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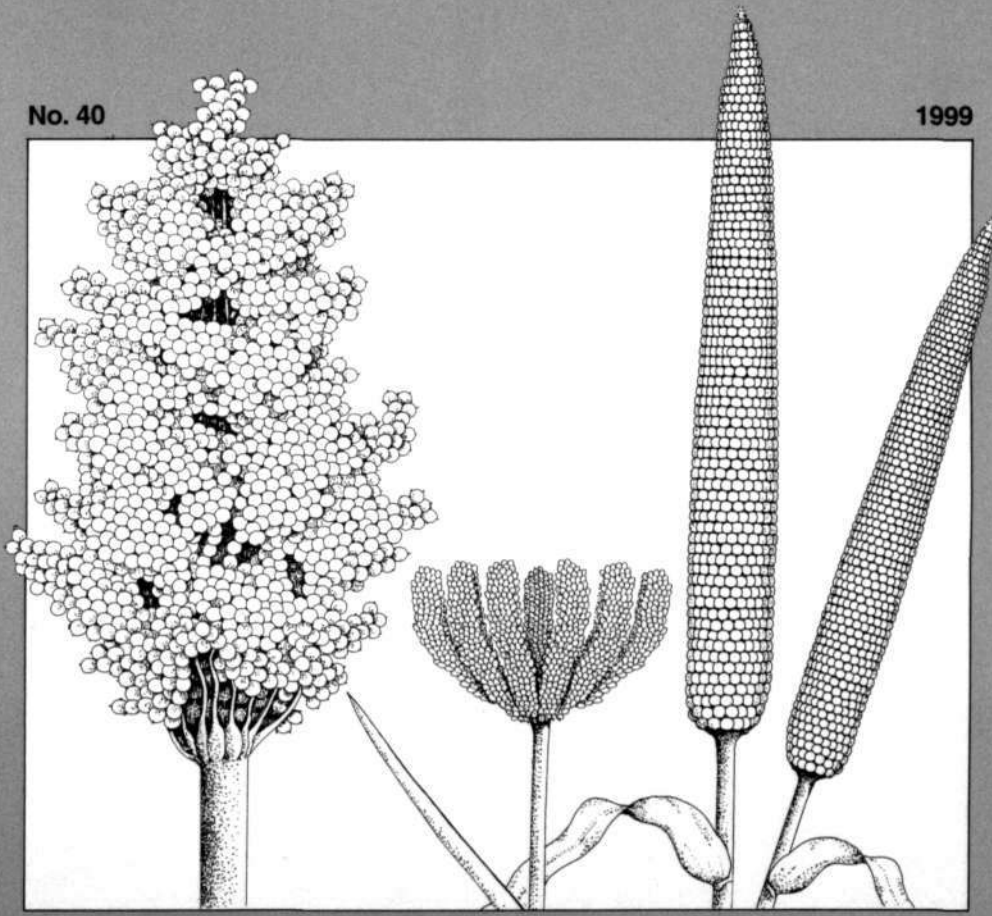

International Sorghum and Millets Newsletter

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Sorghum Improvement Conference
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About SICNA

In 1947, sorghum breeders formed an informal working group to meet and review items of interest in sorghum breeding and genetics. This organization was named 'Sorghum Research Committee'. In the 1960s, with the advent of a number of severe disease and insect problems, special half-day sessions, particularly on diseases, became a part of the Sorghum Research Committee. In 1973, a concept was put forward that all sorghum workers, irrespective of discipline and employer, should meet twice a year to discuss mutual concerns with sorghum research and development. The Sorghum Improvement Conference of North America was that new organization. It is composed of eight disciplinary' committees, dealing with genetics and breeding, pathology, entomology, chemistry and nutrition, physiology and agronomy, biotechnology, utilization and marketing, and agribusiness and commerce. SICNA meets formally once a year in conjuction with the National Grain Sorghum Producers Board. A general program of research, education, and developmental activities is prepared by the disciplinary committees. Funding is through membership participation and contributions from commercial donors. Essentially, SICNA represents the United States sorghum activities but accepts reports and encourages memberships from sorghum and millet researchers worldwide.

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research that can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

Contents

Yield Stability of Forage Sorghum in Semi-Arid Pernambuco, Brazil

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Introduction

In Pernambuco State, about 83% of the physical area is classified as semi-arid. Forage sorghum has potential in this adverse environment because it is drought-tolerant, can yield well, and has a variety of uses (Lira et al. 1986). The work reported is an evaluation of 25 of forage sorghums in 11 different environments in Pernambuco.

Materials and methods

The research was carried out during 1992 to 1996, at the experimental stations of Empresa Pernambucana de Pesquisa Agropecuaria (IPA), located in the semi-arid regions of Pernambuco State. Agronomic performances of 25 forage sorghum cultivars were evaluated in a total of 1 1 environments combined across years and locations. The characteristics of each environment are shown in Table 1.

The experimental design was a randomized block with three replications and stability of cultivar performance was analyzed, following Eberhart and Russell (1966), for the following variables: dry matter yield, lodging index, and water-use efficiency.

Results and discussion

Among the 11 environments in which these 25 forage sorghum cultivars were tested, the following variation in the dry matter yields was detected: Caruaru 1992 produced the lowest mean dry matter yield of 5.41 t ha^{-1}, Arcoverde 1995 produced the highest mean dry matter yield of 14.33 t ha^{-1}. This variation shows the influence of the test environments on expression of yield potential. Environment-specific factors contributing to these differences in trial mean dry matter yields across the 11 test environments include the soil type, level of fertilizer applied, sowing and harvest dates, and such weather factors as sunshine hours and rainfall during the crop cycle. Across-location analysis of variance of dry matter yield showed statistically significant genotype x environment interaction. For the 11 test environments, the 25 cultivars showed wide variation in their reactions. The lower and upper bounds for reliable intervals for linear regression coefficients were determined to be 0.925 to 1.075, and those for dry matter yields were 9.73 to 10.32 t ha^{-1} (Fig. 1).

Table 1. Eleven environments where the research was conducted and mean productivity of the 25 forage sorghum cultivars evaluated in these environments, Pernambuco State, Brazil, 1992-96.

Location	Year	Fertilizer (N-P-K)	Sowing date date	Harvest date	Seasonal rainfall (mm)	Dry matter yield (t ha^{-1})
Sao Bento do Una	1992	50-60-30	01.04.92	04.08.92	268.1	8.86
Sao Bento do Una	1994	90-90-60	11.05.94	20.10.94	366.0	8.41
Sao Bento do Una	1996	60-60-30	29.04.96	10.09.96	272.4	8.11
Caruaru	1992	80-60-30	14.04.92	25.08.92	348.2	5.41
Caruaru	1994	30-60-30	31.05.94	01.06.94	632.5	6.29
Arcoverde	1992	20-30-00	27.03.92	03.08.92	288.0	14.01
Arcoverde	1995	90-160-00	10.05.98	05.09.95	256.7	14.33
Arcoverde	1996	30-60-00	08.05.96	05.09.96	383.0	10.34
Serra Talhada	1994	20-00-00	18.02.94	30.06.94	460.6	11.21
Serra Talhada	1995	20-00-00	16.02.95	13.07.95	528.4	11.12
Serra Talhada	1996	40-00-00	13.03.96	05.09.96	451.7	9.40

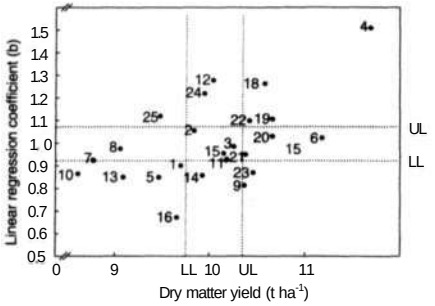

Figure 1. Stability and productivity of 25 forage sorghum cultivars in 11 environments of Pernambuco State, Brazil, 1992-96. UL = Upper limit of reliable interval; LL = Lower limit of reliable interval. Genotype codes (1-25) as given in Table 2.

The genotypes that were considered stable are within this regression coefficient interval. Cultivars adapted to unfavorable environments have regression coefficients that fall below the lower boundary of this interval. For dry matter yield, the cultivars within the interval are considered to be average, while cultivars with higher or lower dry matter yields are considered exceptional. Figure 1 shows the cultivar distribution when across-location mean dry matter yield is plotted against linear regression coefficient. Forage sorghum cultivars with stable yield performance across this set of environments that usually produce above average yields included IPA SF 25, 43-70-02, 41-Ca84-BCa87-B2SB88-BCa89, and 46-Ca84-B2Ca87-BISB88-BCa89. Of these four cultivars, three of them (43-70-02, 41-Ca84-BCa87-B2SB88-BCa89, and 46-Ca84-B2Ca87-BISB88-BCa89) produced across-location mean dry matter yields between 10.38 and 11.18 t ha^{-1} and appear to be broadly

Table 2. Performance of 25 forage sorghum cultivars evaluated in 11 environments, Pernambuco State, 1992-96.

Entry	Cultivar name	Dry matter yield (t ha^{-1})	Regression coefficient (b)	Regression deviation (S^2_d)	Lodging (%)	WUE[1]
1	IPA SF 24	9.70	0.8898	0.5611	19.30	299
2	IPA 322-1-1(2)	9.84	1.0541	7.2681	31.83	328
3	IPA SF 25	10.26	0.9842	0.0073	11.15	279
4	2-03-01	11.69	1.5090	1.8906	15.57	249
5	22-36-01	9.47	0.8480	2.4821	30.43	$16
6	43-70-02	11.18	1.0225	3.1899	18.79	260
7	322-1-2(2)	8.77	0.9243	0.3114	36.92	333
8	322-1-2(5)	9.06	0.9751	0.1243	32.29	318
9	107-B84-B2Ca87-03-SB88-BCa89	10.37	0.8128	1.2004	8.66	279
10	10-Ca84-BlCa87-BlSB88-BCa89	8.61	0.8640	0.3829	36.05	338
11	10-Ca84-B2Ca87-B2SB88-BCa89	10.18	0.9265	1.4924	13.71	282
12	18-Ca84-BlCa87-BaSB88-BCa89	10.04	1.2770	3.3569	18.23	293
13	25-Ca84-BlCa87-BlSB88-BCa89	9.09	0.8496	0.6770	12.05	309
14	25-Ca84-B1Ca87-B2SB88-BCa89	9.93	0.8558	0.1396	17.69	286
15	78-Ca84-B2Ca87-BlSB88-BCa89	10.15	0.9538	1.7133	19.28	280
16	25-Ca84-B2Ca87-BlSB88-BCa89	9.66	0.6727	0.3411	12.28	294
17	25-Ca84-B2Ca87-B2SB88-BCa89	10.18	0.9293	2.5709	15.87	288
18	38-Ca84-B2Ca87-B2SB88-BCa89	10.58	1.2627	1.9208	11.80	290
19	41-Ca84-BCa87-BlSB88-BCa89	10.66	1.1052	1.9390	13.41	264
20	41-Ca84-BCa87-B2SB88-BCa89	10.65	1.0289	1.1892	14.11	271
21	46-Ca84-B2Ca87-BlSB88-BCa89	10.38	0.9488	2.8832	23.66	283
22	46-Ca84-B2Ca87-B2SB88-BCa89	10.42	1.0983	0.2529	14.23	275
23	52-Ca84-BCa87-BlSB88-BCa89	10.47	0.8691	0.1900	17.00	271
24	63-Ca84-B lCa87-B2SB88-BCa89	9.95	1.2183	1.5267	27.19	297
25	IPA 467-4-2	9.48	1.1197	0.7157	28.43	302
F test		*	-	-	*	*
HSD[2]		1.76	-	-	6.95	81.8
CV (%)		22.4	-	-	44.2	24.5

1. WUE = Water-use efficiency (kg H_2O kg^{-1} DM); 2. HSD = Tukey's Honestly significant difference (α < 0.05)

adapted across the 11 test environments (Fig. 1). Cultivars 107-B84- B2Ca87- 03-SB88- BCa89, 25-Ca84-BlCa87 BlSB88-BCa89, and 52-Ca84-BCa87-BlSB88-BCa89, produced dry matter yields across the 11 test environments that were comparable to those of average cultivars, but were selected as being adapted to unfavorable environments (Fig. 1). Cultivar 2-03-01 produced the highest dry matter yield (11.69 t ha^{-1}) among the tested cultivars, but was not stable in its performance, being more adapted to favorable environments (Fig. 1). IPA 467-4-2 yielded less than average and was also not considered stable. Data on dry matter yield, regression coefficient (b), and S^2_d (which measures deviation from regression) for each of the 25 forage sorghum cultivars tested are shown in Table 2, together with information on their water-use efficiency and lodging (%). Water-use efficiencies among the 25 forage sorghums tested varied from 249 to 338 kg water needed to produce one kg of dry matter, a range of about 35%. These results are similar to those obtained by Tabosa et al. (1987). Lodging indexes varied between 9 and 12%, and were considered low and relatively invariant when compared with other results obtained in Pernambuco (Lira et al. 1986; Lima 1998).

Conclusions

- IPA SF 25, 43-70-02, 41-Ca84-BCa87-B2SB88 BCa89, and 46-Ca84-B2Ca-B2Ca87-BlSB88-BCa89 were considered the more productive and stable forage sorghum cultivars tested.
- 107-B84-B2Ca87-03-SB88-BCa89, 25-Ca84-BICa87-BlSB88-BCa89, and 52-Ca84-BCa87-BlSB88-BCa89 produced similar, average, dry matter yields and were adapted to the unfavorable environments.
- Commercial cultivar IPA SF 25 will continue to be recommended for Pernambuco.

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Comparison among Forage Millet and Sorghum Varieties in Semi-Arid Pernambuco, Brazil: Yield and Quality

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Introduction

Stored forage has potential in the semi-arid zone of the Northeast Region of Brazil, notedly to meet the demand for fodder during dry seasons, when high temperatures and low relative humidity result in droughts (Duque 1984) that limit plant development (Lehanc 1981). Forage millet [*Pennisetum glaucum* (L.) R. Br] and sorghum [*Sorghum bicolor* (L.) Moench] crops can provide viable alternatives to grazing in this adverse region. These crops are drought-tolerant, have a wide range of uses, and high production potential (Pontes 1997; Lima 1998). Their fodder production potential and quality are important, because their forage is high in protein and the crops mature early in the season. The objective of this work was to evaluate cultivars of forage millet (hybrids and varieties) and a forage sorghum variety recommended for the region from the aspects of production, quality, and earliness.

Material and methods

The research was carried out in 1996, at Empresa Pernambucana de Pesquisa Agropecuaria (IPA) experiment stations located in semi-arid regions of Brazil. The

geographical coordinates and climate characteristics of the test locations are shown in Table 1.

The trial evaluated seven forage millet cultivars (five hybrids, and one introduced and one local variety) and one forage sorghum cultivar already recommended in the region (Table 2). The experimental design was a randomized block with four replications. Planting density was 20 plants per linear meter. After soil analysis the recommended fertilizers were applied. Plants were harvested at anthesis. Evaluation parameters were: dry matter yield (DMY), dry matter percentage (DM%), daily DM yield (DDMY), and crude protein (CP).

Results and discussion

Data collected at Caruaru on the yield, percentage, and daily DM yield of the first and second harvests are shown in Table 2. Considering the total yield from both first and second harvests, it was observed that pearl millet cultivars, either hybrids or varieties, produced lower yields than the currently recommended forage sorghum variety

Table 1. Geophysical features of the Caruaru and Sao Bento do Una test locations, Pernambuco State, Brazil.

Parameter	Caruaru	Sao Bento do Una
Latitude	08° 34' 38"	08°31' 16"
Longitude	38°00'00" W	36° 33' 00" W
Altitude	537 m	650 m
Climate type[1]	SAM[2]	SAM
Soil type	Litholic	Regosol
Precipitation[3]	223 mm	245 mm
Potential evapotranspiration	1144 mm	1150 mm
Mean temperature	23.1°C	23.8°C

1 Accordtng to Thornithwaite and Matter (1955)
2 SAM = Semi-arid megathermic
3 During the experimental period

Table 2. Performance of forage millet cultivars and a forage sorghum variety (IPA 02-03-01) in the semi-arid region of Pernambuco State, Brazil. Yield potential at Caruaru, 1996.

	Harvest 1			Harvest 2			Total		
	DMY[1]	DM	DDMY	DMY	DM	DDMY	DMY	DM	DDMY
Cultivars	(t ha^{-1})	(%)	(kg ha^{-1} day^{-1})	(t ha^{-1})	(%)	(kg ha^{-1} day^{-1})	(t ha^{-1})	(%)	(kg ha^{-1} day^{-1})
Pearl millet hybrids									
Tift 23A x FS-1	2.64	12.9	47	2.34	22.3	44	4.98	17.6	46
Tift 45A x FS-1	2.78	16.2	50	2.11	23.2	40	4.89	19.7	45
Tift 85A x FS-1	2.62	14.2	47	2.58	24.0	49	5.20	19.0	48
KS 240A x FS-1	3.06	14.8	55	2.39	21.0	45	5.45	17.9	50
NU 378 x FS-1	3.08	12.7	55	1.14	16.6	22	4.22	14.6	38
Pearl millet varieties									
FS-1	4.71	14.5	84	1.47	15.7	28	6.18	16.1	56
IPA Bulk 1-BF (local)	5.26	16.7	94	0.64	17.1	12	5.90	16.9	53
Average	3.45	14.6	62	1.81	20.3	34	5.26	17.4	48
HSD[2]	0.74	1.2	12	0.45	1.2	8	0.88	1.0	6
Sorghum variety									
IPA 02-03-01[3]	9.14	28.3	97	-	-	-	9.14	28.3	97

1. DMY = dry matter yield; DM % = dry matter percentage; DDMY = daily dry matter yield (kg ha^{-1} day^{-1})
2. HSD = Tukeys' Honestly significant difference ($\alpha < 0.05$)
3 Sorghum variety not included in analysis; it flowered in 94 days and was therefore not compared to millet cultivars harvested at 56 or 53 days

(IPA 02-03-01). Compared to the other millet varieties tested, FS-1 produced an outstanding performance, achieving 6.18 t ha^{-1} DMY, approximately 68% that of sorghum variety IPA 02-03-01. The millet growth cycle in these environmental conditions was approximately the same for both first and second harvests, i.e., 56 days and 53 days. The DM% among millet varieties was low, varying from 14.6 to 17.9%. In contrast, when sorghum was harvested after 94 days, it had attained 28.3% DM.

At Sao Bento do Una, the pearl millet DMY, from a

Table 3. Performance of forage millet cultivars and sorghum variety, in the semi-arid region of Pernambuco State. Yield potential at Sao Bento do Una, 1996.

	1st Harvest		
Cultivars	DMY (t ha^{-1})[1]	DM %	DDMY (kg ha^{-1} d^{-1})
Pearl millet hybrids			
Tift 23A x FS-1	5.98	22.2	95
Tift 45A x FS-1	5.93	22.3	94
Tift 85A x FS-1	6.51	20.3	103
KS 240A x FS-1	5.42	22.5	86
NU 378 x FS-1	4.75	19.8	75
Pearl millet varieties			
FS-1	5.89	20.9	93
IPA Bulk 1-BF (local)	6.53	21.4	104
Average	5.86	21.4	93
HSD[2]	0.74	1.2	12
Sorghum variety			
IPA 02-03-01	7.60	29.4	74

1. DMY = dry matter yield : DM % = dry matter percentage; DDMY = daily dry matter yield (kg ha^{-1} d^{-1})
2. HSD = Tukeys' Honestly significant difference (α < 0.05)

Table 4. Protein characterization of the millet and sorghum forage materials, in the semi-arid region of Pernambuco State, 1996.

	CP (%)		CP(kg ha^{-1})	
Cultivars	Caruaru	Sao Bento do Una	Caruaru	Sao Bento do Una
Pearl millet hybrids				
Tift 23A x FS-1	17.0	14.7	717	781
Tift 45A x FS-1	18.2	13.4	693	734
Tift 85A x FS-1	17.6	13.2	673	715
KS 240A x FS-1	16.7	12.7	442	703
NU 378 x FS-1	16.1	12.6	439	643
Pearl millet varieties				
FS-1	16.2	12.5	431	591
IPA Bulk 1-BF (local)	15.5	12.4	407	577
Sorghum variety				
IPA 02-03-01	9.1	6.0	391	407
F test	**	**	**	*
HSD[2]	5.8	3.8	245	324
CV(%)	11.53	10.9	16.2	17.4

1. CP = Crude protein, VC = Variation of coefficient.
2. HSD = Tukeys' Honestly significant difference (α < 0.05); * Significant at α < 0.05; ** Significant at α < 0.01

Table 5. Mean crude protein and relative values of forage millet and sorghum cultivars under semi-arid environmental conditions Pernambuco State, Brazil, 1996.

Cultivars	CP[1] (kg ha^{-1})	Relative value (%)	DMY[1] (t ha^{-1})	Relative value (%)
Pearl millet hybrids				
Tift 23A x FS-1	749	18*	5.48	65
Tift 45Ax FS-1	713	179	5.41	65
Tift 85A x FS-1	694	174	5.85	70
KS 240A x FS-1	572	143	5.43	65
NU 378 x FS-1	541	135	4.48	53
Pearl millet varieties				
FS-1	511	128	6.03	72
IPA Bulk 1-BF (local)	492	123	3.21	74
Sorghum variety				
IPA 02-03-01	399	100	8.37	100

1. CP = crude protein; DMY = dry matter yield

single harvest, was slightly higher than that ohtained at Caruaru with variety IPA Bulk 1-BF that produced 85% of the total DMY of sorghum IPA 02-03-01. However, the average millet DM content was 21.4%, i.e., 8% less than that of the sorghum variety. Millets were harvested after 63 days, while the sorghum cultivar was harvested at 103 days. The daily accumulation rate of DM of IPA Bulk 1-BF was 104 kg ha^{-1} d^{-1} and for hybrid Tift 85A x FS-1, 103 kg ha^{-1} d^{-1} (Table 1). These values are about 40% above of those of the sorghum variety (Table 3).

Protein yields of millets and sorghum as percentages and yields are shown in Table 4. The crude protein percentage of the millets was twice that of the forage sorghum. At Caruaru where millets were harvested earlier than at Sao Bento do Una, crude protein percentages were slightly higher.

Millet hybrids produced better quality forage than did the varieties under both environmental conditions, achieving values of 541 to 749 kg ha^{-1} crude protein. These values are 35-88% higher than that of sorghum IPA 02-03-01 (Table 5). Although the sorghum variety produced 28-47% more DM than the millets, it was of lower quality.

Conclusions

- The DMY potential of sorghum variety IPA 02-03-01 was higher than that of the millets tested
- IPA 02-03-01 forage sorghum is a later cultivar than the millets tested
- Forage millet cultivars compensated for producing less DM than IPA 02-03-01 because they produced more protein, and the hybrids produced more than the varieties
- Depending on the prevailing circumstances in the semi-arid region of Pcrnambuco both the earlier pearl millet cultivars and the later IPA 02-03-01 forage sorghum can be recommended.

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Dry Matter Production Yield and Water-Use Efficiency of Forage Sorghum Lines under Drought Conditions

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is adapted to many local environments, but it is usually cultivated under conditions of high temperature in semi-arid environments. In terms of water-use efficiency, sorghum needs less water to produce the same amount of dry matter as maize (*Zea mays* L.) (332 versus 368 kg H_2O kg^{-1} dry matter). Aside from the crop's potential adaptation to the semi-arid conditions, the usefulness of its products is evident: fodder, grain, straw, hay, and silage (Tabosa et al. 1990). The reported objective was to evaluate sorghum lines, for their dry matter yield (DMY) potential, and water-use efficiency (WUE) at three stages of development ; seedling, pre-flowering, and post-flowering.

Material and methods

The work was done during 1996/97 at the experimental station of the Empresa Pernambucana de Pesquisa Agropecuaria (IPA), in the municipal district of Vitoria de Santo Antao. The sorghum lines (Table 1) were characterized as late flowering, needing between 90 and 110 days to reach the flowering stage. Three different sowing times were tested in three experiments. In the first (EP1), the drought occurred in GS3 (post-flowering), in the second (EP2), the plants suffered drought in GS2 (pre-flowering), and in the third (EP3), they were droughted in GS1 (seedling). The experimental design was a randomized block with three replications. The sorghum lines sown in EP1 and EP2 were irrigated until 13 November 1996 when EP3 was sown.

The irrigated control was grown in humid conditions determined according to Bernardo (1987). Irrigation was interrupted soon after EP3 was sown and from then on the three sowings were subjected to droughts. For each sowing the DMY and WUE were measured following Tabosa et al. (1987). Data were analyzed by analysis of variance (Steel and Torrie 1960).

Table 1. Sorghum lines used in the experiment, IPA station, Vitoria de Santo Antao, Pernambuco, Brazil, 1996/97.

Entry	Name	Entry	Name
1	SFEH-01	11	SFEH-11
2	SFEH-02	12	SFEH-12
3	SFEH-03	13	SFEH-13
4	SFEH-04	14	SFEH-14
5	SFEH-05	15	IPA SF 25
6	SFEH-06	16	IPA 467-4-2
7	SFEH-07	17	IPA 1158
8	SFEH-08	18	IPA 322-1-3
9	SFEH-09	19	IPA 1218
10	SFEH-10	20	IPA 02-03-01

Results and discussion

Figure 1 shows the DMYs for each sowing of the 20 forage sorghum lines evaluated. The lines differed in genetic potential irrespective of the time they were sown. In EP1 at 1% level of probability, lines with high DMYs were SFEH-01 and SFEH-14, and IPA 1218 had low DMY.

Those differences are, probably, more related to the genetic potential of lines than to their tolerance of drought because in the post-flowering phase dry matter yield is hardly affected by abiotic stresses. In EP2, DMYs of tested lines showed wide variation (6.42 to 20.08 t ha^{-1}). SFEH-12, SFEH-08, and SFEH-01 had high DMYs, while IPA 1218 had a low DMY. As in EP1, the observed differences in EP2 are probably due to the genetic potentials of each line.

In EP3 there was again wide variation in DMY (1.63 to 13.71 t ha^{-1}) indicating genetic variability in the lines' adaptation to drought. Statistical analysis showed that the sorghum lines most tolerant to drought were SFEH-01, IPA 1158, and SFEH-08. The most sensitive lines were IPA 1218, IPA 467-4-2, and SFEH-02. Comparing DMYs across the three sowings showed that drought in the seedling phase (GS1) caused a significant reduction (about 50%) in the DMYs of all the sorghum lines, thus indicating the deleterious effects of drought on this stage of ontogenetic development.

Figure 2 shows the significant differences among lines in WUE for the three sowings. In EP1, WUE varied from 265 to 1053 kg H_2O kg^{-1} DM. The more efficient lines

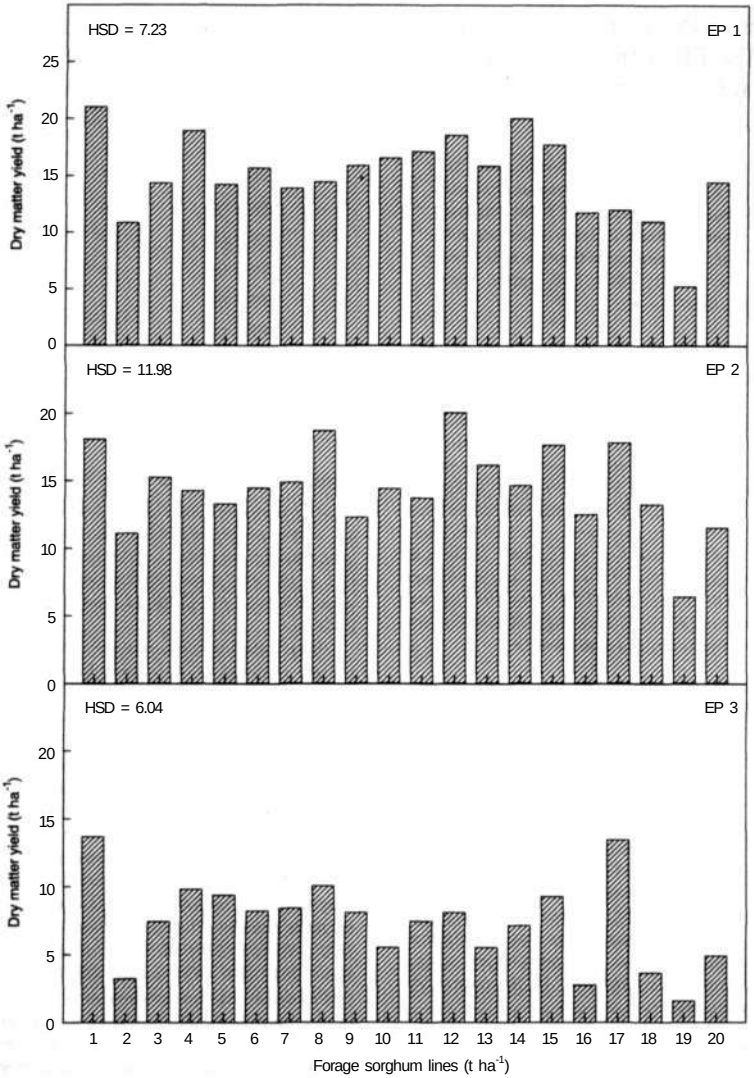

Figure 1. Dry matter yield (t ha^{-1}) of 20 forage sorghum entries (listed in Table 1) harvested at three different times. EP1 (post-flowering drought GS3 phase), EP2 (pre-flowering drought GS2 phase), and EP3 (seedling drought GS1 phase). HSD = Tukey's Honestly significant difference (α <0.05)

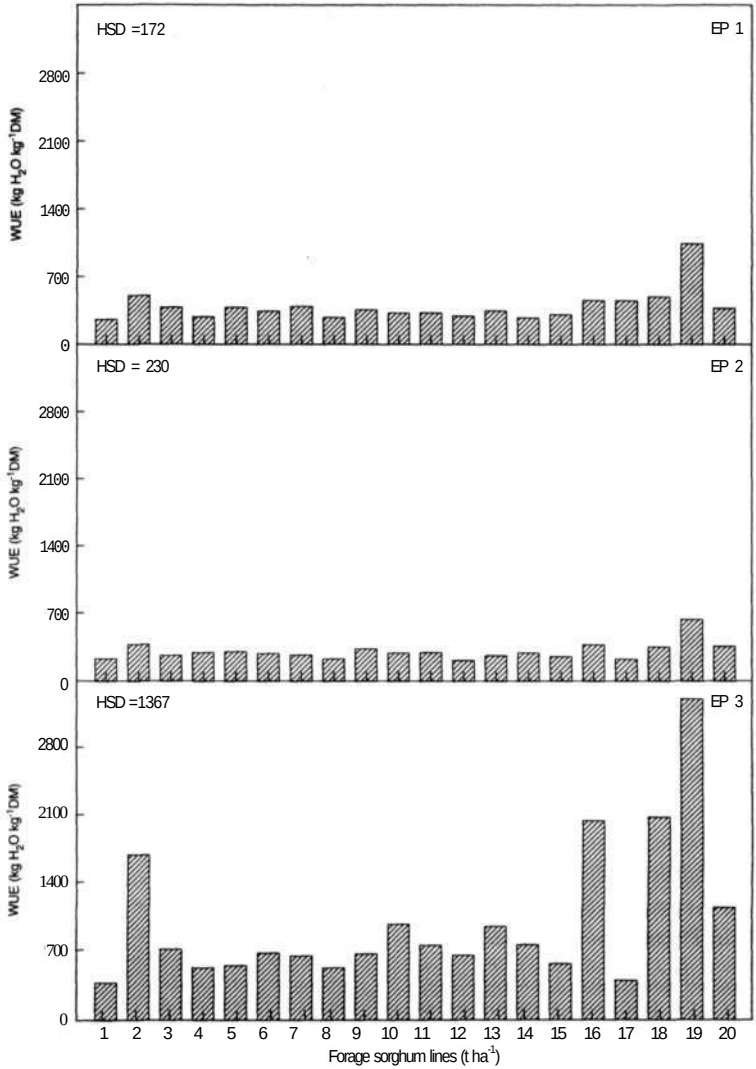

Figure 2. Water-use efficiency (WUE kg H_2O kg^{-1} DM) of 20 forage sorghum entries (listed in Table 1) sown on three different dates. EP1 (post-flowering drought GS3 phase), EP2 (pre-flowering drought GS2 phase), and EP3 (seedling drought GS1 phase). HSD = Tukey's Honestly significant difference (α <0.05)

were SFEH-01, SFEH-14, and SFEH-04, and the least efficient was IPA 1218.

In EP2 there was less variation. IPA 1218 was still the least efficient, while the WUE values of the other lines did not differ significantly. For the three sowings the largest variation in WUE among the tested lines was in EP3, IPA 1218 was least efficient, unlike SFEH-01 and IPA 1158 that were highly efficient, even under drought-stressed conditions.

Conclusions

- The forage sorghum line SFEH-01 produced high DMY and high values for WUE in all three sowings
- Drought in the seedling phase caused a reduction of 50% in the DMY, more than drought in the pre-flowering and post-flowering phases.

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Organic Matter Effects on Forage Sorghum Grown on Sandy Soils in Semi-Arid Pernambuco, Brazil

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Introduction

In the semi-arid region of Pernambuco the importance of forage sorghum [*Sorghum bicolor* (L.) Moench] is emphasized by its xerophilic characteristics. Regosols occupy about 18% of the total physical area of Pernambuco State (Brasil 1973). The main factors restricting agriculture on Regosols are the low levels of fertility and organic matter in these soils. The lack of water is self-evident, so the use of organic fertilizers in the improvement of the soil's physical and chemical properties, mainly its sandy texture, is an old practice and of proven value (Sampaio et al. 1985; Lopes 1986). The most important factor governing the use of organic matter is the availability of low-cost cow manure and chicken litter from local farms (Farias et al. 1986).

Material and methods

The research was carried out during 1994-97, at the Sao Bento do Una Experimental Station of the IPA, located in the semi-arid region of Pernambuco State, whose geographical and climatic characteristics are shown in Table 1.

Table 1. Geographical and climatic characteristics of the Sao Bento do Una Experimental Station Pernambuco State, Brazil.

Parameters	Value / Characteristic
Latitude	08°31' 16" S
Longitude	38°33'00" W
Altitude	655 m
Annual precipitation	650 mm
Potential evapotranspiration	1400 mm
Real evapotranspiration	655 mm
Medium temperature	25°C
Climate type	Semi-arid megathermic
Air relative humidity	55%

Sources: Encarnacao (1980); Anuario Estatistico de Pernambuco (1994).

The experimental design was a randomized block with seven treatments and four replications, where: T1 = no organic fertilizer (control); T2 = 10 t ha^{-1} organic matter (cow manure); T3 = 20 t ha^{-1} organic matter (cow manure); T4 = 30 t ha^{-1} organic matter (cow manure); T5 = 5 t ha^{-1} organic matter (chicken litter); T6 = 10 t ha^{-1} organic matter (chicken litter); and T7 = 15 t ha^{-1} organic matter (chicken litter). These quantities of organic matter were applied to the soil annually.

Seed of forage sorghum IPA SF 25 was sown at the beginning of the rainy season, after manure was spread and incorporated into each treatment plot. Planting density was 15 plants per linear meter, after thinning, at a row spacing of 0.5 m. Plants were harvested at the dough grain stage. The parameters used to evaluate the efficiency of treatments were; Dry matter yield (DMY) and water-use efficiency (WUE), calculated using the formula: WUE = (P/y) x 10, where: WUE = water-use efficiency (kg water kg^{-1} dry matter); P = 70% of the precipitation during crop cycle; y = dry matter yield (t ha^{-1}) (Tabosa et al. 1987).

Results and discussion

Figure 1 (a and b) shows the results of absence and presence of organic matter on DMY and WUE independent of the levels and sources used. The dry matter increment was 493%, when organic matter was added to the soil, significantly different from the control treatment that did not receive inputs. Plants that did not receive organic matter needed 77 times more water to produce the same amount of DM than plants that did.

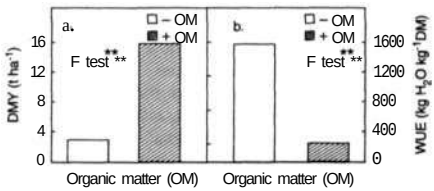

Figure 1. Effect of applying organic matter (OM) to soil on a. forage sorghum dry matter yield (DMY), and b. water-use efficiency (WUE), Sao Bento do Una, semi-arid region, Pernambuco State, Brazil, 1994-97 (F test ** significant at (α < 0.01).

Significant differences were not detected between cow manure and chicken litter in either DMY response or in WUE response. In addition, cow manure levels (10, 20, and 30 t ha^{-1}) did not have significant effects on DMY (14.33, 16.73, and 17.71 t ha^{-1}). Similar results were obtained from the use of chicken litter (5, 10, and 15 t ha^{-1}). At these levels, DMYs were 14.16, 15.48, and 16.26 t ha^{-1}).

Significant differences in effect were not observed between cow manure and chicken litter levels for WUE. Thus, independent of organic matter sources and levels, WUE varied from 161 to 206 kg H_2O kg^{-1} DM. These values are considered highly efficient for sorghum forage crops, according to Tabosa et al. (1990).

Conclusions

- Cow manure levels of 10 to 30 t ha^{-1} and chicken litter levels of 5 to 15 t ha^{-1}, promoted DMY and WUE increments compared to those in the absence of organic matter supplements
- Application of cow manure at a minimum level (10 t ha^{-1}) or chicken litter at 5 t ha^{-1} are recommended for forage sorghum in this region.

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Nutritional Evaluation of Forage Sorghum Varieties in Field Conditions in a Semi-Arid Region of Brazil

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Introduction

Plant species and varieties vary in their nutritional requirements. Thus, it is common that under the same soil fertility conditions, large differences in the nutrition and in the growth of some varieties can be found. The reasons for such differential behavior can be internal or external. Many researchers credit such differential behavior among the plants to genetic control without scientific proof. Consequently, in this study, the nutritional characteristics used in plant breeding are proposed as a strategy whereby to increase fertilizer-use efficiency and increase productivity under conditions of low soil fertility or low technology availability (Clark and Duncan 1991). The objective of the study was to evaluate the nitrogen (N), phosphorus (P), and potassium (K) accumulation and utilization rates in four forage sorghum [*Sorghum bicolor* (L.) Moench] varieties across five growth stages up to harvest.

Material and methods

The work was conducted under field conditions at the Caruaru Experimental Station of the IPA, the agriculture and livestock research corporation of Pernambuco State. In this semi-arid region of Brazil, the soil is classified as Litholic, Euthrophic, and of medium texture. Soil chemical analyses results are presented in Table 1.

Fertilizers were applied uniformly to each plot; 60 kg of P_2O_5 ha^{-1} as triple super phosphate presowing, then 90 kg of N ha^{-1} as ammonium sulphate, applied in three splits at 25, 40, and 60 days after sowing (DAS).

The experimental design was a randomized block, with four replications, in an factorial arrangement among four forage sorghum varieties and five harvest stages. The forage sorghum varieties used were:

- V1 IPA 467-4-2 sweet sorghum
- V2 IPA SF 25 half sweet sorghum
- V3 IPA 7301158 dry culm, early
- V4 IPA 02-03-01 dry culm.

The harvest stages were:

- E1 booting (70 DAS for V3; 90 DAS for V1, V2, and V4)
- E2 anthesis (80 DAS for V3; 100 DAS for V1, V2, and V4)
- E3 grain milk (100 DAS for V3; 120 DAS for V1, V2, and V4)
- E4 dry grain (120 DAS for V3; 135 DAS for V1, V2 and V4)
- E5 straw (160 DAS for all varieties)

After harvesting at each growth stage, the N, P, and K contents of the plants were determined by Kjeldahl (N), molybdanate (P), and flame photometry (K) (Sarruge and Haag 1974). The N, P, K contents; crude protein (CP); P and K percentages; N, P, K soil exportation, and N, P, K absolute accumulation rates (AAR) were evaluated. Analysis of variance was performed to verify the effects of varieties, harvest stages, and their interactions. For data adjustment, first and second degree polynomial functions were used (Tables 2, 3, and 4). The adequacy of each model was assessed using coefficients of determination (r^2) for its ability to predict expected physiologic functions. From the expressions adjusted for quantitative description of the N, P, K accumulation and concentration functions, the following rates were derived, according to Araujo et al. (1996):

- Nutrient (NUT) Relative Accumulation Rate (RAR)
  $RAR = (1/C_{NUT}) \times (dC_{NUT}/dt) = (g\ NUT\ g^{-1}\ NUT\ d^{-1})$
- Nutrient Specific Utilization Rate (SUR)
  $SUR = (1/C_{NUT}) \times (dDM/dt) = (g\ DM\ g^{-1}\ NUT\ d^{-1})$
  where : C_{NUT} = nutrient content, DM = shoot dry matter, and t = time.

Table 1. Soil chemical analysis results, Caruaru Experimental Station, Pernambuco State, Brazil.

Water pH	Ca^{++1}	Mg^{++1}	K^{+1}	H^{+1}	Al^{+++1}	P^2
5.35	3.63	0.87	0.24	3.22	0.08	19.6

1. cmol dm^{-3} (charge centmol) = meq . 100 cm^{-3}, according to Tome Jr. (1997); 2. $mg.dm^{-3}$

Table 2. Adjusted functions and determination coefficients (r^2) of N content, N concentration, N exportation, and N absolute accumulation (AAR), relative accumulation (RAR), and specific utilization rates (SUR) in four forage sorghum varieties (y), as functions of the days after sowing (x).

N variables	Varieties	Functions	r^2
Shoot content	IPA 467-4-2	$y = -0.1464x^2 + 32.5346x - 1238.3714$	0.79
	IPA SF 25	$y = -0.1391x^2 + 32.0112x - 1382.3179$	0.86
	IPA 73001158	$y = -0.0760x^2 + 17.1084x - 569.8250$	0.87
	IPA 02-03-01	$y = -0.0777x^2 + 16.8969x - 425.7010$	0.93
	IPA 467-4-2	$y = -0.0144x + 2.7953$	0.93
Concentration	IPA SF 25	$y = -0.0148x + 3.1092$	0.98
	IPA 73001158	$y = -0.0117x + 3.4806$	0.88
	IPA 02-03-01	$y = -0.0132x + 2.5502$	0.84
	IPA 467-4-2	$y = -0.0288x^2 + 6.2568x - 231.5612$	0.84
Exportation	IPA SF 25	$y = -0.0260x^2 + 5.8709x - 248.0814$	0.88
	IPA 73001158	$y = -0.0149x^2 + 3.2005x - 88.9094$	0.84
	IPA 02-03-01	$y = -0.0152x^2 + 3.2540x - 82.4270$	0.95
	IPA 467-4-2	$y = -8.20.10V - 0.0376x + 16.1088$	0.99
Absolute accumulation rate (AAR)	IPA SF 25	$y = -1.73.10^{-3}x^2 + 0.2246x - 1.0068$	0.97
	IPA 73001158	$y = -7.89.10^{-4}x^2 + 0.0805x + 2.9450$	0.93
	IPA 02-03-01	$y = 6.39.10^{-4}x^2 - 0.3133x + 27.7992$	0.99
	IPA 467-4-2	$y = 0.0178x^2 - 5.6146x + 415.7930$	0.85
Relative accumulation rate (RAR)	IPA SF 25	$y = 0.0141x^2 - 4.7189x + 363.6934$	0.89
	IPA 73001158	$y = 0.0163x^2 - 4.6153x + 308.9269$	0.90
	IPA 02-03-01	$y = 0.0236x^2 - 6.8217x + 475.6073$	0.78
	IPA 467-4-2	$y = -0.0822x + 11.1299$	0.97
Specific utilization rate (SUR)	IPA SF 25	$y = 8.62.10 V - 0.2736x + 21.0270$	0.90
	IPA 73001158	$y = 3.50.10^{-4}x^2 - 0.1190x + 9.7311$	0.99
	IPA 02-03-01	$y = -0.0803x + 11.3342$	0.98

Table 3. Adjusted functions and determination coefficients (r^2) of P content, P concentration, P exportation, and P absolute accumulation (AAR), relative accumulation (RAR), and specific utilization rates (SUR) in four forage sorghum varieties (y), as functions of the days after sowing (x).

P variables	Varieties	Functions	r^2
Shoot content	IPA 467-4-2	$y = -0.0176x^2 + 3.9496x - 150.1617$	0.81
	IPA SF 25	$y = -0.0169x^2 + 3.9114x - 173.1155$	0.79
	IPA 73001158	$y = -0.0141x^2 + 3.1525x - 119.1129$	0.99
	IPA 02-03-01	$y = -8.25.10V + 1.7429x - 29.0438$	0.73
Concentration	IPA 467-4-2	$y = -0.0171x + 3.3990$	0.94
	IPA SF 25	$y = -0.0149x + 3.3530$	0.94
	IPA 73001158	$y = -0.0251x + 4.8906$	0.88
	IPA 02-03-01	$y = -0.0176x + 3.3707$	0.77
Exportation	IPA 467-4-2	$y = -3.52.10 V + 0.7704x - 28.6096$	0.86
	IPA SF 25	$y = -3.13.10^{-3}x^2 + 0.7128x - 30.8588$	0.88
	IPA 73001158	$y = -2.78.10 V + 0.6018x - 20.5405$	0.98
	IPA 02-03-01	$y = -1.62.10^{-3}x^2 + 0.3350x - 5.6076$	0.80

Cont.

Table 3. ***Continued.***

P variables	Varieties	Functions	r^2
Absolute accumulation rate (AAR)	IPA 467-4-2	$y = -1.05.10\ V - 2.89.10^{-3}\ x + 1.8671$	0.99
	IPA SF 25	$y = -2.36.10\ V + 0.0344x - 0.5672$	0.96
	IPA 73001158	$y = -1.95.10^{-4}\ x^2 + 0.0276x - 0.2548$	0.89
	IPA 02-03-01	$y = 1.44.10^{-4}\ x^2 - 0.0540x + 4.2838$	0.97
Relative accumulation rate (RAR)	IPA 467-4-2	$y = 9.25.10\ V - 3.2090x + 251.1752$	0.90
	IPA SF 25	$y = -0.9623x + 120.5518$	0.95
	IPA 73001158	$y = 7.30.10\ V - 2.4356x + 183.7308$	0.99
	IPA 02-03-01	$y = 0.0153x^2 - 4.5055x + 316.5986$	0.81
Specific utilization rate (SUR)	IPA 467-4-2	$y = -0.5323x + 71.8247$	0.99
	IPA SF 25	$y = -0.3828x + 53.3071$	0.95
	IPA 73001158	$y = -0.2344x + 33.7345$	0.87
	IPA 02-03-01	$y = -0.5021x + 70.9328$	0.98

Table 4. Adjusted functions and determination coefficients (r^2) of K content, K concentration, K exportation, and K absolute accumulation (AAR), relative accumulation (RAR), and specific utilization rates (SUR) in four forage sorghum varieties (y), as functions of the days after sowing (x).

K variables	Varieties	Functions	r^2
Shoot content	IPA 467-4-2	$y = -0.0688x^2 + 16.0870x - 363.8287$	0.77
	IPA SF 25	$y = -0.0247x^2 + 4.6699x + 209.6249$	0.50
	IPA 73001158	$y = -0.0506x^2 + 11.7629x - 349.5902$	0.69
	IPA 02-03-01	$y = -2.09.10^{-3}\ x^2 - 2.2593x + 760.6276$	0.57
Concentration	IPA 467-4-2	$y = 3.42.10^{-3}\ x^2 - 0.9350x + 73.0565$	0.90
	IPA SF 25	$y = 3.33.10\ V - 0.9510x + 78.8122$	0.99
	IPA 73001158	$y = 2.70.10^{-3}\ x^2 - 0.7595x + 62.0826$	0.94
	IPA 02-03-01	$y = 4.53.10^{-3}\ x^2 - 1.2541x + 93.9304$	0.94
Exportation	IPA 467-4-2	$y = -0.0173x^2 + 3.8130x - 101.2790$	0.94
	IPA SF 25	$y = -7.46.10\ V + 1.4054x + 14.1512$	0.74
	IPA 73001158	$y = -9.78.10\ V + 2.1291x - 46.2757$	0.65
	IPA 02-03-01	$y = -1.37.10\ V - 0.1026x + 127.5237$	0.72
Absolute accumulation rate (AAR)	IPA 467-4-2	$y = 6.28.10\ V - 0.2945x + 26.8803$	0.99
	IPA SF 25	$y = 1.80.10V - 0.5371x + 37.3933$	0.85
	IPA 73001158	$y = -4.13.10^{-4}\ x^2 + 0.0245x + 4.1131$	0.96
	IPA 02-03-01	$y = 3.46.10\ V - 0.9424x + 61.0194$	0.67
Relative accumulation rate (RAR)	IPA 467-4-2	$y = 0.0254x^2 - 7.1918x + 494.9743$	0.76
	IPA SF 25	$y = 0.0273x^2 - 7.5777x + 511.5218$	0.72
	IPA 73001158	$y = 0.0169X^2 - 4.6375x + 304.3116$	0.84
	IPA 02-03-01	$y = 0.0309x^2 - 8.4358x + 560.8620$	0.68
Specific utilization rate (SUR)	IPA 467-4-2	$y = -0.0722x + 10.0003$	0.95
	IPA SF 25	$y = 7.39.10V - 0.2352x + 18.2083$	0.90
	IPA 73001158	$y = 3.45.10V - 0.1219x + 10.2884$	0.98
	IPA 02-03-01	$y = -0.0660x + 9.3945$	0.98

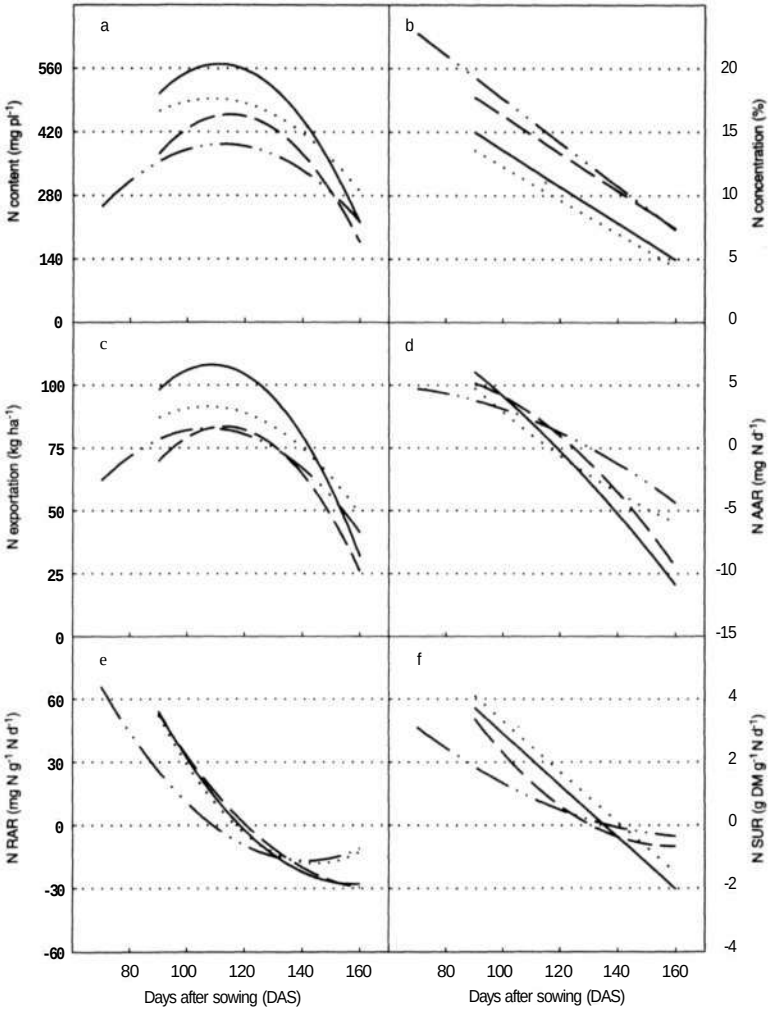

Figure 1. a. N content; b. N concentration; c. N exportation; d. N absolute accumulation rate (AAR); e. N relative accumulation rate (RAR); and f. N specific utilization rate (SUR) of four forage sorghum varieties (V1-V4) grown under field conditions.

V1 IPA 467-4-2 V2 IPA SF 25 V3 IPA 7301158 V4 IPA 02-03-01

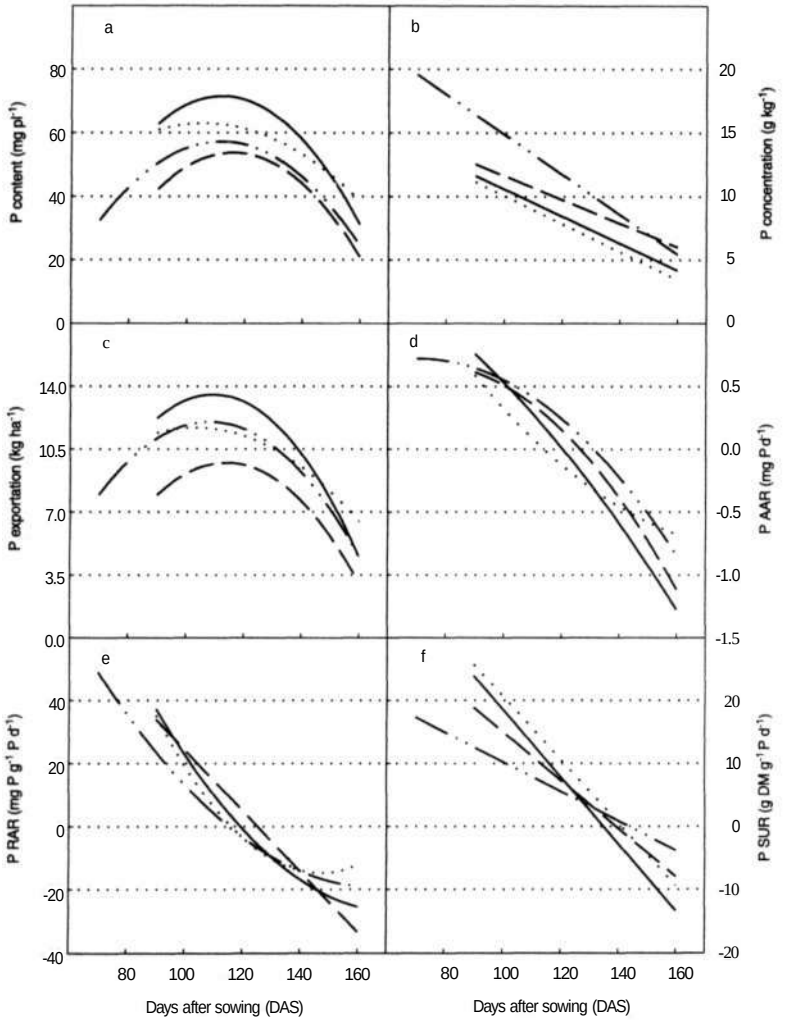

Figure 2. a. P content; b. P concentration; c. P exportation; d. P absolute accumulation rate (AAR); e. P relative accumulation rate (RAR); and f. P specific utilization rate (SUR) of four forage sorghum varieties (V1-V4) grown under field conditions.

V1 IPA 467-4-2 V2 IPA SF 25 V3 IPA 7301158 V4 IPA 02-03-01

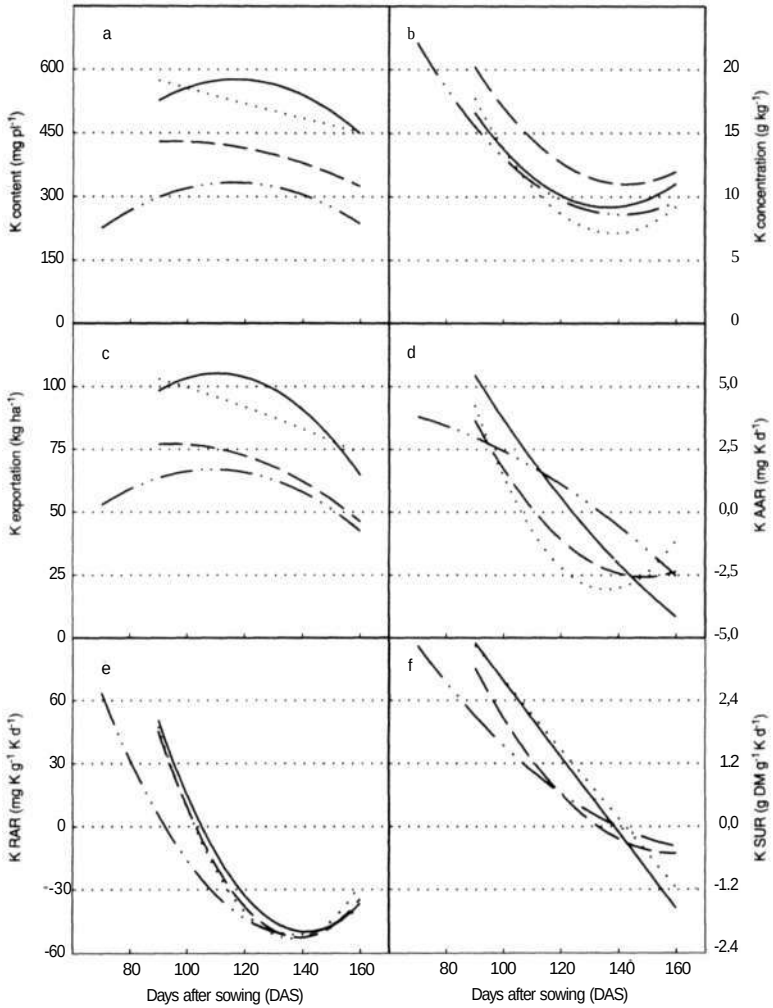

Figure 3. a. K content; b. K concentration; c. K exportation; d. K absolute accumulation rate (AAR); e. K relative accumulation rate (RAR); and f. K specific utilization rate (SUR) of four forage sorghum varieties (V1-V4) grown under field conditions.

V1 IPA 467-4-2 V2 IPA SF 25 V3 IPA 7301158 V4 IPA 02-03-01

Results and discussion

N, P, K content and concentration. The results obtained for these variables presented a second degree distribution (Figures 1a, 2a, and 3a). The highest values were obtained among the anthesis and grain milk stages (100-120 DAS). This variation in N, P, K contents was more influenced by the dry matter yield (DMY) than N, P, or K concentration. The nutrient concentration decreased linearly with the plant ontogeny (Figures 1b, 2b, and 3b). V1 had N (45%), P (13%), and K (73%) higher than V3.

The progressive reduction in N, P, and K concentrations indicates that the nutrient absorption was more affected by plant age than growth, probably due to the progressive decline in their root systems' absorption capacity (Rossielo et al.. 1995). V1 and V4 had lower N, P, and K concentrations than V2 and V3, probably due to a dilution effect of their producing the largest biomass yields. Amongst the varieties that produced the most DMY at 135 DAS (Azevedo Neto and Tabosa 1998), the following N, P, and K concentrations were found:

- V1 8.5 N, 1.1 P, and 9.2 g kg^{-1} K
- V2 11.1 N, 1.3 P, and 11.1 g kg^{-1} K
- V3 19.0 N, 1.5 P, and 8.8 g kg^{-1} K
- V4 7.7 N, 1.0 P, and 7.2 g kg^{-1} K

N, P, K exportation. These variables had similar patterns to those of the N, P, K contents (Figures 1c, 2c, and 3c). The highest nutrient exportation values were reached among E2 and E3 stages (100-120 DAS). Considering that the highest DMY was produced at 135 DAS, the N, P, K nutrient values were:

- V1 88 N, 11 P, and 98 K kg ha^{-1}
- V2 71 N, 8P, and 68 K kg ha^{-1}
- V3 72N, 10 P, and 63 K kg ha^{-1}
- V4 80 N, 10 P, and 89 K kg ha^{-1}

N, P, K absolute accumulation rate (AAR). The AAR indicates the nutrient accumulation velocity and relates closely to the absolute growth rate and nutrient concentrations. Thus, the N, P, and K AARs continually decrease after E1 (Figures 1d, 2d, and 3d). The varieties studied reached negative values of N and P AARS after E3 (120 DAS), and K AAR after the E2 (100 DAS), due to nutrients lost through leaf fall.

N, P, K relative accumulation rate (RAR). The N, P, K metabolic demand, expressed by N, P, K RAR, is influenced by two factors: 1. the root influx, that indicates in an integrated manner the effects of absorption kinetic parameters, and 2. the root area rate, that expresses the root surface necessary for nutrient absorption (Manzatto et al. 1997). The N, P, and K RARs of the varieties reduced with progressive growth stages, with the exception of V3 that had a slightly different pattern from the others, due probably to its earliness (Figures 1e, 2e, and 3e). The N, P, and K RAR values for varieties analyzed were negative after E3, reflecting the nutrient losses already verified by N, P, and K AARs.

Conclusions

- Genotypic differences in N, P, K content and concentration, exportation, and nutritional evaluation rates were identified in the varieties analyzed
- Plant growth analysis, associated with a nutritional study can be used in plant breeding programs
- Sorghum forage varieties IPA 467-4-2 and IPA 02-03-01 used N, P, and K nutrients most efficiently among the varieties tested
- Sorghum forage varieties IPA SF 25 and IPA 7301158 had lower N, P, K exportation values than the other varieties tested at the harvest stages evaluated.

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Sudan Grass Management under Salt Stress in Semi-Arid Pernambuco, Brazil

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Introduction

In recent years the identification and use of forage plants from the semi-arid, saline areas of the northeast region of Brazil has become increasingly important; agronomically and particularly ecologically. The salinity of these areas is the prime factor limiting most crops. There is now evidence that about 25 to 30% of the irrigated areas of the northeast region, are saline or in process of becoming so (Willadino et al. 1994; Azevedo Neto 1997). However, the main problem in the region, is the lack of fodder, particularly in the dry period of the year. Riverside areas and shoals are often used for forage production, but are limited by soil salinity despite sufficient soil moisture that could support forage crops tolerant to salinity. When considering plants tolerant to salinity, management studies and germplasm evaluation in these environments are needed. Sudan Grass [*Sorghum hicolor* (L.) Moench] was previously identified as salinity tolerant in these environments.

The objective of this work was to obtain information on the management of Sudan Grass varieties for forage production in saline environments.

Material and methods

The experiment was carried out during 1996/97, at Empresa Pernambucana de Pesquisa Agropecuaria (IPA), located in the Agreste semi-arid region of Pernambuco, Brazil. Descriptions of the locations are provided in Table 1. The Sudan Grass varieties had been selected earlier as salinity tolerant. They were grown at two spacings and harvested at three different growth stages.

The experimental design was a randomized block, with four replications, in a factorial arrangement. The 2 (varieties) x 2 (spacings) x 3 (harvest stages), were:

Varieties
- V1 PU 7664273
- V2 PU 7664274

Table 1. Geophysical and environmental features of Sao Bento do Una location, Brazil.

Parameters	Value/characterization
Mesoregion	Agreste
Latitude	08°31' 16" S
Longitude	38°33'00" w
Altitude	655 mm
Annual precipitation	650 mm
Potential evapotranspiration	1400 mm
Real evapotranspiration	655 mm
Average temperature	25°C
Climatie type	Semi-arid megathermic
Relative humidity	55%

Sources: Encarnacao (1980);
Anuario Estatistico de Pernambuco (1994)

Spacings
- S1 0.5 m between rows
- S2 1.0 m between rows

Harvest stages
- HS1 booting stage
- HS2 anthesis
- HS3 grain milk stage

The following variables were measured; dry matter yield (DMY) of stems, leaves, and panicles, and total DMY.

Results and discussion

Results are presented in Table 2. Leaf DMY reduced and panicle DMY increased as the plants developed. In general, higher values of leaf/stem ratio were obtained at anthesis, independent of spacing or the variety used. The highest total DMY was obtained at HS2, independent of varieties or spacing. Without considering spacing or harvest stage, the highest values of total DMY were obtained from variety V1. Plants grown at S1 spacing produced more in these conditions than plants grown at S2 spacing.

A significant interaction between V x S was found in total DMY (Table 3). Variety V1 produced more total DMY than V2 at S1 spacing. Variety V1 at S1 spacing produced significantly different total DMY than at S2 spacing (Table 4).

Conclusions

- Sudan Grass varieties showed salinity tolerance
- At 0.5-m row spacing when harvested during anthesis plants produced the highest total DMY
- Varieties PU 7664273 and PU 7664274 can be recommended as forage varieties for saline environments

Table 2. Sudan Grass evaluation in a saline area of Pernambuco State, Brazil, 1996/97.

Treatments		Total dry matter yield (DMY) (t ha^{-1})			
Variety[1] Spacing[2]	Growth stage[3]	Leaf	Stem	Panicle	Total
	HS1	3.05	5.35	1.33	9.78
S1 (0.5m)	HS2	2.67	7.77	2.44	12.89
	HS3	1.77	3.58	3.74	9.11
V1 (Pu 7664273)					
	HS1	2.77	4.48	0.84	8.10
S2 (1.0m)	HS2	1.92	5.24	1.38	8.56
	HS3	1.47	3.23	3.32	8.02
	HS1	2.69	4.70	1.10	8.50
S1 (0.5m)	HS2	1.94	4.66	2.74	9.34
	HS3	1.81	3.99	3.03	8.84
V2 (Pu 7664274)					
	HS1	2.33	3.74	1.04	7.12
S2(1.0m)	HS2	2.10	5.22	2.31	9.64
	HS3	1.71	2.14	3.20	7.05

1. V1 = variety PU 7664273; V2 = variety PU 7664274
2. S1 = 0.5m spacing; S2 = 1.0m spacing
3. HS1 = booting; HS2 = anthesis; HS3 = grain milk stage

Table 3. Analysis of variance, F-test for total dry matter yield (DMY), Sudan Grass evaluation in saline area, Sao Bento do Una, Pernambuco State, Brazil, 1996/97.

	F (dry matter production)			
Source of variation[1]	Stem	Leaf	Panicle	Total
V	14.17 **[2]	2.24 ^{NS}	0.10 ^{NS}	14.21 **
S	19.06 **	4.83 *	4.19 ^{NS}	39.70 **
HS	39.19 **	22.40 **	49.07 **	20.63 **
V x S	1.17 ^{NS}	2.00 ^{NS}	2.19 ^{NS}	7.09*
V x HS	2.15 ^{NS}	1.79 ^{NS}	2.57 ^{NS}	0.53 ^{NS}
CV (%)	12.4	14.0	20.0	7.2

1. CV = Coefficient of variation; V = Sudan Grass variety; S = spacing, HS = harvest stage
2. * = significant at $\alpha < 0.05$; ** = significant at $\alpha < 0.01$; NS = not significant, by Tukey's Honestly significant difference

Table 4. Effect of interaction between variety and spacing on total dry matter yield[1].

	Total dry matter yield (DMY) (t ha^{-1}) x spacing	
Variety S1	(0.5-m)	S2 (1.0m)
V1 (Pu 7664273)	10.58 aA	8.22 aB
V2 (Pu 7664274)	8.88 bA	7.92 aA

1. Means followed by the same letter are not significantly different by Tukey's Honestly significant difference ($\alpha < 0.05$).

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Timing Harvest of Forage Sorghums in Semi-Arid Pernambuco, Brazil

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Introduction

The main factor limiting to livestock performance in the semi-arid region of Pernambuco is the lack of fodder in the dry period of the year. Forage sorghum [*Sorghum hicolor* (L.) Moench] could be a strategic option because of the crops' xerophilic characteristics, adaptation potential, and wide range of potential uses (Lira et al. 1986). Information on the best time to harvest, considering dry matter yield (DMY) and forage quality are very important considering the different natures of the varieties, e.g., succulent culm (sweet sorghum) or dry culm. This research was undertaken to obtain information on the optimum harvest point for four forage sorghum varieties.

Materials and methods

The work was carried out under field conditions from 1992-97 at Empresa Pernamhucana de Pesquisa Agropecuaria (IPA) experimental stations located in the semi-arid region of Pernambuco, Brazil.

The experimental design was a randomized block, with four replications, in an factorial arrangement of 4 varieties of forage sorghum x 5 growth stages to harvest. The experiment was carried out in 13 different environments. The forage sorghum varieties used were:

- V1 IPA 467-4 2 sweet sorghum
- V2 IPA SF-25 half-sweet sorghum
- V3 IPA 7301158 dry culm and early
- V4 IPA 02-03-01 dry culm.

The harvest stages were:

- E1 booting
- E2 anthesis
- E3 grain milk
- E4 dry grain
- E5 straw

Each plot was composed of four 6.0-m rows spaced at 0.80 m, with 15 plants per linear meter after thinning. The crop was sown at the beginning of the rainy season and soil fertilization was preceded by soil analysis.

Data obtained from the 13 sites was analyzed for the DMY, plant height (PH), dry matter percentage (DMP), water-use efficiency (WUE), and crude protein content (CP) determined by the Kjeldahl method according to Silva (1981). The procedure used to estimate WUE was that of Tabosa et al. (1987).

Results and discussion

Dry matter yield (DMY). For this variable, there were significant effects among environments, varieties, and harvest stages. The variety x harvest stages interaction was not significant. Average DMYs were compared independently (Figure 1). The studied varieties, independent of harvest stage, behaved differently for this variable: V1, V2, and V4 did not differ in DMY, but were superior to V3. The DMY at each harvest stage was caluclated, independent of the variety. The lowest DMY was obtained in the E1 harvest stage, and the highest at E3, showing an increment of 46% in DMY from booting to the grain milk stage. DMYs of 7.0 t ha^{-1} are considered high for the semi-arid environments of Pernambuco Stale (Lita et al. 1986).

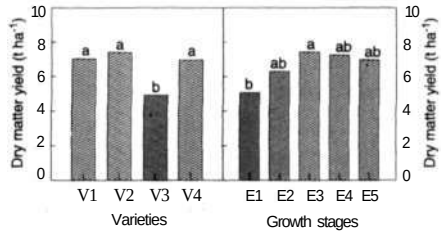

Figure 1. Dry matter yield of 4 forage sorghum varieties and 5 harvest stages, Pernambuco State, semi-arid region, Brazil, 1992-97. Variety or growth stage means under the same letter do not different significantly according to Tukey's Honestly significant difference ($\alpha < 0.05$).

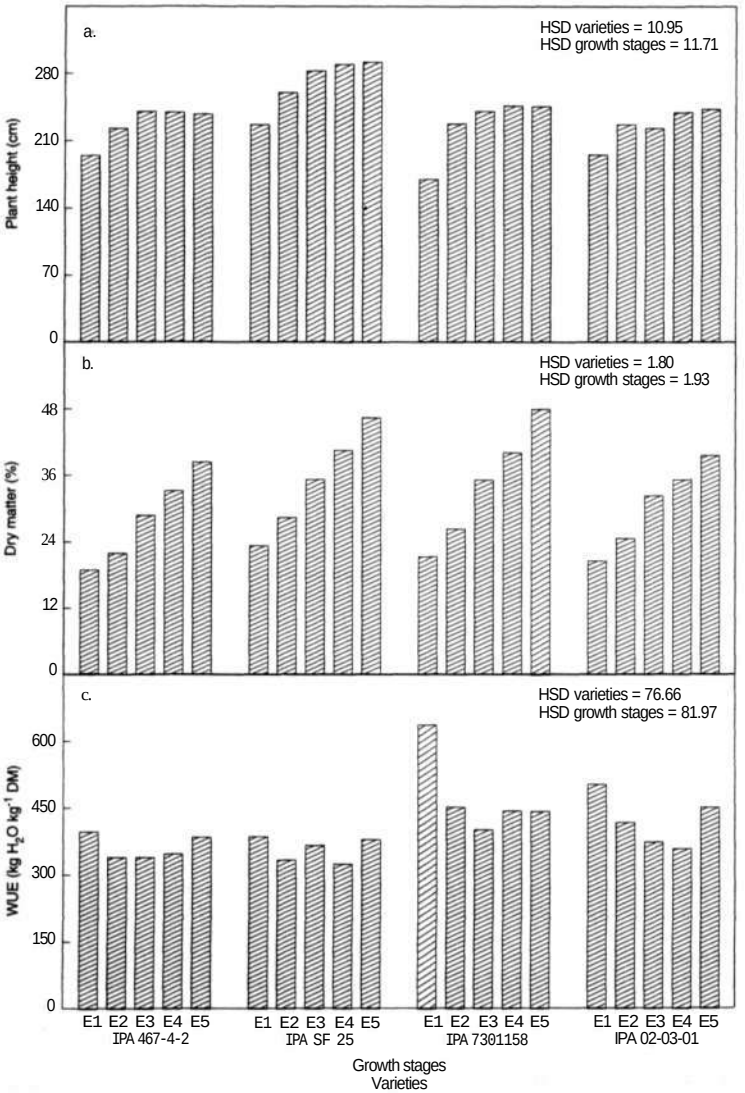

Figure 2. a. Plant height (PH), b. dry matter percentage (DMP), and c. water-use efficiency (WUE) of 4 forage sorghum varieties at 5 harvest stages. Pernambuco State semi-arid region, Brazil, 1992-97. E1 booting, E2 anthesis, E3 grain milk, E4 dry grain, and E5 straw. HSD = Tukey's Honestly significant difference ($\alpha < 0.05$).

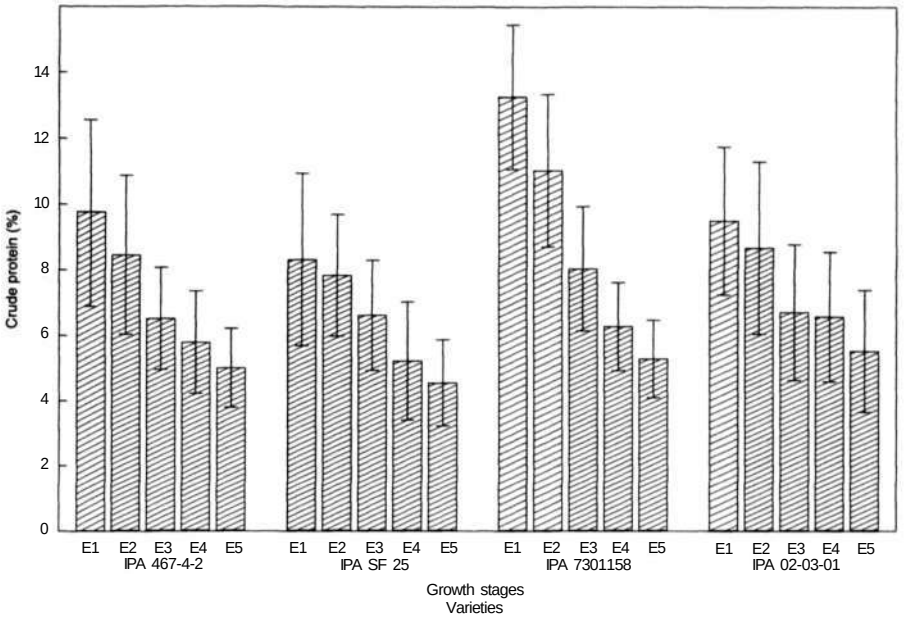

Figure 3. Crude protein content (CP%) of four forage sorghum varieties harvested at various growth stages. E1 booting, E2 anthesis, E3 grain milk, E4 dry grain, and E5 straw.

Plant height (PH), dry matter percentage (DMP), and water-use efficiency (WUE). There were significant effects of variety x harvest stages interaction (Figure 2). For PH, V2 presented superior values independent of harvest stage. Comparing the values obtained among the harvest stages, independent of variety, the highest PHs were found in E4 and E5, and lowest in E1. For dry matter percentage (DMP), considering the varieties studied as a function of the harvest stages, it was shown that at E1 none of the four varieties produced a DMP between 28% and 32%, the values that are considered adequate to produce good silage (Farias and Gomide 1973).

For a sorghum crop, values of WUE around 300 to 400 kg H_2O kg^{-1} dry matter produced are considered highly efficient (Chapman and Carter 1976), V3 at all harvest stages, had low WUE. In V4, the values obtained were only considered efficient in E3 and E4. V1 and V2 values for WUE were always considered appropriate, independent of the harvest stage at which they were measured.

Crude protein (CP). As can be verified from Figure 3, the values of CP decreased with the plant ontogeny in all the analyzed varieties.

Taking as a base the best point at which to harvest, V1 and V4 in E3 produced DMP between 28% and 32%, with CP percentages of 6.5% and 6.7% for V4. V2 at E2 produced 7.8% CP. The percentage of CP observed in V2 was about 20% more than in V3 and V4.

Conclusions

- Forage sorghum varieties IPA 467-4-2, IPA SF 25, and IPA 02-03-01 produced more DMY than IPA 7301158, independent of harvest stage
- The highest DMYs were obtained at anthesis, grain milk, dry grain, and straw growth stages, independent of the variety tested
- IPA SF 25 was considered the best variety of the four tested because of its high DMY, high CP percentage, and high WUE.

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Timing Harvest of Forage Pearl Millets in Semi-Arid Pernambuco, Brazil

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Introduction

The main factor limiting cattle performance in Pernambuco State is the shortage of fodder, mainly in the dry period of the year. This is due basically to the semi-arid region's adverse climate (Villar Filho 1980). Of the 1.8 million head of cattle in Pernambuco State, 90% are concentrated in the semi-arid region, where the pearl millet [*Pennisetum glaucum* (L.) R.Br.] crop could be a viable proposition because of its drought tolerance, high forage yield, and utilization potential (Pontes 1997; Lima 1998). Pearl millet can provide high forage yields of good quality (high dry matter yield (DMY) and protein contents). This work's main objective was to determine the best time to harvest forage millet cultivar IPA Bulk 1-BF in terms of production and forage quality.

Materials and methods

The research was carried out under field conditions, during 1995-97, on experimental stations of the Empresa Pernambucana de Pesquisa Agropecuaria (IPA) in the Agreste and Sertao semi-arid regions of Pernambuco State. Geophysical characteristics of the sites are shown in Table 1.

The experimental design was a randomized block, with four replications. The experiment was carried out in 10 different environments, with five different harvest treatments: 1. booting, 2. anthesis, 3. grain milk, 4. dry grain, and 5. straw stage. Each experimental plot contained 10 8.0-m rows spaced 0.5 m apart. The planting density was 40 plants per linear meter, after thinning. The soil was fertilized following analysis. The variables evaluated were: dry matter yield (DMY) and percentage, crude protein yield and percentage. The results obtained were submitted to analysis of variance and compared by Tukey's Honestly significant difference ($\alpha < 0.05$).

Results and discussion

Dry matter yield. These results show a wide variation in relation to crop growth stages at harvest in each of the 10 investigated environments. However, results from the 3rd and 4th growth stages show more variation than those from growth stages 1, 2, and 5, independent of their environment. It is important to note that DMY levels of 12.7 t ha^{-1} were obtained at the grain milk stage. These results can be used to characterize the production and early potential of the crop in this semi-arid region (Table 2 and Figure 1a).

Dry matter percentage. Table 3 and Figure 1 b show at which phenological stages DM percentage increased. DMY was highest at growth stages 3 and 4 where detected average values were 29.94% and 35.76% reflecting only a small variation (6%) between these stages.

Crude protein percentage and yield. Crude protein mean percentages determined at the five growth stages are shown in Figure 1c. The variation detected for this variable was between 15% (booting) and 6.8% (straw stage). It was 10.5% at stage 3 and 8.3% at stage 4. Thus, high forage protein values coincided with the phenological stages that produced high DMYs.

Table 1. Characteristics of the semi-arid experimental locations, Pernambuco State, Brazil.

Parameter	Caruaru	Sao Bento do Una	Arcoverde	Serra Talhada	Aranpina
Latitude	08°34'38" S	08°31' 16" S	08°25'00" S	07°59'00"S	07°29'00"S
Longitude	38°00'00" W	36°33'00'' W	37°04'00"W	38°19'16" W	40°36'00"W
Altitude	537 m	650 m	664 m	500 m	816m
Annual precipitation	657 mm	655 mm	666 mm	680 mm	743 mm
Climate type[1]	SAM	SAM	SAM	SAM	SAMS

1. SAM = semi-and megathermic; SAMS = semi-and mesothermic; Sources: Anuario Estatistico de Pernambuco 1991; EMBRAPA 1993

Table 2. Forage millet dry matter yield (DMY t ha^{-1}) in 10 semi-arid environments and at 5 growth stages in Pernambuco State, Brazil, 1995-97.

		Growth stage at harvest[1]				
Environments	Year	1	2	3	4	5
Arcoverde	1995	4.29 a[1]	5.08 a	6.36 a	5.78 a	3.33 a
Araripina	1995	3.02 c	4.29 b	5.88 a	5.68 a	5.56 a
Caruaru	1995	4.32 b	6.78 b	6.75 a	6.38 ab	4.71 ab
Sao Bento do Una	1995	2.58 b	5.55 a	5.85 a	5.92 a	5.53 a
Arcoverde	1996	5.16 a	7.15 a	7.76 a	7.34 a	6.31 a
Araripina	1996	4.98 b	4.86 b	6.74 b	12.00 a	8.54 ab
Caruaru	1996	4.54 c	6.63 a	7.01 a	6.34 ab	5.15 bc
Sao Bento do Una	1996	4.49 b	7.01 ab	7.95 a	9.07 a	8.22 a
Serra Talhada	1996	6.26 b	11.14 ah	12.70 a	9.37 ab	6.60 ab
Arcoverde	1997	2.08 b	8.13 a	5.57 ab	6.32 a	6.57 a
Mean		4.17 c	6.66 ab	7.26 a	7.42 a	6.05 b

1. Growth stage 1. booting ; 2 anthesis; 3. grain milk; 4. dry grain: 5. straw
2. Means followed by the same letter within a row are not significantly different by Tukey's Honestly significant difference (α < 0.05).

Table 3. Forage millet dry matter percentage (DM %) in 10 semi-arid environments and at 5 harvest stages in Pernambuco State, Brazil, 1995-97.

		Growth stage at harvest[1]				
Environments	Year	1	2	3	4	5
Arcoverde	1995	19.75 d[2]	23.50 cd	30.25 c	39.00 b	71.00 a
Araripina	1995	15.00 c	18.50 c	25.50 b	29.75 ab	35.00 a
Caruaru	1995	16.13 e	26.95 d	37.12 c	49.63 b	64.76 a
Sao Bento do Una	1995	12.50 c	21.75 b	30.50 a	30.75 a	24.00 a
Arcoverde	1996	21.75 c	27.50 bc	28.50 bc	35.25 b	58.00 a
Araripina	1996	14.00 d	16.75 cd	22.75 c	34.25 b	46.00 a
Caruaru	1996	15.75 d	23.75 cd	29.00 bc	38.75 b	65.50 a
Sao Bento do Una	1996	14.00 d	18.50 d	25.00 c	30.75 b	37.00 a
Serra Talhada	1996	22.50 b	38.75 a	42.00 a	35.75 ab	40.50 a
Arcoverde	1997	10.50 c	33.7$ b	29.75 b	33.75 b	69.50 a
Mean		16.19e	25.07 d	29.94c	35.76 b	52.13 a

1. Growth stage 1. booting; 2. anthesis; 3. grain milk; 4 dry grain; 5. straw
2. Means followed by the same letter within a row are not significantly different by Tukey's Honestly significant difference α < 0.05).

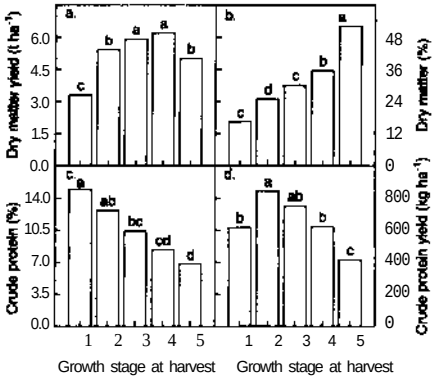

Figure 1. a. Forage millet dry matter yield (DMY), b. dry matter percentage (DM%), c. crude protein percentage, and d. crude protein yield, Pernambuco State semi-arid region. Growth stages at harvest; 1. booting, 2. anthesis, 3. grain milk, 4. dry grain, and 5. straw stages. (Means under the same letter are not significantly different by Tukey's Honestly significant difference ($\alpha < 0.05$).

Highest crude protein yields were observed in stages 2 (843 kg ha^{-1}) and 3 (751 kg ha^{-1}), Figure 1d. Pearl millet fodder harvested at the grain milk stage contains high levels of dry matter and crude protein.

Conclusions

- The highest DMYs were obtained in the grain milk and dry grain stages
- The highest crude protein percentage was observed at booting
- The highest crude protein yields occurred in the anthesis and grain milk stages
- The grain milk stage can be recommended as the best phenological stage at which to harvest, considering dry matter and crude protein yields and forage quality factors.

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Sorghum Research Reports

Germplasm

Study on the Stigma Receptivity of Male-Sterile Cytoplasms in Sorghum

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Introduction

In the utilization of sorghum [*Sorghum bicolor* (L.) Moench] heterosis, the duration of stigma receptivity in a male-sterile line is related directly to synchronizing the flowering phase of male and female parents, and thereby to seed yield in hybrid seed-production plots. The stigma receptivity of some male-sterile lines with a common male-sterile cytoplasm and different nuclei has been studied and valuable results obtained (Pan Jingfang 1966; Niu Tiantang 1982).

In order to expand the cytoplasmic diversity of male-sterile lines, to improve the genetic base of male-sterile lines, and to increase the probability of selecting strongly heterotic sorghum hybrids, the possibility of using non-milo, male-sterile cytoplasms in sorghum hybrids was studied. Some new male-steriles with A_2 cytoplasm were bred (Chen Yue et al. 1995; Wei Yaomimg 1995). It is very important to know if A, and A_3 cytoplasms affect stigma receptivity, and the effect of stigma receptivity on future sorghum production.

Table 1. Seed set of sorghum cytoplasms A_1, A_2, and A_3 in the nuclear genetic background of BTx629 from different pollinating dates, Shenyang, China, 1997.

Cytoplasm	Seed set	Pollination date after flowering (days)																					
		1			3			6			9			12			15			18			
A_1	Number of spikelets	373	395	392	351	378	328	361	312	389	367	280	278	308	291	281	259	257	267	251	262	257	
	Numbers of seed set	368	389	389	340	365	319	369	308	148	134	107	87	81	21	24	19	3	2	5	0	0	0
	Seed set rate (%)	98.7	98.5	99.2	96.9	96.6	97.6	92.4	87.4	48.1	39.2	30.1	29.1	9.2	8.2	7.6	1.1	1.9	0.75	0	0	0	0
	Average seed set (%)	98.9			97.0			92.4	49.3		29.5			8.3			1.3			0		
A_2	Number of spikelets	359	365	361	327	377	389	351	341	386	312	355	297	312	212	279	210	217	261	243	244	269	
	Numbers of seed set	352	358	356	315	364	381	178	161	125	92	86	81	92	19	25	5	2	4	0	0	0	
	Seed set (%)	98.1	98.1	98.6	96.3	96.6	97.9	50.7	47.1	43.7	29.5	24.2	27.3	29.5	9.0	9.0	2.4	0.9	1.5	0	0	0	
	Average seed set (%)	98.3			96.9			47.2			27.0			6.9			0.9			0			
A_3	Number of spikelets	378	376	379	367	381	365	312	311	308	265	355	251	265	265	271	267	261	271	257	237	278	
	Numbers of seed set	375	368	371	358	369	357	198	141	147	87	86	79	87	27	23	2	1	1	0	0	0	
	Seed set (%)	99.2	97.9	97.9	97.5	96.9	97.8	53.2	45.3	46.4	32.8	28.8	31.5	32.8	10.2	8.5	0.75	0.37	0.37	0	0	0	
	Average seed set (%)	98.3			97.4			48.3			31.0			8.5			0.5			0			
SE		±0.145			±0.059			±1.147			±1.409			±0.587			±0.161			±0.000			

Materials and methods

A set of different cytoplasm male-sterile isocytoplasmic lines A_1Tx629, A_2Tx629, A_3Tx629, A_1Tx398, A_2Tx398, A_3 Tx398, A_1Tx631, A_2Tx631, and A_3Tx631 were developed by backcrossing* BTx629, BTx398, and BTx631 lines to different cytoplasms. All materials were introduced to the People's Republic of China from Texas A&M University, USA in 1990. The experiment was conducted at the Sorghum Research Institute (SRI), Liaoning Academy of Agricultural Sciences (LAAS), Shenyang in 1997. The field experiment was a randomized block design with three replications, with two 3.75-m rows, 0.6 m apart in each plot. One row of B-line was sown between every second plot to provide pollen for seed set. The sowing date was 4 May. Twenty flowering panicles were selected during the flowering period. The spikelets on each panicle that had flowered were cut off in the afternoon, and the treated panicles bagged. Two cards with treatment date were tied to each panicle. The following day, two bagged panicles from each plot were pollinated (with pollen from their counterpart B-line) and the pollinating date was recorded on the two cards. All spikelets that had not flowered were cut off, and the crossed panicles were bagged immediately to prevent outcrossing from insect- or windborne pollen. The remaining 18 treated panicles in each plot were pollinated in pairs at 3, 6, 9, 12, 15, 18, and 21 days after treatment. Pollination was repeated the following day to ensure good seed set. The stocks with A_3 cytoplasm were stroked slightly to remove their anthers, because the anthers of the panicles with A_3 cytoplasm are bigger than others and easily mildewed. The bags were removed after pollination so that seed set percentage would not be affected by high temperature, high humidity, or bad ventilation inside the bags. The percentages of seed set recorded at the dough stage of seed development.

Results

Because the spikelets of A_1Tx398, A_2Tx398, and A_3Tx398 were partially aborted and A_1Tx631, A_2Tx631, and A_3Tx631 were so late-maturing that there was not enough pollen for their crosses, the experimental results are reported only for A_1Tx629, A_2Tx629, and A_3Tx629 in Table 1.

Table 1 indicates that the percentage of seed set A_1Tx629 was above 97% for the 1st and 3rd day pollinations. The percentage of seed set decreased rapidly after the 6th day pollination (49.3%). The percentages of seed set for the 9th, 15th, and 18th days' pollinations were 29.5%, 1.3%, and 0. A_2Tx629 and A_3Tx629 were similar to A_1Tx629 in percentages of seed set. The percentages

of seed set in A_2Tx629 and A_3Tx629, were 96.9% and 97.4% for the 3rd day pollination, 47.2% and 48.3% for the 6th day, 1.6% and 0.5% for the 15th day, and 0 for the 18th day. The results for A_1Tx629 were similar to these of other researchers (Pan Jingfan 1966; Niu Tiantang 1982). The analysis of variance for percentages of seed set on different pollination dates was done to determine whether different cytoplasms affect stigma viability. The results showed that none of the differences between replications and cytoplasms were significant, with the exception of variance due to replication on the 6th day. These findings indicate that the A_2 and A, cytoplasm effects on stigma receptivity did not differ from that of the A, cytoplasm, at least in the single nuclear genetic background used in this study. It is very important to use A_2 cytoplasm in heterotic sorghum.

According to the experimental results, A_2 cytoplasm can be used to exploit sorghum heterosis. It could not only overcome the current uniformity of sorghum cytoplasm across all hybrid cultivars in China, but could also enrich the nuclear genetic base of male-sterile lines and increase opportunities to develop new hybrids with high yield and multiple resistances. Male-sterile line V_4A_2 developed by Shanxi Academy of Agricultural Sciences has been used in sorghum production. At present, 7050A_2 a male-sterile line developed by the Sorghum Research Institute is used extensively in sorghum breeding programs. The hybrid combination 7050A_2 x LR9198 gave a good performance with high yield, good quality, resistance to head smut and aphids, and the stay-green trail. It has excellent application prospects. These results present vigorous evidence to support the use of A_2 cytoplasm in sorghum hybrid production.

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Making Heterotic Sorghum Hybrids Using the Partially Fertile Line AS-1 Derived from Tissue Culture

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Mutants with developmentally or environmentally regulated male sterility are well-known in rice (*Oryza sativa* L.) (Sun et al. 1993; Oard and Hu 1995) and wheat *(Triticum aestivum* L.) (Murai and Tsunewaki 1993). Their use in hybrid seed production has been suggested (Jin et al. 1988).

From tissue cultures of a cytoplasmic male-sterile sorghum [*Sorghum bicolor* (L.) Moench] plant we obtained a line designated AS-1 that expresses partial male fertility (Elkonin et al. 1995). When self-pollinated, seed set varied from 0 to 80-90% among plants and within different tillers of the same plant. During flowering, the panicles of this line look sterile and most of their anthers are small and wrinkled in appearance. Several days after anthesis, stigmas under parchment bags remain fresh. However, cytological analyses of pollen from AS-1 revealed the low frequency of fertile pollen, and subsequent seed set was observed only in the lower 1/2 to 1/3 portions of the panicles. The fertility of secondary tillers was generally higher than that of the main panicle, suggesting that photoperiod reduction during plant growth may influence fertility levels in this line.

Hand-pollination of AS-1 panicles using pollen from different sorghum lines resulted in seed set frequencies between 80-100%. The level of self-fertility of AS-1 was sufficient for it to maintain itself, and thus maybe an inexpensive means of producing F_1 hybrids using AS-1 as the maternal parent.

To test this hypothesis, we used the line KVV-181 as a pollen parent. This line tillers intensively and produces large amounts of pollen for long periods; starting before and finishing after the flowering of AS-1. AS-1 was sown in two isolated blocks: one to increase AS-1 pollinated with different AS-1 plants, and the other for hybridization with KVV-181. This plot had two rows of the pollinator along the edges and two rows of AS-1 in the center.

The progeny grown from the AS-1 hybrid block were 81% hybrids and 19% AS-1 selfs. This population manifested significant heterosis for grain yield, outyielding the hybrid Orion by 16% and cv. Volzhskoe-4 by 41% (Table 1). Enough seed was collected from the AS-1 reproduction block to sow new reproduction and hybridization blocks.

Table 1. Characterization and performance of partially fertile sorghum line AS-1 and its hybrid in comparison with standards.

Genotype	Growth (days) 50% anthesis	Growth (days) Maturity	Plant height (cm)	Grain color	Awns	Yield (kg ha^{-1})
AS-1	51	95	141	white	+	3420 a[2]
KVV-181	47	91	127	white	-	3870 b
F_1 AS-1/KVV-181[3]	5498	98	203	white	-	5660 e
Volzhskoe-4	57	101	140	pink	+	4020 c
F_1 Orion	61	105	146	brown	+	4890 d
LSD (<0.05)						397

1. Data from preliminary test trial. Each genotype was grown in 5-m rows in two replications. Values are means from two replications
2. Means followed by different letters are significantly different at *5%* level
3. Data for this population consisted of 81% hybrid and 19% maternal plants

Using AS-1 provides a novel, simple, and cheap two-line method of hybrid seed production. To produce hybrids, the line is used as a female parent, sown in an isolation block with the male parent. Female AS-1 can be maintained without the use of a B-line.

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Genetics and Plant Breeding

Release of 27 Converted Sorghum Lines

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The Texas Agricultural Experiment Station of the Texas A&M University System and the United Stales Department of Agriculture, Agricultural Research Service (USDA-ARS) announce the release of 27 combine-height, early-maturing, converted exotic sorghum [*Sorghum bicolor* (L.) Moenchj lines for use as genetic stocks and germplasm source materials by sorghum breeders. These 27 converted lines were developed in a research program, known as the Sorghum Conversion Program, conducted cooperatively by the USDA-ARS at Mayagiiez, Puerto Rico and the Texas Agricultural Experiment Station.

Table 1. Twenty-seven sorghum converted line releases (1999) and information on original exotic cultivars.

Designation[1]	Registration, PI, or other number[2]	SC number[3]	Local name, or description[4]	Country of origin[5]	Classification[6]		Reason for conversion[7]	Fert Rx[8]
					R	WG		
IS 2144	221552	741	Jan Dawa (?)	Nigeria (?)	D	46(l):Nandyal	Mod Nur	R
IS 2319	217837 (No. 189)	706	Lwalli White	Sudan	C	33; Caudatum	Mod Nur	R
IS 2484	152595 (MN 734)	49*	Ankolib-Red	Sudan	G-C	35; Caudatum-Guinea	Div/Elite/IES	R
IS 2499	(MN 751)	1218	(through USA 1959)	Sudan	G-C	35: Caudatum-Guinea	Midge Res	
IS 3128	213901	823		Mozambique	D-B	45-50: Dur-Doc-Sub	Mod Nur	R
IS 3485	570802 (SU 162)	702	Fanda 128	Sudan	C	33: Caudatum	Mod Nur	
IS 3703	NSL 55832	505	No.42 Iecama Alemaya	Ethiopia	D-B	50: Subglabrescens	Mod Nur	R
IS 5456	NSL 55658	582	Cholam Mohamma	India	D-B	45: Durra-Dochna	Mod Nur	R
IS 5590	NSL 54617	888	Kempu Jola Malkhaid	India	D	41: Durra	Mod Nur	R
IS 5900	NSL 50376	249	Lal Bedra Seja	India	G-C	35: Caudatum-Guinea	Mod Nur	R
IS 6403	NSL 55729	479	Jowar Kalgundi	India	D	46(l):Nandyal	Mod Nur	R
IS 6408	NSL 55734	480	Jowar Kalgundi	India	D	46(1): Nandyal	Mod Nur	R
IS 7369	NSL 50570	276	B A 1 2	Nigeria	G-C	35: Caudatum-Guinea	Mod Nur	BP
IS 7427	NSL 50601	295	BE 34	Nigeria	G	3: Conspicuum	Mod Nur	R
IS 7551	NSL 54237	409	PL 16	Nigeria	G-C	35: Caudatum-Guinea	Mod Nur	R
IS 11080	329323	999	Col. No. 127-B	Ethiopia	D-B	50: Subglabrescens	High Altitude	R
IS 11455	329719	1015	Col. No. R-85	Ethiopia	D-B	50-45: Sub-Dur-Doc	High Altitude	R
IS 11569	329836	1019	Col. No.R-251	Ethiopia	C	39: Caud-Nig	High Altitude	B
IS 12607	248238	106	Glumes glossy	Ethiopia	D-B	41-50: Dur-Sub	Div/Elite/JCS	BP
IS 12641	276806 (SA2324)	150*	Unnamed-R2,43	Ethiopia	D-B	45: Durra-Dochna	Div/Elite/JCS	R
IS 12647	276817 (SA2335)	156	Unnamed-R3,81	Ethiopia	B	12: Dochna	Div/Elite/JCS	B
IS 12650	276820 (SA2338)	159	Unnamed-R3,84	Ethiopia	C-D	40: Caudatum-Durra	Div/Elite/JCS	R
IS 12663	276839 (SA2357)	172	Unnamed-R4,B3	Ethiopia	C	39(l):Zerazera	Div/Elite/JCS	R
IS 12669	276850 (SA2368)	178*	Dongomogof	Ethiopia	D-B	45: Durra-Dochna	Div/Elite/JCS	P
IS 21910	550725	971	Millo Blanco, Local variety	Puerto Rico	D-K	46: Durra-Kafir	Forage/Acid Tol	B
A4 D4	NSL 365720	1215	A4 D4	Niger	G-K	25: Caffrorum-Rox	Sandy Land Variety	
PI 287660	287660	968	S-50-74	Zimbabwe	B	12: Dochna	Anthracnose Res (HBH)	R

1 Designation of converted lines is obtained by adding C to the IS number used in the World Sorghum Collection.

2 Registration and PI numbers identify the converted accession in the U.S. National Plant Germplasm System. (Other numbers are local designations given to the original exotic parent.)

3 The SC number is the serial number given to the exotic variety when entered into the Sorghum Conversion Program and used during conversion. The non-recurrent parent was BTx406, a 4-dwarf Martin B-line, except in the following cases: * = BT x 3121.

4 The local name, number, code, or description of the exotic variety.

5 Country of origin of each exotic line, insofar as records indicate.

6 Classification of exotic line. R = Race is based on Harlan and de Wet (1972) where B = Bicolor, G = Guinea, C = Caudatum, K = Kafir, D = Durra. WG = Working Group number and name where Caud = Caudatum, Doc = Dochna, Dur = Durra, Nig = Nigricans, Rox = Roxburghii, Sub = Subglabrescens and they are based on a Modified Snowden's Classification by Murty and Govil (1967).

7 General reasons for conversion. Mod Nur = Modified nursery selected by KO Rachie, from World Sorghum Collection, 1963 - 64; JCS = J C Stephens, former USDA-ARS sorghum rtsearcher at Chillicothe; Div = Diversity; IES = I E Stokes, former USDA-ARS researcher at Meridan, Mississippi; Midge Res = Reported midge resistant; Tol = Tolerant, Res = Resistant; HBH = Haskell B Harris, University of Georgia, USA.

8 Fert Rx = Fertility reaction as determined from crosses between a milo-kafir cytoplasmic-genetic male-sterile line (A,) and the exotic line; R = Restorer (progeny all male-fertile); B = Maintainer (progeny all male-sterile); BP = Partial maintained

The converted lines were developed through a backcross procedure in which tall, late-maturing tropical sorghum varieties or cultivars were converted to early-maturing, combine-height sorghums. Conversion is accomplished by a crossing and backcrossing program using favorable short-day photoperiods during the winter in Puerto Rico, with selection for early, short genotypes within segregating populations under long-day, summer conditions at Chillicothe, Texas. All converted lines offered for release have received four backcrosses to the original exotic variety. The non-recurrent parent used in 24 of the converted lines was an early-maturing, 4-dwarf Martin B-line, BTx406, of U.S. origin. Three lines were converted using BTx3121 as the early-maturing non-recurrent parent. The exotic varieties are used as male parents in all crosses and backcrosses until the 3rd backcross when they are used as the females in order to recover the original cytoplasm in the converted line.

The converted lines are non-sensitive to photoperiod, will mature normally in the USA, and are generally short-statured, usually 3- or 4-dwarf in height, but occasionally 2-dwarf in height. They represent new sources of germplasm from the World Sorghum Collection and are of a height and maturity to make them readily usable in the United States and other temperate zone areas of the world. These materials should contain new sources of such desirable traits as disease and insect resistance, drought resistance, and improved grain quality, and should be useful to breeders and other sorghum researchers as germplasm sources in developing improved sorghum lines and hybrids. Table 1 gives the designation of the converted lines and information on the original exotic varieties.

Seed will be maintained and distributed by the Texas Agricultural Experiment Station at the Texas A & M University Agricultural Research and Extension Center at Lubbock, Route 3, Box 219, Lubbock, Texas 79401-9757. It will be available in germplasm quantities only. Private seed companies will be charged a fee of $200.00 for the set. Payment should be made to "Texas Agricultural Experiment Station" and should be in U.S. dollars. Genetic material of this release will be deposited with the National Plant Germplasm System, where it will be available for research purposes including development and commercialization of new varieties/cultivars. Those receiving seed are asked to agree to supply, upon request, information about breeding behavior, desirability, and usefulness of the material, and to cite it as the origin of useful derived lines.

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Stay-Green Trait Associated with Yield in Recombinant Inbred Sorghum Lines Varying in Rate of Leaf Senescence

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Introduction

Drought is the major constraint to sorghum [*Sorghum bicolor* (L.) Moench) production worldwide. To reduce the effects of late-season drought, sorghum breeders in Australia, the USA, and India, have been selecting for the non-senescence or stay-green trait. Genotypes possessing the stay-green trait maintain a greater green leaf area under post-anthesis drought than their senescent counterparts (Rosenow 1977). This has raised an important question: does maintaining green leaf area in sorghum automatically improve yield under drought? This question has concerned sorghum breeders for more than two decades, as leaves can remain green simply due to a lack of assimilate demand because the plants have small panicles (Henzell and Gillerion 1973; Rosenow et al. 1983). If this were the case, then selection for stay-green would result in lower grain yield. To better understand the physiological effects of stay-green, particularly its association with yield and lodging resistance, we studied a set of recombinant inbred lines (RILs), varying in their rate of leaf senescence, under post-anthesis drought.

Materials and methods

One hundred and sixty RILs were developed in Queensland, Australia, from a cross between two elite lines (BQL 39, senescent x BQL 41, stay-green) (Tao et al. 1997). The RILs were grown at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in southern India during the 1996 postrainy season. The experimental design was a randomized-block with two replicates. Plot size was 3 x 4 m. The soil was a shallow (<75 cm), cracking, self-mulching, Vertic Inceptisol. The experimental site was fertilized with 40 kg N ha^{-1} prior to sowing. Plots were machine-sown on 1 November 1995 in rows 0.75-m apart, giving a population density of about 7 plants m^{-2}. Emergence (50%) occurred on 5 November 1995. All RILs flowered between 59 and 73 days after emergence. The sorghum crop experienced severe post-anthesis drought. A single 1-m long row was cut from a center row of a 4-row plot on three dates: anthesis (A), mid-grain filling (A+25d), and physiological maturity (black layer). Green leaf area was measured for each plot at all harvest times with an electronic planimeter (LiCor). Grain yield, 100-grain weight, and grain number per row were also determined for all plots at maturity. Each sample was dried in a forced draft oven at 80°C for 48 h before weighing. Harvest index was derived by dividing grain yield by above-ground dry mass.

The relationships between stay-green, grain yield, and yield components were investigated by a series of phenotypic correlations between:

- Grain yield and both grain number m^{-2} and grain size
- Green leaf area at anthesis and both grain number m^{-2} and grain size
- Green leaf area at A+25d and both grain yield and harvest index
- Grain size and relative rate of leaf senescence.

Only data from plots with 100% seed set were used to develop these relationships, thereby preventing any confounding effect of variable seed set on leaf senescence.

The relative rate of leaf senescence was calculated from the slope of the linear decline over time from anthesis (A) to maturity (M) of green leaf area, relative to green leaf area at A, expressed as loss of relative green leaf area (%) per day :

$$[(1\text{-}GLAM/GLAA)* 100]/\text{days from A to M}$$

where: GLAM = green leaf area at maturity (cm^{-2} m^{-2});
GLAA = green leaf area at anthesis (cm^{-2} m^{-2}).

Results and discussion

Grain yield under the prevailing post-anthesis stress conditions was correlated with both grain number (r = 0.723***, Fig. 1) and grain size (r = 0.339***, Fig. 2), although grain number was the primary determinant of yield, accounting for 52% of the variation in yield. Grain numbers were correlated with green leaf area at anthesis (r=0.424***, Fig. 3). Therefore, green leaf area at the beginning of the grain-filling period was positively related to potential grain yield.

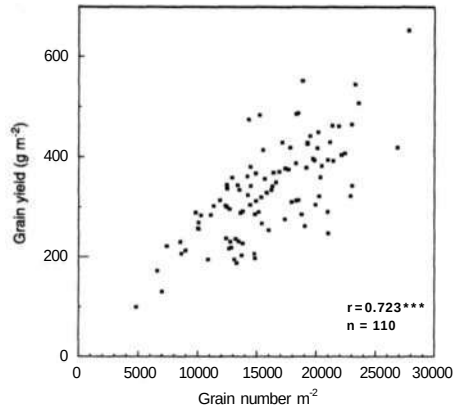

Figure 1. Relationship between grain yield and number m^{-2} in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

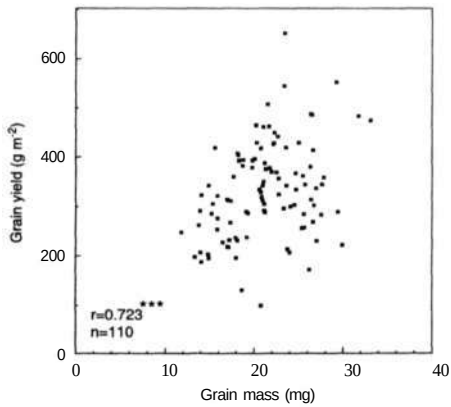

Figure 2. Relationship between grain yield m^{-2} and grain mass in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

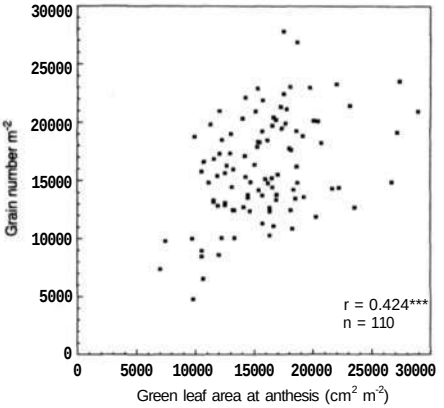

Figure 3. Relationship between green leaf area at anthesis and grain number m^{-2} in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

Grain size was a secondary yield determinant and was independent of green leaf area at anthesis. It was, however, correlated with the relative rate of leaf senescence during the grain-filling period (r = -0.632***, Fig. 4), such that reducing the rate of leaf senescence from 3 to 1% loss of leaf area per day resulted in doubling grain size from about 15 to 30 mg. Stay-green thus had a major positive benefit on filling the grains that were set.

The maximum green leaf area per plant generally occurs about 10 days before anthesis in sorghum (Borrell et al. 2000a) and is an important determinant of green leaf area at maturity, since it sets the initial 'benchmark' of green leaf area per plant. It is from this benchmark that leaf area declines according to the onset and rate of senescence, thereby determining the amount of green leaf area at any point during the grain-filling period, and ultimately at maturity. Leaf area at mid-grain filling (A+25d) is a potentially useful single integrator of both of these factors, and an important determinant of grain yield in terminal stress environments for two reasons. Firstly, leaf area at mid-grain filling reflects differences in grain numbers at anthesis due to the variation in leaf area production prior to anthesis (Fig. 3), and secondly, it reflects reduced senescence rates that result in enhanced grain filling (Fig. 4). It is not surprising then, that green leaf area at mid-grain filling was related to both grain yield (r=0.643***, Fig. 5) and harvest index (r = 0.308**, Fig. 6). This is an important finding, suggesting that the association between high grain sink/source ratio and senescence under water-limited conditions reported by Hen/ell and Gillieron (1973), Duncan et al. (1981), Rosenow et al. (1983), and Tangpremsri (1989) is not necessarily always the rule.

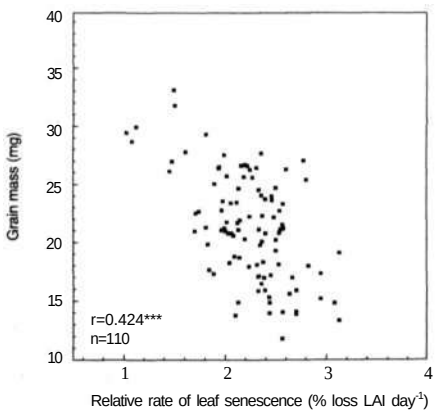

Figure 4. Relationship between the relative rate of leaf senescence and grain mass in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

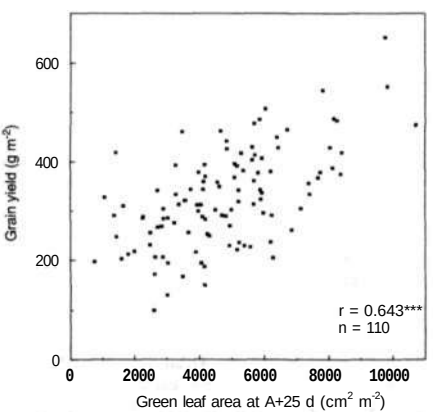

Figure 5. Relationship between green leaf area at 25 days after anthesis and grain yield m^{-2} in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

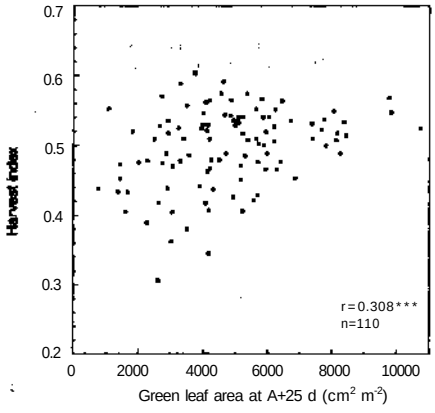

Figure 6. Relationship between green leaf area at 25 days after anthesis and harvest index in a set of 160 recombinant inbred lines (RILs) from the cross between BQL 39 (senescent) and BQL 41 (stay-green), grown during the 1995/96 postrainy season at Patancheru, India.

Our study indicates that leaves do not stay green only because of a small sink demand. Rather, as documented in earlier studies, they stay green under post-anthesis drought because of higher leaf nitrogen status (Borrell and Hammer 2000) and transpiration efficiency (Borrell et al. 2000c), resulting in maintenance of photosynthetic capacity and, ultimately, higher grain yield and lodging resistance (Borrell et al. 2000b).

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Pollen Grain Production in Male-Fertile Lines of Sorghum

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important cereal crops in Mexico. In 1997 it was sown on approximately 1.5 million ha. Ergot [*Claviceps africana* (Frederickson, Mantle, & de Milliano)] is a new disease in the Americas. In Mexico, it was first seen on the coast, or in the coastal region of the Gulf of Mexico in 1997 (Diario Oficial 1997) in fields of commercial hybrid sorghum; by the end of the year the disease was present throughout most of the country where sorghum is grown.

A-lines of sorghum are highly susceptible to ergot. B-lines, R-lines, and F_1 hybrids are less susceptible due to their ability to produce pollen. However, they can become susceptible if their pollen production is disrupted. There are several reasons for this: including such environmental conditions as low temperature, and the inherent ability of the genotype to produce pollen per se (Bandyopadhyay et al. 1997).

There have been reports of severe damage caused by ergot to commercial hybrids, with levels ranging from 5 to 90%. In most cases, infection has been attributed to low temperatures during specific growth stages that affect pollen production; however the ability per se to produce pollen by the commercial hybrid could also be a factor. Male parent lines may play an important role in transmitting the ability to produce pollen to the hybrid (Bandyopadhyay et al. 1997). The objective of this research was to characterize a group often male parents by their ability to produce pollen.

Materials and methods

Research was conducted in the Facultad de Agronomia, UANL, Mexico. Ten male parents (FA 170, 10251, 10330, 10331, 10333, 10249, FA 163, 90, 10106, and 10250) and a commercial hybrid (Pioneer 8282) were used in the experiment. Three seeds of each genotype were sown in a greenhouse in 19-L plastic buckets in a completely randomized design with three replications. After 3 weeks they were thinned to one plant per bucket. At panicle emergence, two spiklets of each genotype were sampled to check the developmental state of the anther in the flower. A sample of two spiklets from the top, middle, and bottom of the panicle of each genotype were taken.

To determine the number of pollen grains per flower, three anthers from each flower (five flowers from each spikelet) from the two spiklets were placed in a microtube with 30 uL of sulfuric acid (99%) for 1 h. Once the anther membrane was destroyed by the acid, the microtubes were placed in a shaker for 10 seconds to produce a homogeneous solution. A sample was taken from the solution and placed in a Neubauer chamber. The number of pollen grains was determined using the following equation:

$$N = \frac{(n)(v)}{0.1}$$

where: N = number of pollen grains per flower
n = number of pollen grains observed in the central part of the Neubauer chamber
v = total volume of the solution.

The data were analyzed using analysis of variance.

Results and discussion

The analysis of variance showed highly significant differences between the genotypes. Table 1 provides the means of the results ranked by pollen production and indicates that these hybrids fell into five statistical groups. FA 163 was the male parent with the highest pollen production with 12600 pollen grains per flower. The male parent with the lowest pollen production was 10251 with 6,045 pollen grains per flower.

Table 1. Pollen grain production in male-fertile parent lines of sorghum, Marin, Nuevo Leon, Mexico, 1998.

Genotype	Pollen grain production[1]
FA 163	12,600 a
Pioneer 8282	11,205 b
90	11,080 b
10330	9,948 c
10249	9,800 c
10250	9,777 c
10331	9,385 c
10106	9,300 c
10333	9,150 c
FA 170	7,916 d
10251	6,045 e

1. Entry means followed by the same letter are not significantly different by Tukey's Honestly significant difference ($\alpha < 0.05$)

These results agree those from another experiment by Zavala-Garcia et al. (unpublished) in which FA 163 hybrids developed with four types of cytoplasm (A_1 T x 398, A_2Tx398, A_3 Tx398, A_4 Tx398) averaged less infection when artificially inoculated (38%) than those hybrids made with 10251 that had infection rates of 64%. Our data indicate that hybrids made using male parents with high pollen grain production per flower, such as FA 163, may produce hybrids that are less vulnerable to ergot infection.

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Participatory Evaluation of Sorghum Cultivars in Northern Nigeria

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Sorghum [*Sorghum bicolor* (L.) Moench] is the most widely grown and major staple crop in the Sudanian Savanna agro-ecological zone of Nigeria. Sorghum, traditionally a food crop, has also become a cash and industrial crop since 1986 when Nigeria banned the importation of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L), and sorghum was identified as a substitute raw material for the brewing industry. The major constraints limiting sorghum production in Nigeria include the progressive decline in the amount of rainfall and its poor distribution, poor soil fertility, and incidence of parasitic weeds such as *Striga* (Yayock and Owonubi 1986; Andrews 1976).

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with the Institute for Agricultural Research (IAR), Zaria, Nigeria, had developed improved sorghum cultivars that are early-maturing, drought-tolerant, and high-yielding. These promising cultivars were evaluated in farmers' fields in northern Nigeria during 1996 in collaboration with IAR. The objectives of the study were to assess cultivar performance cultivar, their acceptability by farmers, and the costs of production .

The three cultivars tested were: ICSV 111, ICSV 400, and ICSV 247. They are all early-maturing (100-110 days to maturity), and can therefore escape terminal drought stress, a common occurrence in the region. The study was conducted in Jigawa, Kano, and Katsina states in northern Nigeria. Three villages were chosen in each state on the basis of rainfall gradient. Table 1 shows the biophysical characteristics of the nine study villages. There were 14 participating farmers in Jigawa, 19 in Kano, and 14 in Katsina. These farmers were selected based on their previous interaction with extension agents and on their willingness to collaborate in the work. Plot sizes were approximately 0.1 ha.

Table 2 shows the mean sorghum grain yields obtained in the nine selected villages. Overall, there was no significant difference among yields of varieties across the nine villages. In general, ICSV 111 performed better than the other varieties in each village of all the three states. On average, across the nine villages all three improved varieties all out-yielded the local varieties. All three improved varieties maintained stable yields across the three states. They performed better than the local varieties in the drier north. Rainfall was adequate and reasonably well-distributed in all three states and therefore did not constitute any major limiting factor to crop performance during 1996.

Labor constituted approximately 83% of the total production costs for each of the cultivars whereas inputs (seeds and fertilizer) represented only a small proportion

Table 1. Location and bio-physical details of nine villages in northern Nigeria selected for participatory evaluation of improved sorghum cultivars, 1996.

State	Village name	Agroecological zone	Coordinates		Soil type	Rainfall (mm)
			Latitude	Longitude		
Kano	Kofa	Southern Sudan	11° 34'	8° 17'	Loamy	898
	Panda	Southern Sudan	11° 31'	8° 04'	Loamy	875
	Badume	Northern Sudan	12° 12'	8° 19'	Sandy	704
Jigawa	Kantoga	Southern Sudan	11° 30'	9° 23'	Sandy loam	850
	Dalari	Northern Sudan	12° 36'	9° 48'	Sandy	639
	Gijigami	Northern Sudan	12° 34'	9° 25'	Sandy	673
Katsina	Gora	Southern Sudan	11° 55'	7° 43'	Loamy	1050
	Rimaye	Northern Sudan	12° 19'	7° 54'	Loamy	728
	Barhim	Northern Sudan	12° 58'	7° 41'	Sandy	734

Table 2. Mean grain yields (t ha^{-1}) of sorghum cultivars in nine villages in Kano, Jigawa, and Katsina states in northern Nigeria, 1996.

State/village	ICSV 400	ICSV 247	ICSV 111	Local
Kano				
Kofa	1.08	0.88	0 9 2	1.04
Panda	1.07	0.83	1.13	0.57
Badume	1.34	1.37	1.61	1.01
Jigawa				
Kantoga	1.02	0.96	0.97	1.01
Dalari	1.78	1.55	1.49	0.55
Gijigami	1.40	1.81	1.77	1.03
Katsina				
Gora	1.04	0.99	1.22	1.00
Rimaye	1.07	1.39	1.41	_[1]
Barhim	1.10	1.00	1.18	-
Mean	1.21	1.20	1.30	0.89
SE	± 0.252	± 0.343	± 0.288	± 0.224

1. = Data not available

Table 3. Costs and returns of producing improved and local sorghum cultivars in northern Nigeria, 1996.

Costs/returns	ICSV 400	ICSV 247	ICSV 111	Local
Output (t ha^{-1})	1.21	1.20	1.30	0.89
Gross revenue (₦ ha^{-1})	14544	14376	15600	10668
Labor cost (₦ ha^{-1})	7880	7840	7960	7540
Other costs (₦ ha^{-1})				
Seeds	300	300	300	180
Fertilizer	800	800	800	800
Depreciation	500	500	500	500
Total cost (₦ ha^{-1})	9480	9440	9560	9020
Net income (₦ ha^{-1})	5064	4936	6040	1648
Returns (₦ ha^{-1})	32.85	32.59	35.18	24.37
Yield required to cover costs (t ha^{-1})	0.79	0.79	0.80	0.75

1. US $1 : ₦80

of the total production costs (Table 3). The variety ICSV 111 had the highest gross revenue per ha (N15600) followed by ICSV 400 (N14544), ICSV 247 (N14376), and the local varieties (N10668). The positive returns per ha indicate that more labor could still be profitably used to produce these varieties. All the farmers obtained grain yields higher than the 0.75 t ha^{-1} required to recover the costs of production.They considered the early maturity of the improved varieties to be a very important and desirable characteristic. They believe that these varieties are drought-tolerant because they can escape terminal drought since they mature earlier than the local varieties.

Another outstanding characteristic pointed out by farmers was the case with which the improved varieties can be threshed by hand. The grain size and medium height (about 1.90 m) of the improved cultivars were acceptable to the farmers. The fodder of the improved cultivars was considered more succulent and palatable than that of the local variety. However, because of the semi-compactness of their panicles, the improved varieties were more susceptible to insect damage, mainly from head bug (*Eurystylus oldi* Poppius syn. *E. rufocunealis* Poppius syn. *E. immaculatus* Odhiambo syn. *E. maculatus* Odhiambo syn. *E. marginatus* Odhiambo), and bird attack.

Participating and non-participating farmers were excited about the performance of the improved sorghum cultivars. They exchanged seeds of the improved varieties among themselves to sow in the following season.

This participatory on-farm evaluation of sorghum cultivars, that was a part of a larger diagnostic study, facilitated the characterization of production systems and the selection of benchmark sites in the study area. New improved sorghum varieties were demonstrated to farmers who were enthusiastic to grow them.

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Biotechnology

Counting Stomata to Determine Regenerant Pioidy Levels in Haploid Sorghum Tissue Culture

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Counting chromosomes in root tips is the routine way to determine the ploidy level of plants regenerated from tissue culture. However, in many cases regenerated plants have poor root systems that significantly hamper the use of this method. Pioidy level is highly important for cultures of haploid origin, especially for anther culture, that could produce both haploid and diploid regenerants.

To solve this problem, we attempted to develop a simple, rapid, and inexpensive technique to determine pioidy levels by counting stomata under a microscope. It is well-known that in haploid plants stomatal size is significantly less than in diploids, and that in a microscope's visual field there are significantly fewer stomata in diploid leaves than in haploid leaves. To prove this, we studied the stomatal numbers in the leaves of regenerants from callus cultures obtained from the panicle of a haploid plant of sorghum [*Sorghum bicolor* (L.) Moench] cv. Milo-145.

The lower epidermis from the middle part of mature leaf laminae (with ligule) from regenerated plants was used. The mean number of stomata per seven microscope

Table 1. Stomata number per microscopic visual field in plants with different ploidy levels regenerated from sorghum callus cultures of haploid origin.

	Stomata number[1]						
Ploidy	3.1-4.0	4.1-5.0	5.1-6.0	6.1-7.0	7.1-8.0	8.1-9.0	9.1-10.0
level[2]	Number of regenerants						
n			1	3	3	6	3
2n 2		1	2				
4n	1						
Control plants[3]		D				H	
r_h[4]							0.681
P							0.01

1. Number of stomata per single microscope visual field (mean of 2 leaves and of 7 fields for each leaf)
2. Ploidy level determined by counting chromosomes in the roots 3-4 weeks later when they were transfered to soil
3. Donor haploid leaf (H) and leaf of the seedling of the autodiploid line (D) obtained in vivo from this haploid used as controls
4. Biserial coefficient of correlation, calculated for n and 2n plants, significance evaluated using Students' t-test (Zaitsev 1984)

visual fields (x400) was counted for two leaves from each plant. The leaves of the donor haploid plant and autodiploid line obtained from this haploid were used as controls. The ploidy level in each plant was also determined by counting chromosomes in the root tips 3-4 weeks later, at the point when they were ready for transfer into soil.

Our data indicated that numbers of stomata in the leaves of regenerated plants varied significantly (Table 1). In diploids and regenerant diploids, stomata numbers were lower than in haploids and never exceeded 6.0 per visual microscope field. In all haploids, the stomata number was greater than 6.0 except for one plant that was perhaps, a chimeara. The majority of haploid regencrants had 8.0-9.0 stomata per visual field. The haploid donor leaf (H) had the same number, while the leaf of the control diploid plant (D) had 4.5. In the only tetraploid regenerant found, this value was 3.2. Statistical analysis confirmed a high level of significance (P=0.01) in correlation between regenerant ploidy levels and stomata numbers in their leaves.

These data demonstrate that counting stomata under a microscope may be an effective and inexpensive way to determine regenerant ploidy levels.

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Abiotic Factors

Germination of Sorghum Following Seed Treatment, Wetting and Drying, and Drought Stress

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Successful establishment of a sorghum [*Sorghum bicolor* (L.) Moench] crop depends on its successful emergence. Seed in the soil may be exposed to drought followed by precipitation events, and vice versa. Seed responses at different hydration levels can vary from germination on the one hand to deterioration on the other. Additionally, water uptake is only reversible for a certain period of time without damaging seed viability. This experiment describes the effects of wetting and drying treatments followed by storage and post-storage seed treatments on the germination of sorghum.

Seed of the variety ICSV 745 were soaked in distilled water for 24 h at 20°C and dried to their original weight at 25°C for 24 h (W-D-1), or soaked in distilled water for 24 h, dried, rewetted in water for 24 h, and dried again (W-D-2). A dry, untreated lot of seed was used as the control (W-D-0). After treatment, seeds were stored at 20°C and 60% RH for 2 weeks. Following storage, seeds were treated in one of the following ways: Soaked in 25 g NaCl L^{-1} for 4 d at 8°C, soaked in water for 4 d at 8°C (wet control), or not treated (dry control). Seeds were sown in batches of 50 between pleated filter paper and

Table 1. Effect of wetting-drying treatments and post-storage soaking treatments on germination of sorghum seed.

Treatment	Final germination (%)	Mean germination time (d)	Germination index
Wetting-drying			
W-D-0[1]	55.0 b[2]	3.0 a	218.4a
W-D-l	61.1a	2.8 a	241.7 a
W-D-2	49.5 b	3.0 a	183.6 b
Post-storage			
Dry control	70.1b	3.0 a	270.5 b
25 g NaCl L^{-1}	18.2 c	2.9 a	72.9 c
Wet control	77.3 a	2.8 a	300.4 a

1. W-D-0 = Dry, untreated seed, W-D-l = Soaked in water and dried once, and W-D-2 = Soaked in water and dried twice
2 Means in columns in each half of the table with the same letter are not significantly different by Duncan's Multiple Range Test ($a < 0.05$)

germinated at 40/25°C (day/night temperatures) under 0, -7.7, -10.0, and -12.5 bar simulated through polyethylene glycol solutions (PEG 10,000). Treatments were replicated three times for every post-storage treatment and drought level, and analyzed, after arcsin transformation of germination data, using analysis of variance.

Results revealed that one cycle of wetting and drying (W-D-1) gave significantly higher germination percentages than either W-D-0 and W-D-2 treatments, and a higher germination index than W-D-2 (Table 1). Post-storage soaking in water brought about a significantly higher germination percentage and index than the dry control or 25 g NaCl L^{-1}. The salt treatment reduced both the final germination percentage and germination index. Neither pre-storage nor post-storage wetting-drying or soaking treatments affected the mean germination time.

Stimulating the Germination of IRAT 204 Sorghum under Simulated Drought through Seed-soaking Treatments

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Germination and establishment of sorghum [*Sorghum bicolor* (L.) Moench] under arid and semi-arid conditions usually requires the ability of the seed to withstand drought and heat stresses. Such stresses delay or reduce germination and affect final stand establishment. Various seed-soaking treatments have been designed to improve seed germination and emergence. This study reports the effect of soaking sorghum seed in NaCl solutions for various periods of time on their germination under drought-stressed conditions in the laboratory. This was part of an overall research program studying various methods for improving stand establishment of sorghum under drought and heat stress conditions.

IRAT 204, an improved variety, was used for this study. Treatments included soaking seed in 8 or 16 g NaCl L^{-1} solutions for 1, 2, or 3 days (d), or in water for the same period at 10°C in the dark. After treatment, seed were dried at 25°C for 24 h and stored at 22-25°C and 55% RH for 10 d. Seeds were sown in batches of 50 between pleated filter paper moistened with 40 mm of a polyethylene glycol solution with an osmotic potential of -10 bar to simulate drought. Germination was conducted at 40/25°C (day/night temperatures) for 10 d and various germination parameters calculated. Treatments were replicated four times, germination percentages were transformed using arcsin, and data analyzed using analysis of variance.

Table 1 shows the effect of seed treatments and their durations on germination characteristics of IRAT 204. An 8-g NaCl treatment for 2 d improved the germination percentage over seed soaked in water for 1 or 3 d, 8 g NaCl for 1 d, or 16 g NaCl for all three durations. Germination index was also improved in comparison to the water-soaked seed, 16 g NaCl treated seed at all three treatments, and those soaked in 8 g NaCl for 1 d. Seed treatment with 8 g NaCl improved the speed of germination, as reflected by the mean germination time, only in comparison to seed water-soaked for 2 d. Our research suggests that soaking IRAT 204 seed in 8 g NaCl L^{-1} solutions for 2 d at 10°C in the dark may improve the germination of such seed under drought stress.

Table 1. Interactive effects of seed treatments and their duration on germination characteristics of IRAT 204 seed under drought-stressed conditions.

Seed treatment	Durations (d)	Final germination (%)	Mean germination time (d)	Germination index
Water control	1	78.6 bc[1]	4.2 ab	255.0 bcd
	2	86.6 ab	5.2 a	219.3 cd
	3	72.6 c	4.7 ab	223.6 cd
8 g NaCl L^{-1}	1	53.3 d	3.4 b	201.0 cd
	2	94.6 a	3.6 b	348.0 a
	3	86.6 ab	4.0 ab	298.3 ab
16 g NaCl L^{-1}	1	84.0 bc	4.4 ab	275.3 bc
	2	58.0 d	4.1 ab	200.0 cd
	3	54.0 d	4.1 ab	185.3 d

1. Means in columns followed by the same letter are not significantly different by Duncan's Multiple Range Test ($\alpha < 0.05$)

Imbibition Rates of Sorghum Seeds as Affected by Seed-soaking Treatment and Temperature

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Seed treatments involving the controlled hydration of seeds under water potentials sufficiently low to permit pre-germinative metabolic activity without protrusion of the radicle through the seed coat have been investigated and utilized in a number of species. Earlier work in this laboratory focused on using NaCl as the osmotic agent preventing germination during the soaking treatment. The concentration and duration of salt treatment and temperature have both been found to have a substantial influence on germination. This study was conducted to compare the imbibition rates of treated seeds as affected by such factors.

Sorghum [*Sorghum* bicolor(L.) Moench] cv. SPV 462 seeds were soaked in 10, 20, 40 g NaCl L^{-1} solutions at 25°C in the dark, or soaked in distilled water under the same conditions. Each individual seed was weighed prior to treatment, placed in a separate petri dish in the solutions, and re-weighed after blotting dry at 2, 4, 6, 8, 10, 24, 48, and 54 h after initial soaking. Seed imbibition rates were calculated for these periods.

In a second test, seeds were soaked in solutions of 8 or 16 g NaCl L^{-1} at 10°C for 1, 2, or 3 days (d), dried at 25°C for 36 h and placed in petri dishes containing distilled water. Imbibition rates were calculated after 1, 2, 3, 6, and 24 h.

The third experiment was conducted on CSV 15 seed soaked in 6 g NaCl L^{-1} for 3 d at 25°C or untreated. Seeds were dried, stored for 3 weeks at 25°C and 60% RH, and subsequently soaked in distilled water at 10 or 40°C. Imbibition was recorded after 2, 6, and 20 h. All treatments were replicated nine times for every duration and temperature, and data were subjected to an analysis of variance procedure using SAS.

Results showed that seeds imbibed water at a high rate during the first 10 h regardless of seed treatment, however, after 24 h, seeds soaked in NaCl solutions took up significantly less water than those soaked in water alone. The duration of pre-treatment in NaCl and the salt concentration did not affect this imbibition rate up to 24 h, but seeds exposed to 40°C during imbibition, whether pre-treated in 6 g NaCl L^{-1} or untreated, imbibed significantly larger amounts of water than those exposed to 10°C at 2, 6, and 20 h after initial soaking (Table 1).

These results would explain the fact that higher salt concentrations and lower incubation temperatures during pre-sowing seed-soaking treatments help prolong the quiescent status of seed when metabolic activity takes place without premature germination occurring during soaking.

Table 1. Effect of seed treatment and incubation temperature on the imbibition rate of sorghum CSV 15 seed.

Seed treatment	Incubation temperature (°C)	Imbibition (%)[2] after various soaking times (h)		
		2	6	20
Untreated	10	12.1 b[1]	16.7 c	30.0 c
	40	22.1 a	36.0 a	45.4 a
6 g NaCl L^{-1}	10	13.5 b	22.1 b	33.1 c
	40	18.3 a	31.7 a	38.7 b

1. Means in columns followed by the same letter are not significantly different by Duncan's Multiple Range Test ($\alpha < 0.05$)
2 Imbibition represents % increase in weight after soaking over the dry weight of seed before soaking

Pests and Diseases

Widening Geographical Distribution of *Claviceps africana,* an Important Ovary Pathogen of Grain Sorghum

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In Africa, ergot disease of sorghum [*Sorghum hicolor*(*L.*) Moench] is caused by *Claviceps africana* Frederickson, Mantle & de Milliano that, particularly in eastern and southern Africa, can become e pidemic in male-sterile lines designed for F_1 hybrid seed multiplication. Most commonly, the anamorph, *Sphacelia sorghi* McRae is recognized as the honeydew stage, often producing a white

secondary multiplication proliferation of airborne spores (Frederickson et al. 1989). Though pathologically similar, *S. sorghi* on the Indian sub-continent consistently appears to be the anamorph of *Claviceps sorghi,* Kulkarni, Seshadri & Hegde that is distinctive not only in its sclerotial form, but also most particularly in the teleomorphic fructification (Frederickson et al. 1991). *Claviceps sorghi* sclerotia are free from the ergot alkaloids that so often characterize *Claviceps* sclerotia. In contrast, C. *africana* has a unique array of alkaloids with dihydroergosine being the most abundant. A series of clavine alkaloids, chanoclavine, and the dihydrogenated clavines festuclavine and dihydroelymoclavine can also be found. All these clavines are intermediates in the biosynthetic pathway to dihydroergosine (Barrow et al. 1974). The ergot alkaloid composition confirmed that C. *africana* was the pathogen that has substantially constrained F_1 hybrid seed production in Thailand (Boon-Long 1988; Frederickson et al. 1991). *Sphacelia sorghi* pathogens have occurred on sorghum in southern Japan (T. Tsukiboshi, National Grassland Research Institute, Tochigi, personal communication). Direct comparison was therefore made between two geographically distinct Japanese isolates of *S. sorghi* and an isolate of 5. *sorghi* (C. *africana)* from Zimbabwe by growing them separately on male-sterile sorghum in a horticultural tunnel at the Chelsea Physic Garden, London, to flower in August-September 1993. All three isolates were highly pathogenic, expressed similar typical disease symptoms, and produced small, amorphous (though sclerotial-like) parasitic bodies protruding slightly from infected florets.

Approximately 2-g samples of dissected parasitic fungal tissues were extracted for ergot alkaloids (Mantle 1968) and the extracts analyzed by TLC, HPLC with diode array spectrophotometric detection, and by capillary gas chromatography-mass spectrometry. TLC and HPLC demonstracted a similar pattern of ergot alkaloids in the three samples. The identity of festuclavine was confirmed without derivatization by an identical GC retention time, (min), in a linear gradient from 140-310°C over 34 min, and the characteristic mass spectrum (molecular ion m/z 240 and important fragmentions at m/z 197, 154, and 144). Dihydroergosine decomposed in this system, and trimethylsilvl derivatization was also unsuccessful. Therefore, the presumed dihydroergosine was isolated by preparative silica gel chromatography from one Japanese *S. sorghi* sclerotial extract and analyzed by positive mode FAB mass spectrometry. The ion at m/z 550 (M+H)+ confirmed the identity as dihydroergosine (Mantle and Waight 1968). The alkaloid compositions of the three samples were conclusively similar to that long-established for the African sorghum ergot pathogen (Mantle 1968). *Claviceps africana* is now clearly indigenous to southern Japan, as well as to Thailand. The pathogen probably has little or no reliance on a teleomorphic fructification in initiating new infections, but rather relies on secondary sporulation of asexual conidia. While windborne spread is unlikely to acount for inter-continental dissemination, preventing the pathogen from becoming endemic in grain-producing areas in the Americas would be desirable, since the fungus has not yet spread to these continents. Routine fungicidal dressing of seed imported into the Americas should exclude this potential sorghum pathogen.

[Editor's refe: Introduction of this pathogen to the Americas has now occurred.]

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A Simple Method for Long-term Preservation of Cultures of *Colletotrichum graminicola* and C. *gloeosporioides* Causing Anthracnose in Sorghum

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Long-term preservation and maintenance of pathogen isolates is essential for studies on pathogenic variability and virulence monitoring. Once the pathogen isolates are appropriately characterized for their morphologic, pathogenic, and genetic diversity they become reference isolates for future studies. Frequent subculturing of necrotrophic pathogens is not only laborious, but it can also induce spontaneous natural mutations in actively growing cultures. There are numerous reports of reduced viability and pathogenicity of isolates due to repeated subculturing on synthetic media. In our studies on pathogenic variability in *Colletotrichum graminicola* (Ces.) Wils. and *C. gloeosporioides* (Penz.) Sacc, the causal agents of anthracnose of sorghum (Mathur et al. 1998), we faced the problem of adequately maintaining a large number of isolates (>200) by repeated subculturing on oatmeal agar (OMA) at monthly intervals. We found the process laborious and observed visible change in the growth pattern and morphology of isolates due to repeated subculturing. In some cases reduced spore viability and likely reduced infectivity were also observed. In order to study pathogenic variability among isolates by artificial inoculation on a set of sorghum differential lines under greenhouse conditions, we needed a cost-effective, long-term, and simple way to preserve a large number of isolates in a form readily retrievable for retesting and evaluation. A method for the long-term preservation of cultures of *C. graminicola* and *C. gloeosporioides* that is a modification of the method described by Latterell and Rossi (1986) for *Pyricularia oryzae* Cavara, the rice blast pathogen is described.

Pure cultures of *Collectotrichum graminicola* and *C. gloeosporioides* were raised from diseased leaves and grains of sorghum collected from different states of India, and stored at 4°C. Single-lesion bits (20-25 from each infected leaf) were cut, washed twice with distilled sterilized water (DSW), surface sterilized with 0.1% $HgCl_2$ solution for 2 min, rinsed with DSW and placed on OMA in petri dishes. Infected sorghum grains showing acervuli were soaked in water for 20 min, then in $HgC1_2$ for 2 min, rinsed twice with DSW, placed on sterilized moist blotting papers in petri dishes and incubated at 25°C under continuous fluorescent light for 3 days. The spores that developed on these grains were streaked onto OMA. The plates were incubated at 25°C under continuous fluorescent light for 7 days, then colonies of *Colletotrichum* spp were picked off and transferred to fresh OMA plates. Isolates of C. *graminicola* and *C. gloeosporioides* thus obtained were purified by hyphal-tip culturing. The isolates were tested for pathogenicity on a set of differential sorghum lines under greenhouse conditions.

Leaves of the anthracnose-susceptible sorghum line IS 18442 were used to preserve the cultures. Third and fourth leaves from pot-grown, 21-day-old plants were used. The leaves were thoroughly washed in running tap water, gently dried with a cotton swab, and cut into 6-cm long pieces. Each piece (abaxial side up) was placed in a petri dish lined with double-layered moistened blotting paper, and autoclaved. The leaf-pieces were septically inoculated with either a conidial mass or an agar disc removed from the periphery of an actively growing culture of individual isolates of *C. graminicola* and C. *gloeosporioides.* The petri dishes were sealed and incubated at 25°C under continuous fluorescent light for 10 days till good sporulation occurred on the leaf pieces. The petri dishes were then transferred to a laminar flow bench and their lids were left open for about 6 h to dry the cultures. The dried cultures (on pieces of leaf togther with blotting papers) were aseptically transferred to autoclaved brown paper seed envelopes (18 x 10 cm), that were then sealed, labeled, and placed in plastic bags. The plastic bags, each containing 10-12 envelopes of dried cultures, were stored at -20°C.

To retrieve a culture, a sliver of freshly poured OMA from a petri dish was removed aseptically, lightly touched on the surface of the dried culture, and transferred to the center of an OMA plate. The plates were sealed and incubated at 25°C under continuous fluorescent light. Growth of *C. graminicola* and *C. gloeosporioides* occurred within 24 h and the isolates were retested for pathogenicity on a susceptible sorghum line.

Currently we have about 150 isolates stored this way, some of which have been tested at monthly intervals for viability, typical cultural characteristics, and pathogenicity and found to remain true to their types for up to 2 years. In the methods described by Latterell and Rossi

(1986) they used rice nodes from rice straw in DSW in culture tubes and corn leaf pieces as media, inoculated with the pathogen isolates, and incubated at 24-27°C and stored at -18°C. Some of these cultures were reported to remain viable for up to 20 years. We believe the method should be equally effective for *C. graminicola.* The storage takes very little space, and a pure culture of any isolate can be revived within 2 days. The method is simple, economical, and effective, and with minor modifications could be used for other foliar pathogens.

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A Simple Technique for Preserving *Sphacelia sorghi* Honeydew Inoculum

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A simple technique that can be used to store the honeydew inoculum of *Sphacelia sorghi* MacRae has been developed. The stored inoculum can subsequently be used to recover tthe isolate as and when required. This technique involves the use of cellophane strips and petri dishes for the long-term preservation of honeydew inoculum under aseptic conditions.

Cellophane strips (7 cm x 1.5 cm) were cut to fit into the lower part of petri dishes and sterilized by swabbing with absolute alcohol. Petri dishes were sterilized by heating in a hot air oven (75°C for 24 h). The lower parts of the petri dishes were divided into equal halves with vertical sterilized paper barriers. Two cellophane strips were positioned one in each portion of the petri dish. *Sorghum bicolor* (L.) Moench panicles (variety 'Bilijola') with ergot symptoms at the honeydew stage were brought to laboratory and a portion of the honeydew mass was placed on the cellophane strips at three points using a sterilized scalpel (Fig. 1). The petri dishes were closed

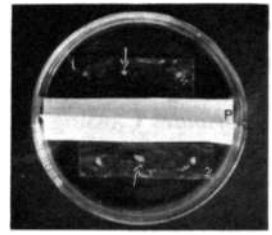

Figure 1. Method developed to store *Sphacelia sorghi* honeydew inculum under aseptic conditions. Arrows indicate the masses of honeydew placed on cellophane strips (1 and 2) that are separated by a paper barrier (P).

and sealed with parafilm. The sealed petri dishes were stored under laboratory conditions at temperature ranging from 26°C to 30°C and relative humidity ranging from 75% to 80%.

The viability of the conidia from the stored honeydew mass was periodically tested at 10-day intervals. For each test, a honeydew mass was removed from the cellophane strips and inoculated onto potato dextrine agar (PDA) medium and observed for the development of colonies of *Sphacelia sorghi.* The conidia present in the honeydew mass were considered viable as long as inoculation resulted in the production of fresh colonies *S. sorghi.*

Under the laboratory storage conditions, the honeydew mass produced fresh colonies of *Sphacelia sorghi* for up to 9 months (Table 1), indicating that the conidia they contained were viable (Futrell and Webster 1966). After 9 months in storage, the pathogen showed a declining trend in producing fresh colony growth on PDA, indicating their loss of viability.

The technique described here is very simple and helpful in storing pathogen inoculum up to 9 months. Small pieces of conidial mass from pure cultures of *S. sorghi* can also be transferred onto cellophane strips and stored in the same way. The technique could possibly also be used to store the inocula of fungi that produce their spores/conidia in a mucilaginous mass [e.g., *Colletotrichum graminicola* (Ces.) Wils., *C. gloesporiodes* (Penz.) Sacc, *Ramulispora sorghi.* (Ellis & Ev.) Olive & Lefebvre, *Gloeocercospora sorghi* Bain & Edgerton ex Deighton *Septoria nodorum* (Berk.) Berk, and *Cercospora* spp etc.]. However, this possibility needs to be tested. The 5. *sorghi* pathogen can be revived on culture media as and when required for use in epidemiological studies. The technique described is useful in maintaining pathogen virulence, that is often lost when pathogens are maintained through repeated subcultures.

Table 1. Viability of *Sphacelia sorghi* conidia under stored conditions.

Period of storage	Period of observation at 10-day intervals	Production of fresh ergot colonies on PDA	Remarks
Dec 1996 - Nov 1997	Dec 1996 - May 1997	Viable, good fresh colony growth	Enormous production of microconida, macroconidia, and secondary conidia
	May 1997 - Sep 1997	Viable, but poor colony growth	Microconida, macroconidia slowly loose their original shape and become round and thick-walled
	Sep 1997 - Nov 1997	No germination of conidia, fresh colonies not produced	No secondary conidial production. All the conidia became rounded double-celled, thick-walled and resembled chlamydospores.

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Modified Method to Assess Endosperm Texture in Sorghum

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Introduction

Plant breeders and cereal technologists have used the term 'hardness' to describe the endosperm textural characteristics of sorghum [*Sorghum bicolor* (L.) Moench) grains. The endosperm texture of cereal grains including that of sorghum is considered an important character in storage, milling, and food processing. The embryo plays a major role in water uptake and mold susceptibility of sorghum. A corneous endosperm texture and the presence of more epicuticular wax contribute to increased weathering resistance (Glueck and Rooney 1980). Endosperm texture is usually determined by visual examination of the kernels cut in half longitudinally and is rated on a 1-5 scale (Rooney and Miller 1982). The present study was made to develop a rapid and accurate method to differentiate endosperm texture in sorghum.

Materials and methods

Sixteen sorghum genotypes including varieties, hybrids, and germplasm accessions grown under comparable conditions were used in the study. Ten seeds of each genotype were soaked in water overnight, they were then cut into two halves along the long axis from the hilar region, and their endosperm texture determined using a hand lens. The endosperm texture was determined by visual examination of longitudinal half kernels and scored on a 1-5 scale (1 = 0-20% floury and 5 = 81-100% floury). These ratings were determined by comparing the endosperm under study with a figure given by Rooney and Miller (1982).

Simultaneously, a modified method was developed to assess the texture of the endosperm. The seeds were soaked for 14 h at room temperature (28°C ± 2°C) in water containing 1-2 drops of toluene to prevent bacterial growth. The kernels were then surface dried by rolling them on blotting paper. Individual kernels were cut into two halves through the hilar end with a sharp razor blade. The cut halves were then fixed to a mounting board using adhesive resin so that the cut ends were exposed. After fixing and labelling all the cut halves of all the genotypes, the board was placed in a polythene bag with a small cuvette containing a few iodine crystals at one end. The open end of bag was heat sealed. A 100-W electric light bulb was held about 10 cm above the bag for 10 min. The heat thus generated caused the iodine crystals to vaporize. The iodine vapour was absorbed more readily by

starchy and floury endosperms that had absorbed more moisture than other parts of the seed. Those portions of the endosperm were stained a very dark brown to red color, whereas the corneous portion of the endosperm was not deeply stained. Detailed observations for each genotype were recorded, and they were scored on the extent of staining using a proposed 10-grade scale (Table 1).

Results and discussion

When evaluated by the method of Rooney and Miller (1982), genotypes CSH 1, IS 84, 296B, IS 2825, IS 8283, IS 14385, and IS 14388, had predominantly floury endosperm textures, while those of SPV 462, CSH 5, CS 3541, and IS 14332 had more corneous textures (Table 1). While evaluated by the iodine vapour method, genotypes, CS 3541, SPV 462, and CSV 10 had more corneous endosperms, followed by IS 14332. Many genotypes with red or brown stained grains had floury endosperms. The results from the two methods are more or less similar, but visual evaluation is easier using the iodine method (Somani and Indira 2000). Endosperm corneousness contributes to grain mold resistance, confinning the results of earlier workers. Endosperm

Table 1. Endosperm texture of 16 sorghum genotypes as assessed by two procedures

Genotype	Endosperm texture: Rooney and Miller (1-5 scale)[1]	Endosperm texture: Iodine method (1-10 scale)[2]	Details of endosperm texture in iodine coloration method
SPV 462	2	8-9	Portion near to embryo stained deep red
CSV 10	3	8-9	Portion adjoining embryo stained dark red and just a shade in the center.
CSV 11	3	6-7	Only floury portion in the center stained red brown color
CSH 1	5	2-3	Embryo and adjoining tissues stained dark brown, and a wide band up to the stylar area stained light red brown
CSH 5	2	5	Embryo and area near embryo stained red, and thin straight streaks from red area observed
CSH 9	3	5-6	Embryo and area near embryo stained red with thin red radiating streaks
CSH 14	3	3-4	Entire surface stained red brown, peripheral tissues not stained
CS 3541	3	9	Very small portion in center stained red
IS 84	4	2-3	Entire surface in center stained red brown, and peripheral portion stained light brown
CK 60B	3	3	Most of the floury portion in the center stained red brown
296 B	4-5	1	Small peripheral portion unstained
IS 2825	5	1	Entire cut surface stained red brown
IS 8283	4-5	1	Entire surface stained dark purple
IS 14332	<2	8	Very small area near embryo stained deep red and small portion in the center stained light brown
IS 14385	5	1	Entire surface stained light purple
IS 14388	4-5	1	Entire surface stained dark purple

1. According to Rooney and Miller (1978) 1 = lowest proportion floury endosperm (0-20%); 5 = highest proportion floury endosperm (80-100%)
2. Iodine method; 1 = lowest proportion floury endosperm; 10 = highest proportion floury endosperm

corneousness contributes towards resistance to grain molds in white-grained genotypes. The iodine vapor absorption test described facilitates visual assessment of endosperm corneousness in sorghum.

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A New Method of Inoculating Grain Sorghum Spikelets with Sorghum Midge Eggs by Water Injection

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A new method of infesting flowering sorghum [*Sorghum bicolor* (L.) Moench] spikelets for midge (*Stenodiplosis sorghicola* Coquillett) resistance screening work has been developed. It uses midge eggs injected into individual sorghum spikelets with an adjustable volume micro-pipette. This method was developed to overcome the inconsistent egg lay achieved across a range of midge-resistant sorghum lines.

In the new method, a small volume of water containing a set number of eggs is injected between the glumes of each spikelet. After injection the water evaporates leaving the eggs attached to the inside structures of the spikelet. A variety of egg densities were tested, ranging from exactly 2 eggs per spikelet up to 4—6 eggs per spikelet. Not all eggs remained within each spikelet. One trial that involved infecting exactly 2 eggs per spikelet over a number of lines with spikelets of different size and shape resulted in an average of 0.8-1.1 eggs per spikelet, and 50-75% egg infestation of spikelets with eggs. Similarly injecting 4-6 eggs per spikelet resulted in 2-3 eggs per spikelet, and 80-95% infestation of spikelets with eggs. In all the trials, most of the eggs were found positioned on the inside of the glumes regardless of spikelet dimensions, with the remaining eggs on other structures within the spikelet, or on the outside of the glumes.

The possibility of using eggs stored in water for prolonged periods was tested in a laboratory bioassay by the water injection method. Freshly laid midge eggs were stored in water from 0- 21 days in the refrigerator at 4°C. The results indicated that eggs stored in water for 4 h were significantly more viable (80%) hatch) than eggs stored for 1-7 days in the refrigerator (40-65% hatch). No viable eggs were retrieved after 14 or 21 days.

Using midge eggs stored in water prior to injection into sorghum spikelets appears to be a useful and practical technique for midge-resistance studies. This technique needs to be improved for precise and consistent egg insertion into each spikelet across a range of sorghum lines. It could then be used to conduct a range of tests for antibiosis and tolerance mechanisms for resistance to sorghum midge.

Integrated Pest Management (IPM) Components for Control of Armored Bush Cricket on Pearl Millet and Sorghum in Farmers' Fields in Namibia and Zambia

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Armored bush crickets (*Acanthoplus* spp) are sporadic but economically important pests of cereals in several countries in southern Africa. In outbreak seasons,

A. discoidalis J. Irish causes on average 30% grain yield loss on pearl millet in Namibia (Wohlleber 1996), while *A. speiseri* Brancsik causes up to 60% yield losses on sorghum in the Gwembe valley of southern Zambia (Musonda and Leuschner 1990). In both countries, and in neighboring Zimbabwe, Botswana, Mozambique, Malawi, and Tanzania, the pest is a threat to poor farmers' livelihoods both in outbreak seasons and also in years of low pest population density.

Before the 1990s, the biology of armored bush crickets was very poorly understood. Recently however, the taxonomy of the group has been improved by a revision of southern African genera (Irish 1992), whilst Mbata (1992) and Musonda and Leuschner (1990) have extended ecological knowledge *of* these pests. Musonda and Leuschner (1990), Leuschner (unpublished), and especially Wohlleber (1996) and Wohlleber et al. (1996) have started to develop management strategies. These strategies include; use of short-duration varieties, clean weeding within and around fields, use of insecticide baits along field borders, selective spraying on nearby bushes, and egg search and collection. Farmers in Namibia and Zambia have developed their own cultural practices that include early sowing, clean weeding, field border trenches, early harvesting, stooking pearl millet, and hand-picking crickets in Namibia, and lower leaf stripping on sorghum in Zambia.

The strategies were tested individually in Namibia and Zambia and most of them were found effective to some degree (Musonda and Leuschner 1990; Wohlleber 1996). To ensure sustainability however, these strategies were combined to form an integrated pest management (IPM) strategy) and tested for the first season in 1997/98. Different component combinations were tested and verified in on-farm trials in Namibia and Zambia. The combinations were:

Namibia. Early sowing and hand-picking were common to most farmers;

1. Mixed local cultivars of pearl millet and sorghum; clean weeding
2. Short-duration pearl millet variety Okashana 1 mixed with local cultivar Karango; clean weeding; selective bush spraying; field edge baiting
3. Mixed local cultivars of pearl millet and sorghum; clean weeding; predatory birds
4. Okashana 1 mixed with local pearl millet cultivar and cowpea *[Vigna unguiculata* (L.) Walp.]; clean weeding; kraal manure application
5. Okashana 1 mixed with local pearl millet, sorghum, cowpea and melons *(Cucumis* and *Citrullus* spp); early sowing at field borders, late sowing in the middle of fields; clean weeding; trench preparation along bushy field borders
6. Okashana 1 mixed with cowpea and melons; kraal manure application; clean weeding; early harvesting, and stooking
7. Mixed local cultivars of pearl millet and sorghum; kraal manure application; clean weeding; early harvesting and stooking

Zambia. Early sowing, sole crop of short-duration sorghum variety Kuyuma, mixed cropping of long-duration variety Longo, were common to all on-farm participating farmers;

1. Early-sown Kuyuma; clean weeding; lower leaf stripping; and hand-picking
2. Early-sown Kuyuma and Longo; trench preparation for Kuyuma field; clean weeding within and around fields; hand-picking
3. Early-sown Kuyuma; clean weeding; hand-picking
4. Early-sown Kuyuma; weeding once at 4 weeks after germination.
5. Local cultivar Longo mixed with cowpea, mung beans [*Vigna radiata* (L.) Wilczek], and melons

In Namibia and Zambia, farmers' fields (0.25-0.5 ha) were used as replicates. In cases where farmers own large fields and agreed to have different combinations, farmers acted as blocks. Crickets were counted at crop maturity/harvest on 5-m x 5-m sub-plots marked out randomly in each field. Crop maturity/harvest period coincides with the highest population peak for the crickets. Similar but separate sub-plots were used for damage and yield assessments.

The estimated cricket population density in Namibia and Zambia during the 1997/98 season was 25-30% that of a normal outbreak season. The low pest population densities were an outcome of low and unevenly distributed rainfall in Namibia (total 250-350 mm) and Zambia (total 400-500 mm). Grain yield loss was estimated at 5-15% on pearl millet in Namibia and 10-40% on sorghum in Zambia. Tables 1 and 2 show the cricket population density, panicle damage, and estimated grain yields under different component combinations tested in Namibia and Zambia.

In Zambia the long-duration sorghum cultivar Longo suffered severely from terminal drought that resulted in no grain being produced. Despite low and poorly distributed rainfall for crop establishment, the improved short-duration pearl millet variety Okashana 1 and improved short-duration sorghum variety Kuyuma performed well in terms of the grain yields that farmers harvested at the end of the season. Similarly, most of the components especially early sowing, use of kraal manure, weeding,

Table 1. Performance of IPM components for control of armored cricket on pearl millet, Namibia, 1997/98.

Cropping pattern	IPM component combinations	Crickets at at harvest (numbers)	Damaged panicles (%)	Estimated grain yield (t ha^{-1})
Mixed local cultivars of pearl millet and sorghum	Early sowing[1], clean weeding, hand-picking[1]	5.2	20.4	0.5
Okashana 1 mixed with local millet Karango	Clean weeding, Selective bush spraying, field edge baiting	3.1	15.3	0.8
Mixed local cultivars of pearl millet and sorghum	Clean weeding, predatory birds	5.3	18.2	0.5
Okashana 1 mixed with local sorghum and cowpea	Clean weeding	5.4	9.0	0.7
Okashana 1 mixed with local millet, sorghum, cowpea, melons	Early sowing along field borders and sowing in middle of fields, trench along bushy borders	3.0	4.3	0.9
Okashana 1 mixed with cowpea and melons	Clean weeding, kraal manure, Early harvesting and stooking	5.1	4.1	1.3
Mixed local cultivars of pearl millet and sorghum	Clean weeding, kraal manure, Early harvesting and stooking	22.4	4.2	0.6
Mean		7.1	10.8	0.8
SE		± 1.5	± 2.6	± 0.3

1. Practices common to all farmers in northern Namibia

Table 2. Performance of IPM components for control of armored cricket on sorghum, Zambia, 1997/98.

Cropping pattern	IPM component combinations	Crickets at at harvest (numbers)	Damaged panicles (%)	Estimated grain yield (t ha^{-1})
Sole crop short-duration variety Kuyuma	Early sowing[1], clean weeding, leaf stripping, hand-picking[2]	2.2	5.4	0.7
Sole crop Kuyuma	Clean weeding, trench around field, hand-picking[2]	2.1	4.5	0.8
Sole crop Kuyuma	Clean weeding, hand-picking[2]	3.1	5.3	0.5
Sole crop Kuyuma	One weeding within field 4 weeks after germination	9.3	33.2	0.3
Local long-duration cultivar Longo mixed with cowpea, melons and mung beans	Clean weeding	4.3	No panicles matured	No yield
Mean		4.2	9.7	0.5
SE		± 1.1	± 2.9	± 0.2

1. Early sowing was practiced by all participating farmers
2. Practice imported from Namibia and accepted by some farmers in Zambia

hand-picking, early harvesting, and stooking were all advantageous to crop performance.

The pest population estimates were similar for Namibia and Zambia. However, damage was slightly higher in Zambia than in Namibia due to the fact that all farmers' families in Namibia have a traditional commitment to hand-picking the crickets daily from their fields and crushing them or suffocating them in polythene bags before burning them. This tradition is lacking in Zambia. Some of the extension personnel in Namibia have also been trained to use a forecasting tool (a cricket egg-hatching trap) developed by Wohlleber et al. (1996) to monitor cricket egg hatch after the first heavy rains. This information enables the extension staff to inform farmers in time to initiate management practices. The Sorghum and Millets Improvement Program (SMIP) facilitated exchange visits of one technical staff directly involved with the farmers in each of Namibia and Zambia. These visits were in anticipation that the exchange of technologies between the two countries will continue to develop.

During the course of field work in the 1997/98 season, a few Zambian farmers were convinced and accepted that hand-picking crickets from their fields was helpful in reducing panicle damage. According to the farmers in Zambia, hand-picking did not involve extra costs from them because it was carried out at the same time as farmers were scaring birds from their fields. The search for additional management components including population forecasting and the use of semio-chemicals (chemical smells or cues, e.g., pheromones) and bio-pesticides to complement the above practices is anticipated in the near future. The technologies were only tested and verified with a few farmers, particularly in Zambia. There is a need for follow-up verification with more farmers for effective diffusion and spillover to neighboring countries.

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Evaluation of Sorghum Genotypes for Relative Resistance to Corn Leaf Aphid, *Rhopalsiphum maidis*

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The corn leaf aphid, *Rhopalsiphum maidis* (Fitch.), was first reported in Haryana on sorghum by Singh (1985). For the last few years corn leaf aphid attacks on maturing sorghum have been observed to be increasing during September and October when they reduce grain and green fodder yields and the quality of the fodder. The aphids initially appear in patches in the field and are generally found deep in the whorl of middle leaflets, and on the undersides of leaves. Even stems and panicles can be seen to be infested. Both nymphs and adults suck the plant sap and cause yellowish mottling of the leaves. Consequently marginal leaf necrosis appears. The aphids produce an abundance of honeydew on which molds grow.

This pest is becoming a regular problem on sorghum at the harvesting stage, a time when chemical control is very difficult and uneconomic. Thus, sorghum genotypes with resistance to aphids would be an extremely valuable way to control this pest. The present investigations were undertaken to identify the sorghum genotypes least susceptible to corn leaf aphid.

Table 1. Relative performance on a 1-9 scale of sorghum genotypes for resistance to corn leaf aphid (pooled reactions 1997 and 1998).

	Category (aphid density rating)	Genotype
1	Few aphids present with very low infestation (1-10%)	CSH 13R, HC 308
2	Few aphids present with low infestation (11-20%)	HC 171, PC 200, S 512, S 513
3	Aphids appeared in very small colonies with light infestation (21-30%)	GFS 206, HD 22, HD 23, RS 660
4	Aphids appeared in small colonies with medium infestation (31-40%)	FS 101, GFS 142, GK 905, HD 17, SSV 84, 855 F
5	Aphids appeared in medium colonies with medium infestation (41-50%)	FS 103, FS 156, GFS 203, PC 162, TNFS 9601, UPFS 34
6	Aphids appeared in dense colonies with high infestation (51-60%)	FSH 92079, GFS 204, MFSH 3, PC 151, PC 161, SPV 1359
7	Aphids appeared in dense colonies with very high infestation (61-70%)	Jumbo, RFSH 93, SSG 1001, SSV 84, TNFS 9602
8	Aphids appeared in high density colonies with very high infestation (71-80%)	GFS 205, MFSH 15, PSSG 333, SSG 500, UPFS 35
9	Aphids appeared in severe density colonies with severe infestation (more than 80%)	MFSH 17, SSG 1000

Forty dual-purpose sorghum genotypes collected from different sources were screened against corn leaf aphid during 1997 and 1998 at the Forage Research Area, CCS Haryana Agricultural University, Hisar, Haryana, India in a randomized block design with three replications and 6.0-nr plots. Observations were recorded for aphid density rating on a 1-9 scale (Table 1).

Based on this evaluation, the 40 sorghum genotypes were grouped into different categories (Table 1). None of the genotypes was free from aphid infestation. Two genotypes, CSH 13R and HC 308 were almost free from aphid attack under field conditions. The most severe aphid infestations were found on MFSH 17 and SSG 1000. Kadam and Mote (1983) also found some sorghum genotypes resistant to corn leaf aphid in the material they screened.

The present results suggest that resistance in sorghum genotypes to corn leaf aphid can be attributed to the color and size of their leaves. This insect prefers broad-leaved plants with light green color and green midribs (juicy stem character) rather than dark green plants with narrow leaves and non-juicy character (white midrib color). Therefore, it is suggested that further research work is undertaken on morpho-physiological plant characters to determine their possible relationship with resistance to corn leaf aphid in sorghum, and that genotypes with superior resistance are used to breed more productive aphid-resistant cultivars.

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Genetics and Plant Breeding

Evaluating Farmers' Pearl Millet Cultivars: Results from a Workshop on Farmer Participation in Breeding and Conservation of Genetic Resources

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Institutional framework

On 11 September 1998, 17 scientists from India, Germany, and the United States attended a workshop organized within the framework of the project 'Enhancing Quality, Diversity and Productivity of Farmers' Pearl Millet Genetic Resources in Rajasthan, India'. This project was a collaborative activity of ICRISAT, and the University of Hohenheim, Germany, funded by the German Federal Ministry for Economic Cooperation and Development, Bundesministerium fur wirtschaftliche Zusammenabeit und Entwicklung (BMZ).

The workshop participants were plant breeders and germplasm specialists, representing the Central Arid Zone Research Institute (CAZRI), the Rajasthan Agricultural University (RAU), the National Bureau for Plant Genetic Resources (NBPGR), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Objectives

The objectives of the workshop were to describe the effects of farmers' own seed management practices on pearl millet [*Pennisetum glaucum* (L.) R. Br.] populations and to identify possible implications for breeding and conservation of genetic diversity in this crop. Farmer cultivars were compared with selected improved varieties that had similar characters or were being used in the region.

Evaluation

Fifteen demonstration plots were grown at the Agricultural Research Station Mandore (RAU) near Jodhpur, Rajasthan. The plant material (Table 1) included 2 traditional landraces, 5 improved varieties, and 8 farmer cultivars, samples of which had been collected over a period of 3 years (1994-96). All plots were grown without irrigation and with moderate fertilizer application.

Results

The overall performance of all cultivars was influenced by the unfavorable rainfall conditions of the season (90 mm of erratic rainfall after sowing). Therefore, symptoms of severe drought stress were observed in most of the plots at the time of evaluation, and flowering was delayed. The landrace populations and those improved populations that had been developed mainly from landrace material performed better under these conditions than other improved varieties. This observation confirms the often-stated opinion of farmers, that the risk of failure is higher in most improved varieties than in their landraces.

Effects of farmers' seed management on yield, morphological traits, earliness, quality aspects, and variability were observed. The farmer strategies were:

- Mixing exotic material into a landrace over 3 consecutive years
- Mixing exotic material into a landrace, followed by positive mass selection by the farmer
- Mixing seed from different sources
- Growing seed of an improved variety over several years under farmers' conditions

The improved cultivars recommended for western Rajasthan (FCB-IC 846 and Raj 171) performed relatively well, whereas the other three were clearly not adapted to the local growing conditions.

Group discussion

Participants agreed that farmers' participation could contribute to the quality of agricultural research. They identified the following topics that have possibilities for farmers' participation:

- Understanding farmers' strategies
- Identifying objectives for breeding programs and selection for local adaptation
- Developing strategies for germplasm collection/ evaluation

Table 1. Pearl millet genotypes evaluated by workship participants at Rajasthan Agricultural University, Agricultural Research Station, Mandor, Jodhpur, Rajasthan, rainy season 1998.

Landraces (ICRISAT genebank)	
Nokha	Landrace from Nokha, Bikancr district (annual rainfall <350 mm)
Jakharana	Landrace from Jakharana, Alwar district (annual rainfall >650 mm)
Farmers' cultivars	
4 samples	Collected from three farmers in the village Aagolai (Jodhpur district), representing different seed management strategies
2 samples	Collected from one farmer in the village Kichiyasar (Bikaner district), representing seed grain from two different seasons
2 samples	Collected from one farmer in the village Nunwa (Ajmer district), representing grain from two different seasons following distribution of the varieties RCB-IC 911 and CZP-IC 923
Improved varieties and hybrids (adapted from Yadav and Weltzien 1998)	
Raj 171	A full-season grain and stover variety, bred from selections from Inter-Varietal Composite, released in 1992
ICMV 155	A full-season grain and stover variety, bred from 59 plants of New Elite Composite C4 (ICMV 84400), released in 1991
RCB-IC 911	Rajasthan Composite, bred by random mating 140 S_1 progenies of RCB-IC 901 (Bold Seeded Composite of ICRISAT)
CZ-IC 923	Bred by random mating 21 S_1 progenies selected from ICMV 82132 x ICMV 87901, released in 1996
FCB-IC 846	A product of RAU-ICRISAT collaboration, based on Early High Tillering Population (CO) selected for grain yield

It was suggested that participatory variety selection could be a possibility for the higher rainfall areas of Rajasthan, or where farmers have access to irrigation. For the marginal regions of western Rajasthan, identifying ready-made solutions seems to be more difficult. Participants, therefore, suggested that farmer participation in earlier breeding stages could help to produce adapted plant material. Germplasm specialists underlined the need to conserve landraces from those regions where the mixing strategy is prevalent. Institutional challenges emerging from more farmer-oriented research work were also discussed.

A detailed workshop report is available free of cost from the authors.

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Agronomy

Participatory Evaluation of Pearl Millet Cultivars in Northern Nigeria

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Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most important food crop in the drier areas of the Sudan Savanna agro-ecological zone of Nigeria where rainfall is inadequate for such other cereal crops as maize (*Zea mays* L.) and sorghum. Major constraints to millet production are poor soil fertility, drought, and biotic stresses e.g., *Striga* and downy mildew [*Sclerospora graminicola* (Sacc.) J. Schrot.] (Singh and Thakare 1986; Yusuf 1996). Although many improved varieties have been developed and released by the Institute for Agricultural Research (IAR), Zaria, Nigeria, only Ex-Bornu (SAMMIL-1) has been adopted by farmers.

Table 1. Location and bio-physical details of nine villages in northern Nigeria selected for participatory evaluation of pearl millet cultivars, 1996.

State	Village name	Agro-ecological zone	Coordinates		Soil type	Rainfall (mm)
			Latitude	Longitude		
Kano	Kofa	Southern Sudan	11° 34*	8° 17'	Loamy	898
	Panda	Southern Sudan	11°31'	8° 04'	Loamy	875
	Badume	Northern Sudan	12° 12'	8° 19'	Sandy	704
Jigawa	Kantoga	Southern Sudan	11° 30	9° 23'	Sandy loam	850
	Dalari	Northern Sudan	12° 36'	9° 48'	Sandy	639
	Gijigami	Northern Sudan	12° 34"	9° 25'	Sandy	673
Katsina	Gora	Southern Sudan	11° 55'	7° 43'	Loamy	1050
	Rimaye	Northern Sudan	12° 19'	7° 54'	Loamy	728
	Barhim	Northern Sudan	12° 58'	7° 41'	Sandy	734

GB 8735 is an improved pearl millet variety that was released in Chad and Mauritania and is reported to be grown by many farmers in those countries. It is early (70-80 days to maturity) and is well-suited to very dry areas as it can escape terminal drought. It is high-yielding and has large gray seeds. It is resistant to downy mildew and because it flowers early usually escapes damage from head miner [*Heliocheilus albipunctella* (de Joannis)], but is susceptible to stem borer *(Coniesta ignefusalis* Hampson). The objective of this study was to introduce this promising variety to farmers in northern Nigeria, assess its performance, its acceptability to farmers, and the costs of production in the region.

The study was carried out in Jigawa, Kano, and Katsina states in northern Nigeria, in the rainy season, 1996. Three villages were chosen in each state on the basis of the rainfall gradient. Table 1 shows the biophysical details of the nine study villages. Fifteen farmers participated in the trial in Jigawa, 12 in Kano, and 7 in Katsina. These farmers were chosen in the light of their previous interaction with extension agents and their willingness to collaborate in this work. Plot sizes were about 0.1 ha.

Pearl millet grain yields obtained in the nine study villages are shown in Table 2. There were no significant differences among yields of the different varieties across the villages, except at Kantoga where yields were low due to waterlogging. The improved variety GB 8735 outyielded the local variety in all nine villages, and its grain yields were stable across the three states.

Most of the farmers obtained yields above the average of 0.73 t ha^{-1} needed to recover the costs of production. Labor costs accounted for 83% of the total production costs while the costs of inputs (seeds and fertilizers) constituted only 11% (Table 3). GB 8735 gave the highest returns, N 15834 compared to N 11635 from the local variety. The positive returns per hectare indicate that more labor could be profitably used to produce these varieties.

Table 2. Mean grain yields (t ha^{-1}) of improved pearl millet GB 8735 and local cultivars in nine villages in Kano, Jigawa, and Katsina states in northern Nigeria, rainy season 1996.

State/village	GB 8735 (Improved)	Local
Kano		
Kofa	1.25	-[1]
Panda	1.23	0.85
Badume	1.26	0.90
Jigawa		
Kantoga	0.93	0.76
Dalari	1.29	1.09
Gijigami	1.23	0.93
Katsina		
Gora	1.39	1.15
Rimaye	1.16	0.85
Barhim	-	-
Mean	1.22	0.90
SE	± 0.145	± 0.171

1. - = Data not available

Farmers liked GB 8735 mainly because of its easiness. Other desirable characteristics were the bright color and large size of the seeds, and the uniformity of the plants at maturity. Farmers also liked the taste of the food prepared from GB 8735. Because it is very early, GB 8735 had the tendency to mature before the end of the rains, rendering the panicles prone to mold. It is also

Table 3. Costs and returns of producing improved pearl millet GB 8735 and local cultivars in northern Nigeria, 1996.

Costs/returns	GB 8735 (Improved)	Local
Output (t ha^{-1})	1.22	0.90
Gross revenue (₦ ha^{-1})[1]	15834	11635
Labor cost (₦ ha^{-1})	7960	7920
Other costs (₦ ha^{-1})		
Seeds	300	300
Fertilizer	800	800
Depreciation	500	500
Total cost (₦ ha^{-1})	9560	9520
Net Income (₦ ha^{-1})	6274	2115
Returns (₦ ha^{-1})	35.76	25.34
Yield required to cover cost (t ha^{-1})	0.74	0.73

1. US$1 = ₦80

more susceptible than local cultivars to attack by birds because of its earliness. If sown late, it does not establish well. It is therefore necessary to follow such recommended agronomic practices as sowing on the appropriate date to avoid some of these problems. The earliness of this variety enables farmers to practice double cropping.

GB 8735 generated a lot of interest from both participating and non-participating farmers. Non-participating farmers did everything they could to obtain seeds from participating farmers to sow in the following season.

This participatory on-farm evaluation of pearl millet varieties, that was a part of a larger diagnostic study, facilitated the characterization of production systems and the selection of benchmark sites in the study area. The study demonstrated the new improved variety to farmers who were very excited about it, and are willing to continue to grow it. This enthusiasm should further enhance the release process.

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Cytogenetical Studies on Chromosomal Interchanges of Pearl Millet

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Reciprocal translocations or chromosomal interchanges refer to the exchange of segments between non-homologous chromosomes of a complement and can be used in chromosome mapping of genes. In pearl millet, *Pennisetum glaucum* (L.) R. Br. syn. *P. americanum* (L.) Leeke syn. *P. typhoides* (Burm.) Stapf. & Hubb. (2n=2x=14), a number of interchanges including a tester set were developed (Minocha et al. 1982). Hence, it became imperative to have relevant information on the chromosomes involved and breakpoint points of interchanges (pi) before these could be put to use. Nine interchange stocks (RT-1, RT-2, RT-3, RT-4, RT-8, RT-9, RT-17, RT-23, and RT-32) were developed and maintained as homozygotes by following standard testcross procedures while four stocks, (RT-7, RT-31, RT-33, and RT-34) were maintained in the heterozygous state. All thirteen interchange stocks revealed the exchange of segments between two non-homologous chromosomes, one of which was detected as chromosome 7, a nucleolus organizer, in RT-23 and RT-34. In order to establish the unambiguous identity of translocated chromosomes and map their pi in various interchanges, cytological, cytogenetical, biochemical, and genetical methods were followed. The results are summarized in Table 1.

In most of the interchange stocks studied, the pi were found distributed in the heterochromatic region of the telomeres and centromeres of their involved chromosomes. This confirms observations that in pearl millet major heterochromatic blocks are located near the centromeres and telomeres of the chromosomes (Kaul and Sidhu 1998). Heterochromatin is known to be susceptible to break in tomato (Gill et al. 1983) and this appears to be true for pearl millet as well.

Once the interchanges were documented with details of their involved chromosomes/arms and pi, these were crossed with various genetic marker stocks. Based on the joint segregation of semi-sterility (in the form of quadruple) and gene markers in the F_2 and/or testcross generations, 13 genes for qualitative traits (basal car branching *Bebl ;* purple bristle *Bep;* bristling *Br1* and *Br2 ;* hairy leaf *hl1* and hl*2;* hairy node *Hn1* and *Hn2,* purple anther *Pal* and *Pa2,* purple plant and seed pigmentation *Ppl;*

Detection of *Sclerospora graminicola* Mycelium in Infected Pearl Millet Leaves

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To diagnose some diseased plants, particularly when symptom expression is doubtful, it becomes necessary to make internal observations of a suspected leaf for the presence or absence of mycelium. The routine method of staining mycelium using Clorox® (Clorox Company, Oakland, CA 94612, USA) containing 5.25% sodium hypochlorite is unsatisfactory, even though this method reveals the presence of downy mildew (DM) [*Sclerospora graminicola* (Sacc.) J. Schrot] oospores in infected pearl millet leaves. We describe a simple method that allows the easy detection of fungal mycelium inside an infected pearl millet leaf.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] leaves systemically infected with downy mildew were collected from DM-susceptible cultivar HB 3 during the 1995 rainy season at ICRISAT, Patancheru, India. Samples of young and old leaves were washed with a moist cotton swab to remove old spores and soil/plant debris. They were cut into 1-cm^{-2} pieces, and the pieces transferred to Carnoy's solution (Carnoy 1886) in 25 mL beakers to prevent water evaporation and autolysis. The beakers were sealed with thin parafilm and incubated at 25 ± 1°C in the laboratory for 6 h (young leaves) to 10 h (old leaves). The excess Cornoy's solution was then decanted and the pieces of leaf transferred to another beaker containing lactophenol. This beaker was sealed with aluminium foil and incubated at 60°C for 4 h in a hot-air oven (Gallenkamp). The samples were removed from the oven and allowed to cool at room temperature (25°C). Once cooled the pieces of leaf were transferred to beakers containing 1% cotton blue lactophenol and incubated at 60°C for 4 h, after this they were mounted in clear lactophenol, and observed under a microscope. The processed pieces of leaf showed dark blue stained coenocytic mycelium of *S. graminicola* present within their tissues (Figure 1).

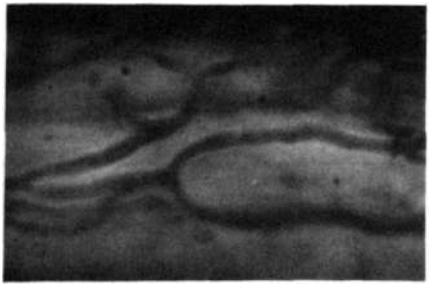

Figure 1. Dark blue stained coenocytic mycelium of *Sclerospora graminicola* inside tissues of pearl millet leaves (x 132).

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Identification of Nematode Resistance in Pearl Millet Grain Hybrids

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Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] has potential as a drought-resistant grain crop in the United States. It can be used in rotations with other field crops and has a flexible sowing date from mid-April to the beginning of August in southern and southeastern USA. Earlier research on forage types showed differential responses of cultivars to various nematode species (Johnson and Burton 1977 and McGlohon et al. 1961). The objective of this research was to study the response of 14 pearl millet grain hybrids developed in our breeding program to *Meloidogyne incognita* (Kofoid and White) Chitwood and *Paratrichodorus minor* (Colbran) Siddiqi.

Materials and methods

Field plots of pearl millet hybrids resistant to rust *(Puccinia substriata* Ellis & Barth. var *indica* Ramachar & Cumm. syn. *Puccinia penniseti* Zimm). were established on a Tifton loamy sand in June 1998 and maintained through October 1998. The plots were naturally infested with *Meloidogyne incognita* and *Paratrichodorus minor.* The experiment was a split plot with pearl millet hybrid entries as whole plots and nematicide treatments as subplots. Treatments were replicated five times. Treated and

Table 1. Effects of soil chemical treatment on nematode population densities and grain yield in rust-resistant pearl millet grain hybrids[1].

Pearl millet hybrid	Telone II treatment	Nematodes per 150 cm^{-3} soil, 1998				Grain yield (kg ha^{-1})
		9 July		8 October		
		M.i.[3]	*P.m.*	*M.i.*	*P.m.*	
97-106 x 117	Treated	4a	0a	12a	2a	3537 a
	Untreated	6a	0a	26 a	10a	3641 a
97-107 x 115	Treated	4b	0a	8b	22 a	3655 a
	Untreated	34 a	8a	232 a	14a	3351 b
97-108 x 117	Treated	2a	0a	20 a	2a	2508 b
	Untreated	18a	0a	26 a	24 a	3000 a
97-109 x 115	Treated	0a	4a	8a	22 a	2707 a
	Untreated	12a	2a	48 a	8a	2495 b
97-109 x 117	Treated	0a	0a	0a	2a	2545 b
	Untreated	18a	2a	18a	6a	2804 a
97-111 x 114	Treated	0a	8a	10a	6a	3351 b
	Untreated	2a	6a	208 a	4a	3607 a
97-111 x 115	Treated	0a	2a	34 a	0a	3351 b
	Untreated	4a	10a	226 a	2a	3607 a
97-111 x 117	Treated	0a	0a	4a	2a	2863 a
	Untreated	10a	0a	40 a	10a	2960 a
97-112x 114	Treated	0a	0a	16a	12a	3089 a
	Untreated	8a	4a	32 a	6a	2745 b
97-112 x 115	Treated	0a	0b	14a	14a	4124 a
	Untreated	16a	14 a	74 a	12a	4005 a
97-112 x 117	Treated	0a	2a	2a	4a	2669 a
	Untreated	12a	4a	44 a	8a	2514 a
97-113 x 114	Treated	0a	0a	6a	14a	2902 a
	Untreated	10a	6a	28 a	16a	2800 a
97-113 x 115	Treated	2a	2a	10a	8a	4479 a
	Untreated	18a	8a	172 a	12a	3579 b
HGM-100 (std)	Treated	0b	0b	6a	0a	3366 b
	Untreated	20 a	12a	14a	16a	3662 a

1. Data are means of five replications comparing soil chemical treatments (Telone II and untreated)
2. *M.i. = Meloidogyne incognita. P.m. - Paratrichodorus minor*
3. Means followed by the same letter for each hybrid are not significantly different by Duncan's Multiple Range Test ($\alpha < 0.05$)

untreated plots for each entry were paired in plots 0.9-m wide and 5.9-m long. One, 3-dichloropropene (1,3-D) Telone II was injected at 56.1 L ha^{-1} through a single chisel in one row per plot and bedded. The other row in each plot was left untreated and served as a control. Ten cores of soil (2.5-cm diameter x 25-cm deep) were collected from each row of each subplot on 9 July, 28 August (data not presented), and 8 October, and nematodes were extracted from a 150-cm^3 subsample for each plot by centrifugal flotation (Jenkins 1964), identified, and recorded.

Results and discussion

Numbers of nematodes in the soil were low on 9 July (2 weeks after the pearl millet was sown) in both treated and untreated plots, but as expected, tended to have lower values in Telone II treated plots (Table 1). Both *M. incognita* and *P. minor* numbers tended to increase at the 8 October sampling (more so in untreated than treated plots, as expected), but significant differences ($P = 0.05$) were only observed for *M. incognita* between treated and untreated plots of pearl millet hybrid 97-107 x 115. Numbers of *M. incognita* tended to increase more in the soil of plots growing hybrids with 115 as the male parent than those with 117 as the male parent. Plants in the treated plots were taller and greener than those in the untreated plots during the first month after sowing, but the differences gradually disappeared by anthesis. Significant grain yield differences were observed between treated and untreated plots for 9 of the 14 hybrids. Plants in untreated plots of 5 of the 9 hybrids yielded more grain than plants in the treated plots. Telone II treatment did not significantly affect grain yield in 5 of the hybrids. The data indicated differences existed for resistance to *M. incognita* and *P. minor* nematodes among the 14 pearl millet hybrids. The fibrous rooting system of pearl millet probably allows this crop to flourish under certain populations of nematodes as the plants matured, due to increased root branching, but this hypothesis needs further study.

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Acknowledgment

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Population Reproductive Statistics of Millet Head Miner (Lepidoptera: Noctuidae) Reared in a Laboratory in Niger

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Introduction

Millet head miner (*Heliocheilus albipunctella* de Joannis) significantly damages pearl millet [*Pennisetum glaucum* (L.) R. Br] grown in the Sahel. Young larvae cut and feed on flowers and perforate the glumes of pearl millet. Late-instar larvae bore and create tunnels in the kernels on pearl millet panicles (Gahukar et al. 1986). Cultural and chemical management tactics have been used to reduce damage by millet head miners in West Africa, but are impractical and expensive. A life table was used to study cohort development and assess the number of millet head miners surviving or dying in each life stage.

Materials and methods

Life table parameters, including reproduction, development, and survival, were assessed for millet head miners reared using 4 temperatures and 4 diets in a laboratory. Cohorts were reared only on Bio-Serv® 9782 diet or on 3 pearl millet-based diets, i.e., spike parts at early exsertion, mid-flowering, or soft-dough stages. Millet head miner adults (1f:1m) from a laboratory colony were placed with freshly cut pearl millet panicles into oviposition cages. Eggs were counted and kept in a petri dish until they hatched. Each neonate larva was put into a

plastic cup containing 15 mL of an artificial or a millet-based diet. Cups were distributed among 4 incubators maintained at 24, 26, 28, or 30 ± 1°C; a photoperiod of 12:12 (L:D) h; and 70% relative humidity (RH). Numbers of surviving and dead larvae were recorded and used to construct life tables. Standard techniques developed by Southwood (1978) and Price (1997) were used to calculate the net reproductive rate of multiplication in terms of females produced per generation ($R_o = al_x m_x$) and cohort-generation time, a period during which offspring were produced ($T = al\ m_x\ x\ /al_x\ m_x$).

Results and discussion

The population reproductive statistics estimated from the fecundity and life table data (Kadi Kadi 1999) are summarized in Table 1. When millet head miners were fed Bio-Serv® diets, R_o increased from 3.53 females per female at 24°C to 5.84 females at 30°C. Mean net reproductive rate was 4.09 females per female at the 4 temperatures. T_e ranged from a low of 21.51 days at 28°C to a high of 33.04 days at 30°C. Mean T_e at the 4 temperatures was 25.02 days. When millet head miners were fed early exserted millet panicles, R_o and T_c were greatest at 24°C. R_o at 24°C was 4.33 females per female and T_c was 23.86 days. Mean R_o was 3.64 females and T_c was 22.93 days at the 4 temperatures. When a mid-flowering millet diet was used, R_o and T_c were greatest at 24°C (3.77 females and 24.95 days) but least at 28°C (2.89 females and 16.98 days). Mean R_o was 3.34 females and T_c was 21.44 days at the 4 temperatures. Using soft-dough stage millet as a diet, R_o and T_c generally increased as temperature increased. R_o increased from 3.26 females per female at 24°C to 3.86 at 30°C. Mean R_o of 3.52 females was estimated at the 4 temperatures. Mean T_c was 19.79 days, higher than the T_c values recorded at 24 or 30°C.

In summary, the highest R_o values of 5.84 and 4.33 females per female were estimated when millet head miners were fed the Bio-Serv* diet at 30°C and the early exerted millet diet at 24°C. Overall mean R_o tended to be highest at 24°C (3.72 females) and 30°C (4.35 females). These values were lower than the R_o values of 21.09-71.17 females per female, Srinivasaperumal et al. (1992) reported for immature stages of the noctuid, *Earias vittella* (Fabricius), reared on 3 hosts in a laboratory. Mean T_c values were 20.29-24.86 days at the 4 temperatures when millet head miners were fed the 4 diets. T_c tended to be shortest at 26 and 28°C and was only 16.98 days when millet head miners were fed mid-flowering millet diets at 28°C. Srinivasaperumal et al. (1992) reported T_c values of 34.24-39.22 days when *E. vittella* was reared on three hosts in a laboratory. The T_c of 33.04 days for millet head miners fed the Bio-Serv® diet at 30°C was similar to the 34.24 days Srinivasaperumal et al. (1992) reported for *E. vittella* reared on okra, [*Abelmoschus esculentus* (L.) Moench] at 27°C. T_c was shortest (mean of 19.78 days) when millet head miners were fed soft-dough stage millet diets. The suitability of their food affected millet head miner population abundance and reproductive capability in the laboratory.

Table 1. Net reproductive rates and cohort generation times for pearl millet head miner reared on Bio-Serv® 9782 and three pearl millet-based diets at ICRISAT Sahelian Center, Sadore, Niger, 1996 and 1997.

Diet	Reproductive value	Temperature (°C) 24	26	28	30	Mean
Bio-Serv® 9782	R	3.53 ± 0.03	3.49 ± 0.02	3.48 ± 0.02	5.84 ± 0.02	4.09 ± 0.04
	T_c	22.13 ± 0.01	23.38 ± 0.02	21.51 ± 0.01	33.04 ± 0.01	25.02 ± 1.80
Panicle parts at early exsertion	R	4.33 ± 0.03	2.98 + 0.01	3.60 ± 0.05	—	3.64 ± 0.24
	T_c	23.86 ± 0.04	20.36 ± 0.04	21.58 ± 0.02	—	22.93 ± 0.64
Mid-flowering stage panicles	R	3.77 ± 0.07	—	2.89 ± 0.09	3.35 ± 0.05	3.34 ± 0.20
	T_c	24.95 ± 0.05	—	16.98 ± 0.02	22.40 ± 0.10	21.44 ± 1.50
Soft-dough stage panicles	R	3.26 ± 0.06	3.23 ± 0.03	3.72 ± 0.02	3.86 ± 0.06	3.52 ± 0.11
	T_c	18.37 ± 0.04	20.53 ± 0.03	21.10 ± 0.05	19.13 ± 0.03	19.78 ± 0.41
Mean	R_o	3.72 ± 0.20	3.23 ± 0.10.	3.42 ± 0.12	4.35 ± 0.50	
	T_c	22.33 ± 0.94	21.42 ± 0.61	20.29 ± 0.72	24.86 ± 2.70	

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Notes and News

News Items

R Bandyopadhyay Receives Award

Ranajit Bandyopadhyay of the Genetic Resources and Enhancement Program, ICRISAT was presented with an Outstanding Achievement Award by the National Grain Sorghum Producers Board (NGSP) and the Sorghum Improvement Conference of North America (SICNA) during the 21st Biennial Grain Sorghum Research and Utilization Conference, on 22 February 1999 at Tucson, Arizona, USA. The award is presented occasionally to recognize significant contributions towards improvement of sorghum industry in North America. The award is normally given to individuals, but in 1999 it was given to an international team of three scientists for their work on sorghum ergot, a devastating disease that took the sorghum industry in the Americas by surprise. The team consisted of D E Frederickson (University of Zimbabwe, Harare; currently a Visiting Scientist at Texas A & M University, College Station), N W McLaren (Grain Crops Research Institute, Potchefstroom, South Africa) and R Bandyopadhyay. After the arrival of sorghum ergot in the U.S. in 1997, Bandyopadhyay worked for 10 months in 1998 at Texas A & M University (with R A Frederiksen) and the United States Department of Agriculture (USDA) (with J A Dahlberg) on various aspects of the disease. One of the key areas of his work was dissemination of appropriate research information and advice to various sections of the sorghum industry. Bandyopadhyay's posting was covered by a Memorandum of Understanding on collaborative research between Texas A & M University and ICRISAT.

NGSP is the national body representing the interest of sorghum trade in the U.S. and elsewhere. Its membership includes growers, researchers, extentionists, seed companies, and people associated with different facets of sorghum trade. SICNA is an organization of sorghum researchers that prepares a general program of research, education, and developmental activities in the U.S. SICNA is a co-publisher (with ICRISAT) of the International Sorghum and Millets Newsletter.

Previous Outstanding Achievement awardees associated with ICRISAT include H Dogget (1981) and L R House (1993). Other awardees include such sorghum stalwarts such as R A Frederiksen (1995), G L Teetes (1995), D T Rosenow (1993), F R Miller (1989), L W Rooney (1985), J C Stephens (1963) and J R Quinby (1963).

Notes

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Information for ISMN contributors

Publishing objectives

The International Sorghum and Millets Newsletter (ISMN) is published annually by the Sorghum Improvement Conference of North America (SICNA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). It is intended to be a worldwide communication link for all those who are interested in the research and development of sorghum (*Sorghum bicolor* (L) Moench), pearl millet *(Pennisetum glauctim* (L.) R. Br.), and finger millet (*Eleusine coracana* (L.) Gaertn.), and their wild relatives. Though the contributions that appear in ISMN are reviewed and edited, it is expected that the work reported will be developed further and formally published later in refereed journals. It is assumed that contributions in ISMN will not be cited unless no alternative reference is available.

ISMN welcomes short contributions (not exceeding 600 words) about matters of current interest to its readers.

What to contribute?

Send us the kind of information you would like to sec in ISMN.

- **Contributions should be current, scholarly, and their inclusion well-justified on the grounds of new information.**
- Results of recently concluded experiments, newly released varieties, recent additions to germplasm collections, etc.
- Genome maps and information on probe-availability and sequences, and populations synthesized for specific traits being mapped. Glossy black and white prints of maps should be included, if possible. Partial maps can also be submitted.
- Short reports of workshops, conferences, symposia, field days, meetings, tours, surveys, network activities, and recently launched or concluded projects.
- Details of recent publications, with full bibliographic information and 'mini reviews' whenever possible.
- Personal news (new appointments, awards, promotions, change of address, etc.).

How to format contributions—deadline 30 June

- Keep the items brief—remember, ISMN is a newsletter and not a primary journal. About 600 words is the upper limit (no more than two double-spaced pages).
- If necessary, include one or two small tables (and no more). Supply only the essential information; round off the data-values to just one decimal place whenever appropriate; choose suitable units to keep the values small (e.g., use tons instead of kg). Every table should fit within the normal typewritten area of a standard upright page (not a 'landscape' page).
- Black-and-white photographs are welcome—photocopies, color photographs, and 35-mm slides are not. Please send disk-files (with all the data) whenever you submit line figures and maps.
- Keep the list of references short—not more than five references, all of which should have been seen in the original by the author. Provide all the details including author/s, year, title of the article, full title of the journal, volume, issue, and page numbers (for journal articles), and place of publication and publishers (for books and conference proceedings) for every reference. Incomplete references will not be accepted.
- Express all quantities only in SI units. Spell out in full every acronym you use.
- Give the correct Latin name of every crop, pest, or pathogen at the first mention.
- Type the entire text in double spacing. Contributions should be sent on diskette, on a double-sided/high density IBM-compatible disk. MS Word files arc preferred.
- Contact the Editors for detailed guidelines on how to format text.
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ISMN will carefully consider all submitted contributions and will include in the Newsletter those that are of acceptable scientific standard and conform to requirements. The language of the Newsletter is English, but we will do our best to translate articles submitted in other languages. Authors should closely follow the style of the reports in this issue. Contributions that deviate markedly from this style will be returned for revision, and could miss the publication date. If necessary, we will edit communications so as to preserve a uniform style throughout the Newsletter. This may shorten some contributions, but particular care will be taken to ensure that the editing will not change the meaning and scientific content of the article. Wherever we consider that substantial editing is required, we will send a draft copy of the edited version to the contributor for approval before printing.

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