cowpea is grown in rotation with sorghum, it is better to apply P fertilizer to the sorghum crop and allow cowpea to benefit from the residual P effect.

Partial budget analysis indicates that when no nitrogen fertilizer is applied cowpea is the best preceding crop to sorghum. Sorghum as a preceding crop exhibited consistent increases in net return with increase in nitrogen fertilizer application. In all uses sorghum benefits from legumes as preceding crops in the rotation. The highest net return was obtained using groundnut as a preceding crop with 80 kg ha^{-1}.

When the effect of residue return and fertilizer use were considered, results showed that a 100% residue return rate combined with 2.5 bags each of 15-15-15 and sulphate of ammonia was the best option. When no fertilizer was used the highest net return came from a 50% crop residue return rate.

Economics/Marketing

The IER developed and released white-seeded, tan-plant Guinea type cultivar, N'Tenimissa, was use in identity preserved (IP) marketing and in value-added products and commercial utilization. In building upon the initial success in 2001 of a local entrepreneur in grain trading from the Bamako area of Mali, Mr. Diawara, he arranged in 2002 with assistance of Dr. Jupiter Ndjeunga (ICRISAT) and Mr. A. Diallo (IER) for a much larger increase of N'Tenimissa grain. In 2001, 11 tons of grain were available for the entrepreneur to sell and/or process. The goal in 2002 was 200 tons of grain. Four villages were involved, 2 in the Bamako area and 2 in the Sikasso area in Southern Mali, Kafara, Safebougoula, Garalo, and Yanfoliye. It involved 110 farmers and about 200 ha. Farmers in these villages contracted with the grain trader. More than 220 tons were harvested with an average grain yield of 2,000 kg ha^{-1}. Unfortunately, because of financial and other problems involving the grain trader and his company, the contracts were not fulfilled. Understandably, the farmers were "very unhappy" over this situation. However, part of this production was sold to the grain trader and in local markets for an increased priceof 10-20 FCFA per kg compared to the local market price. The short and long term impact of this unfortunate situation is unkown at this time, and its effect on 2003 plans is unclear.

In 2001, Mr. Diawara was successful thru contracting with farmers in receiving 11 tons of N'Tenimissa grain. When the demand for the flour from GAM declined due to the removal on tariffs on wheat, causing wheat prices to fall, the entrepreneur was successful in utilizing alternate markets. He sold about one ton as 1 kg bags of sorghum flour called Sorgho Phar for 500 CFA in local markets and the demand was excellent. He sold 7 tons as whole grain in markets around Bamako, and the grain sold for a good price premium. The demand for this good quality N'Tenimissa whole grain was excellent according to the grain trader, even maybe better than for the 1 kg bags of flour. This illustrates the important point that enhanced quality grain is recognized and can be used to develop new IP marketing of sorghum grain and stimulate the involvement of local entrepreneurs in developing and marketing new urban food products in addition to being a marketable product itself in Mali. Also, most farmers have a preference for the grain for their own use due to its white color and clean grain.

Institution Building

The sorghum and millet programs received, through INTSORMIL collaboration, a computer, and various field and laboratory research equipment and breeding supplies.

Many Malian scientists trained at INTSORMIL institutions are senior staff making important contributions in sorghum and millet research within the IER including:

Dr. Aboubacar Touré (Texas A&M) - Currently Sorghum Breeder, Mali National Coordinator for sorghum, Mali INTSORMIL Coordinator, and on INTSORMIL Technical Committee.

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

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

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

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

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

Mr. Sidi Bekaye Coulibaly (Nebraska and Texas Tech/Texas A&M) - Previously sorghum physiology/agronomy and sorghum breeding and INTSORMIL Coordinator. Currently sorghum/millet breeder, Cinzana.

Students currently in training include Niaba Témé who successfully completed his B.S. and M.S. at Texas Tech University and is currently a Ph.D. student at Texas Tech University. Karim Troaré, former IER millet and sorghum breeder is now a Ph.D. student at Texas A&M University. Mr. Tiecoura Traore has initiated a M.S. program in sorghum entomology at West Texas A&M University.

Bocar Sidibé, Abocar Toure, Kissima Traore, SibPne Déna, and Moussa Sanogo received short term training in the USA provided by INTSORMIL in breeding and plant pathology.

Dr. Aboubacar Touré, Malian sorghum breeder, is a member of the streering committee of the West and Central Africa Sorghum Research Network, WCASRN (ROCARS).

U.S. scientists traveling to the region included: Dr. Bonnie Pendleton (Mali - October, 2002), Dr. Jeffrey Wilson (Mali-October, 2002), Dr. John Sanders (Mali and Senegal - October, 2002), Dr. Darrell Rosenow (Mali - November, 2002), Dr. Lloyd Rooney and Bruce Hamaker (Senegal - January, 2003).

Several host country scientists traveled to Ethiopia in November, 2002, and participated in the INTSORMIL P.I. Conference where they interacted extensively with U.S. and other host country scientists and planned future collaborative activities. Scientists traveling to the P.I. Conference in Addis Ababa, Ethiopia included Aboubacar Touré, Niamoye Diarisso, Mamadou Doumbia, Mamourou Dioute, Mamadou N'Diaye, Abdoul Demba M'Baye, Mamdou Balde, and Ababacar N'Doye (ITA), from Senegal; and Sakka Buah, Ibrahim Atokple; Steve Nutsugah, and Paul Tanzubil from Ghana.

Dr. Aboubacar Touré also attended a R.F. sponsored Conference on Biotechnology, Breeding, and Seed Systems for African Crops, November 2002, Entebbe, Uganda. IER scientists also attended a workshop on Alternative and protein-enriched sorghum and millet food products, Pretoria, South Africa.

Mr. Steven Nutsugah, Pathologist, Ghana participated in the Fusarium Workshop, Kansas State University, Manhattan, Kansas, June 2003.

Networking

An efficient sorghum and millet research and technology transfer network has existed though the West African regional sorghum and millet networks, WCASRN (ROCARS) and ROCAFREMI. The INTSORMIL/IER collaborative program is integrated on a regional basis. Technologies developed in Mali are transferable to most countries in West Africa particularly in the areas where head bugs, drought, and grain mold which are common. Exchange of elite germplasm with useful traits is ongoing among breeders in the region. The emerging interaction with NGOs, the University of Mali (IPR de Katibougou), farm organizations, and extension in conducting on-farm research and tests is a positive one that efficiently utilizes scarce resources and personnel. The program is using this approach to evaluate new improved breeding cultivars and other technologies in the West Africa Region. Efforts are underway to reinforce coordination of research programs and activities with other countries in West Africa. Collaborative INTSORMIL research was initiated in Ghana and Senegal in the 2001 season, and efforts have been taken to tie some of this in with researchers and programs in Burkina Faso, Nigeria, and Niger.

The program has also interacted with ICRISAT, TROPSOILS, NOVARTIS, etc. There has been a long history of collaboration with ICRISAT in Mali especially in breeding, entomology, and weed science. The program has assembled, planted, increased and characterized the Mali Sorghum Collection in collaboration with USDA-ARS, ICRISAT, ORSTOM, CIRAD, and seed is in storage in Mali and has been introduced into the U.S. and grown out under quarantine. The seed increase and characterization were completed in 2001 and the complete set of data on the over 40 grain, glume, and plant characters was compiled and sent to the USDA/ARS for entry in the GRIN system. The development of a working group for active use is ongoing. After the seed is processed, complete sets will be sent, as appropriate, to ICRISAT, ORSTOM, and Mali.

New Ghana and Senegal Collaboration

Plans to initiate INTSORMIL collaborative research in Ghana and Senegal began in November 2000, with arrangements to bring two scientists each from Ghana (Drs. S. Buah, agronomist and I. Atokple, sorghum breeder) and Senegal (Ndiaga Cissé, sorghum breeder and Demba M'Baye, pathologist) to Bamako to meet with Darrell Rosenow, Aboubacar Touré, and other key Malian IER scientists. Dr. Buah already had previously initiated a collaborative program in agronomy with Dr. Maranville. The discussions were all fruitful and positive with three initial areas of collaboration among Malian, Ghana, and Senegal scientists agreed upon: 1) Sorghum Breeding with the establishment of a germplasm exchange program centering on a West African Regional Breeding Nursery to which all breeders would contribute new breeding germplasm or cultivars annually, and would be assembled and distributed by Dr. Touré in Mali; 2) Sorghum Pathology centered initially on a West African Disease Nursery to which all pathologists and breeders would contribute entries annually and would be assembled and distributed by M. Diourte in Mali; and 3) *Striga* research with initially a *Striga* nursery of known or suspected *Striga* resistant local cultivars and selected lines from Dr. Gebisa Ejeta evaluated at several sites. The lines will be assembled in Mali and distributed by Acar Troare. Also Dr. Ejeta will look at some of the sources for types of resistance involved. In addition, INTSORMIL scientists in the U.S. will provide breeding germplasm for midge resistance, drought resistance, grain mold resistance, other disease resistance, and elite sources of worldwide germplasm for the new breeding programs in Ghana and Senegal. Requests were made by scientists in Ghana and Senegal for the future development of collaboration in millet breeding, entomology (head bugs and midge), cereal technology and utilization, and agronomy. Dr. Buah has continued his collaborative activities in Ghana based on previously developed work plans with Maranville.

Research Accomplishments - Summary

The most significant impact of INTSORMIL has been the strengthening of the IER both through staff training and research capacity building. Interdisciplinary and cooperative research in sorghum and millet which are in place at the IER are mainly due to INTSORMIL/IER collaborations. The multidisciplinary approach to solving technical problems have been promoted by the INTSORMIL, and is functioning well in Mali.

Breeding

From on-farm trials, the Guinea-type cultivar 97-SB-F5-DT-63 (N'Tenimissa*Tiemarfing) has been selected, seed saved, and grown by local farmers and has been released and named "Wassa" which mean 'satisfaction' in Bambara. Farmers like it over N'Tenimissa because of its whiter, higher quality grain.

Two other new breeding lines, true Guinea cultivars (N'Tenimissa*Tiemarfing) were widely tested and given the names Zarra and Keninkedie, and will be increased for use in value-added products. All three of these new cultivars have superior grain quality and less stem breakage then N'Tenimissa.

Eight local photosensitive sorghum cultivars have been improved through mass selection and are grown by farmers on a significant area in Mali (CSM 388, CSM 219E, CSM 63E, Foulatiéba, Séguétana CZ, CMDT 45 , CMDT 39).

The white-seeded, tan-plant Guinea type breeding cultivar, N'tenimissa, was released. It's yield is equal to or slightly superior to local checks. It has good farmer acceptance regarding yield and food use. Flour from N'tenimissa is currently being marketed commercially (20% N'tenimissa and 80% wheat flour) in a cookie called DeliKen by the private company, GAM, in Bamako.

A local entrepreneur in Mali successfully produced , in 2001, over 11 tons of grain of the white, tan plant guinea cultivar, N'Tenimissa, under identity preserved (IP marketing procedures. This grain trader also developed a new market by packaging and selling one kilo bags of flour (Sorgho Phar) in Bamako markets, with a demand so strong he was having trouble keeping the product on the shelf. In 2002, his contracted production for 200 tons was derailed due t financial and other problems in his company unrelated to the N'Tenimissa effort.

Varieties of millet selected for the tallest expression of the D2 dwarfing complex (1.7 to 1.9 m) have given good performance in millet/legume intercropping studies.

Testing in Texas and Mali has demonstrated that the drought response in Mali is similar to the drought response in West Texas, increasing the probability of success in breeding for enhanced drought tolerance.

The Mali Sorghum Collection of indigenous cultivars from Mali was successfully grown in 1997, was characterized and seed increased and distributed. A small working collection has been identified. There was greater diversity in the collection than anticipated. Approximately one-third of the Collection was grown in St. Croix in spring 2000 with seed increased and characterization completed. The remaining two-thirds was grown in a St. Croix quarantine growout in winter, 2000-01, and seed increased and characterization completed. A tentative working collection was identified.

Entomology

The adverse effect of head bugs on the grain food quality of introduced sorghum across West Africa was first recognized and documented in Mali.

The INTSORMIL collaborative sorghum entomology research program in Mali has discovered the best source of genetic resistance to head bug (*Eurystylus marginatus*) in a non-Guinea type sorghum, a major constraint to the quality of grain sorghum in Mali, in an IER Malian developed cultivar, Malisor 84-7.

An easy, efficient technique for screening for head bug resistance using bagged vs. non-bagged heads has been developed and is used cooperatively by the breeders and the entomologists.

Observations indicate that head bug infestations in on-farm trials is much lower than in Station Nurseries. This means that sorghum with somewhat lower levels of head bug resistance may well work at the farm level, even though they may show significant damage under certain Station infestations.

Sorghum selfing bags work equally well with cages in head bug evaluations and are much more cost and labor efficient.

Natural infestation appears superior to infested cages for head bug screening.

Pathology

Grain yield increase of 20% can be obtained by treating millet seed with Apron plus.

Protection from head bugs will be a requirement for evaluation of grain mold resistance.

Long smut (*Tolyposporium ehrenbergii*) is severe in the drier regions of Mali. Anthracnose (*Collectostrichum graminicola*) is a very serious sorghum disease in Mali.

Studies were conducted on covered kernel smut (*Sphacelotheca sorghi*) by using traditional fungicides and the results showed that "Gon" (*Canavalia ensiloformis*) used in seed treatment had the same effects as Apron Plus 50DS and Oftanol.

Agronomy

Micro-dose fertilizer application increases the grain and stover yield of millet on sandy soils. Its effect on sorghum and on heavier soils is highly variable.

INTSORMIL/IER research has demonstrated that millet or sorghum planted after peanut or cowpea results in 36-63% yield increases.

INTSORMIL collaborative research has shown an increase in pearl millet grain yield and biomass production due to previous cowpea crops and equivalent to the application of 30 to 40 kg ha^{-1} N.

The joint INTSORMIL/Soil Management CRSP collaborative program has addressed soil chemical properties associated with nutrient deficiencies toxicities in sandy soils of the Cinzana Station. Some Durra varieties from Niger and northern Mali show tolerance to soil toxicity (Bagoba, Babadia Fara, and Gadiaba)

A method of screening large numbers of sorghum and millet lines for early generation and selection for seedling stage drought resistance using a charcoal pit has been adapted and is used.

Nitrogen use efficiency (NUE) of improved sorghum cultivars has been better than that of local cultivars at higher N rates, while local cultivars had better NUE at zero and very low N rates.

Without fertilizer application all tested cropping systems (including legume rotations) mine the soil of nutrients.

Crop rotation with cowpea and leaving crop residues in the field (either incorporated or on the surface) increases the sustainability and productivity of pearl millet cropping systems.

New IER developed sorghum cultivars show moderate levels of acid soil tolerance.

Weed Science

Several *Striga* resistant lines from Purdue evaluated in Mali showed good *Striga* resistance, but had inferior grain quality compared to local cultivars.

Striga resistance using lab screening to *Striga asiatica* in the US works under field conditions to *S. hermonthica* in Mali.

New sources of resistance to *Striga* were identified: Séguétana CZ, CMDT 45, CMDT 30, CMDT 39.

Several new Guinea breeding line/cultivars such as Wassa show good *Striga* tolerance.

Grain Quality and Utilization

Mini tests for evaluating milling and tô properties were developed and currently are used in the laboratory. Sorghum with hard endosperm and thick pericarps was definitely required for efficient traditional hand pounding. The size and shape of the pearl millet kernels affects dehulling properties significantly.

Head bugs damage reduced sorghum milling yields and produced tô with unacceptable texture and keeping properties.

Parboiling can convert sorghum and millet into acceptable products. It improves dehulling yieds, especially for soft grains. The cooked milled products can be eaten like rice.

The combination of cowpea and millet flour (1:3) significantly improved the nutritional status of young children. This technology has been transferred to many villages especially in the Cinzana area.

Mileg, a weaning food using primarily millet flour has been developed by private entrerprise and marketed in stores in the Bamako area. The product was developed using technology developed in the IER Cereal Technology laboratory.

New white-seeded, tan-plant, tan-glume guinea-type breeding cultivars, have good potential for use in developing new high quality, value added food products. They posses excellent guinea traits and yield potential.

Deli-ken, a cookie using 20% N'Ténimissa flour and 80% wheat flour has been developed by private entrerprise GAM and marketed in stores in Mali.

A new market for N'Tenimissa flour has been developed with the successful marketing of 1 kg bags of N'Tenimissa flour in Bamako by a local entrepreneur.

Economics/Marketing

In Mali, a local entrepreneur successfully produced grain from the white-seeded, tan-plant Guinea cultivar, N'Tenimissa, under identity preserved (IP) marketing procedures, involving 38 ha and 50 farms in 4 villages. From 38 tons harvested, over ll tons were sold to the grain trader. When the demand for sorghum flour by GAM for cookies dropped due to reduced tariff on wheat imports, a new market for the N'Tenimissa flour was developed with the marketing of one kilo bags of N'Tenimissa flour (Sorgho Phar) in markets in Bamako. Demand was so strong, there were problems keeping the product on the shelf. A portion of the grain was also sold directly in local Bamako markets, and sold well at a premium price.

An economics study on the benefits of new technology in Mali suggests that new technology in the traditional cereals of sorghum and pearl millet would provide a greater increase in benefits compared to new technology introduction in the new cereals, maize and rice.

The domestic cereal economy has been helped by devaluation with the increased relative price of sorghum and millet to rice. A future devaluation is expected to result in much more substitution of traditional cereals now that there is only a minimal rice tariff.

In spite of substantial introduction of new sorghum and millet cultivars, there has been minimum aggregate impact on yields. Only where inorganic fertilizers and improved water retention or irrigation were combined with new cultivars, have there been large yield increases. Given the low soil fertility and irregular rainfall in semi-arid regions, both increased water availability and higher levels of principal nutrients will be necessary for substantial yield increases. Improved cultivars alone are unlikely to have a significant effect upon yield.

The lack of a consistent supply of high quality sorghum and millet grain is the major constraint limiting value-added grain processing.

Lack of farm credit for millet and sorghum, compared to cotton and maize, discourages adoption by farmers of improved millet and sorghum technology, especially in the Sudano-Guinean (higher rainfall) zone.