Breeding procedure

Jinliang No. 5 is an R-line with good combining ability and several superior performance characteristics. Several widely used hybrids have been developed using it as a restorer, but is highly susceptible to head smut [*Sporisorium reilianum* (Kuhn) Langdon and Fullerton] and has a few other short-comings. Hence, it was felt necessary to improve by tissue culture.

Shoot tips including the first node were excised from the germinating R-line seeds. Murasige-Skoog (MS) medium enriched with 2,4-D and KJ (potassium iodide) was used as a callus-induction medium, and MS medium enriched with KI and indole acitic acid (IAA) was used as the regeneration medium. Regenerated plants (R_o generation) were transplanted into the field. Harvested R_o seed was advanced to the R_1 generation. Somaclonal lines harvested individually were the R_2 generation. Somaclonal lines R_{111} and R_{119} differed from Jinliang No. 5. They were short, with deep green leaves, tight panicles, and were highly resistant to head smut. These lines were used as R-lines to create hybrids. The cross 7501 A x R_{111} was high-yielding and resistant to lodging and head smut in initial yield evaluation. The hybrid produced 9180 kg ha^{-1}, outyielding the check hybrid by 13.5 kg ha^{-1} in the provincial-level regional yield trial 1996/7.

Hybrid characteristics

Jinza No. 18 is a highly uniform and genetically stable hybrid. It matures in about 130 days, has an average plant height of 185 cm and a 1000-grain mass of 36 g. It is characterized by strong hard stems, tight panicles, and big red grains with black glumes. Compared to currently cultivated commercial hybrids, it has higher 1000-grain mass, shorter and more resistant to lodging, head smut, and leaf diseases.

Seed production and cultural points

The parental lines can be sown at the same time during hybrid seed production although the restorer line R_{111} flowers 3-5 days later than the male-sterile line.

The hybrids yields well on irrigated highly fertile land. The optimum plant density is 90,000-100,000 plants ha^{-1}. It is necessary to spray to reduce aphid incidence and infestation.

Effectiveness of the somaclonal breeding technique

Research has demonstrated that sorghum plants can be successfully produced by tissue culture. It also indicated the existence of somaclonal variations in the filial generations of R-plants that can be used to improve sorghum. This technique enables the breeding period to be shortened, and genetical variants to be stabilized rapidly. Somaclonal variants were screened, successfully projecting somaclonal breeding as an effective supplementary breeding technique.

New Sources of Resistance to Grain Mold in Converted Zerazera Sorghum

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Introduction

Although 49 fungal species have been reported to be associated with the grain mold complex the species of *Alternaria, Aspergillus, Curvularia, Drechslera, Fusarium, Penicillium,* and *Phoma* have been identified as major ones (Navi et al. 1999). The association of *Fusarium* spp. and *Aspergillus* spp. with grain mold has been a cause of concern because of their ability to produce toxins (Bhat et al. 2000). Fumonisin toxicity to humans and poultry was reported for the first time in India by Bhat et al. (1997).

Zerazera landraces of sorghum that are distributed in the eastern region of Sudan are medium tall with tan color, and look relatively clean in the field. Their grain shape is of the Caudatum type with short glumes, mostly ivory yellow to cream in color. The grain color is yellow, straw, or white, and their endosperms are highly corneous and flinty and white to yellow in color. Zerazera sorghums have been extensively used in various sorghum improvement programs because of their agronomic desirability, superior grain quality and tolerance to diseases and drought (Prasada Rao and Mengesha 1981). Hence, attempts were made to screen some of the converted Zerazeras for resistance to grain molds. Both field (Bandyopadhyay and Mughogho 1988a), and in vitro screening techniques (Singh and Navi 2001) were used to identify high levels of resistance in sorghum with straw-colored grain, particularly in the Guinea alleles background. Accessions that were resistant to mold under artificial epiphytotic conditions and with good agronomic traits are reported in this paper.

Table 1. Evaluation of 43 Zerazera sorghum selections both in vitro and in field nurseries at three Indian locations (Bhavanisagar (BVS), Mysore (MYS) and Patancheru (PTN)J for grain mold resistance during the 1993 and 1994 rainy seasons

						Mean field grain mold score[4]				
IS No.	Pedigree	Origin	DTF[1]	PLHT[2]	LAB[3]	BVS	MYS	PTN	Locations mean	TGMR[5]
41376	IS 956C-13	Sudan	54	90	2.2	5.8	4.0	2.6	4.1	2.3
41402	IS 18758C-164	Ethiopia	79	175	2.5	3.0	2.6	2.5	2.7	2.0
41403	IS 18758C-170	Ethiopia	73	160	2.5	2.7	3.1	2.3	2.7	2.0
41412	IS 18758C-234	Ethiopia	73	165	2.5	2.5	2.3	2.4	2.4	2.3
41413	IS 18758C-242	Ethiopia	73	140	2.5	2.2	2.5	4.2	3.0	3.4
41424	IS 30469C-286	Ethiopia	70	125	2.5	2.5	4.4	3.9	3.6	3.0
41437	IS 2579C-342	Sudan	72	110	2.7	2.3	2.7	3.8	2.9	2.5
41473	IS 24695C-544L	Ethiopia	79	135	2.7	2.6	2.6	5.1	3.4	3.0
41488	IS 18758C-597S	Ethiopia	79	110	2.7	3.3	2.5	3.2	3.0	3.0
41489	IS 18758C 597T	Ethiopia	77	200	2.8	2.7	3.0	2.3	2.7	2.2
41720	IS 18758C 618	Ethiopia	54	125	2.8	3.6	3.0	2.1	2.9	2.0
41509	IS I8758C -698	Ethiopia	86	215	2.8	3.1	3.0	1.9	2.7	2.0
41510	IS 30469C 718	Ethiopia	79	230	3.0	3.5	3.0	3.9	3.5	3.5
41512	IS 24695C 730	Ethiopia	70	105	3.0	2.3	2.3	2.4	2.3	2.0
41513	IS 24695C - 734	Ethiopia	72	95	3.0	3.6	2.5	3.7	3.3	3.5
41530	IS 24695C -808	Ethiopia	74	115	3.0	2.5	5.4	3.6	3.8	3.4
41538	IS 24695C-842	Ethiopia	87	140	3.0	3.2	3.3	3.7	3.4	3.5
41543	IS 24695C-858	Ethiopia	77	150	3.0	2.7	2.0	3.2	2.6	3.0
41549	IS 18758C 886	Ethiopia	72	145	3.2	4.7	3.6	4.5	4.3	4.0
41550	IS 18758C 890	Ethiopia	70	115	3.2	2.4	3.2	4.8	3.5	4.3
41551	IS 18758C-894	Ethiopia	72	130	3.2	2.0	2.3	2.9	2.4	2.2
41564	IS 6248C-952	India	83	220	3.2	3.4	4.3	3.6	3.8	3.2
41596	IS 24695C-1085	Ethiopia	81	155	3.2	3.5	2.8	4.3	3.5	3.5
41598	IS 24695C-1089	Ethiopia	75	140	3.2	2.0	2.4	3.4	2.6	3.0
41601	IS 24695C-1101T	Ethiopia	81	200	3.2	2.3	4.4	3.3	3.3	2.7
41602	IS 18758C-1107S	Ethiopia	83	155	3.3	3.8	4.4	5.6	4.6	4.5
41603	IS 18758C-1107T	Ethiopia	83	185	3.3	3.0	3.3	3.0	3.1	3.0
41607	IS 18758C-1131	Ethiopia	75	150	3.3	1.8	2.5	2.9	2.4	2.3
41608	IS 30469C-I137	Ethiopia	72	120	3.3	2.3	2.5	3.4	2.7	3.0
41609	IS 30469C-1143D	Ethiopia	77	130	3.3	3.3	2.3	4.1	3.2	3.4
41612	IS 30469C-1157	Ethiopia	79	150	3.3	3.0	3.4	2.8	3.1	2.1
41613	IS 30469C - 1161	Ethiopia	85	215	3.3	2.5	3.1	2.9	2.8	2.4
41614	IS 30469C-1167	Ethiopia	83	200	3.5	2.8	2.5	2.3	2.5	2.0
41617	IS 30469C 1179	Ethiopia	70	170	3.5	4.0	2.8	1.8	2.9	2.0
41620	IS 30469C - 1199	Ethiopia	72	110	3.5	3.0	2.8	2.7	2.8	2.5
41621	IS 30469C - 1205	Ethiopia	81	135	3.5	2.0	3.0	3.1	2.7	2.6
41669	IS 18758C - 1476	Ethiopia	81	140	3.5	2.0	4.4	5.2	3.9	4.5
41673	IS 30469C -1502	Ethiopia	70	195	3.5	3.3	3.0	2.3	2.9	2.2
41674	IS 30469C-1508D	Ethiopia	79	225	3.5	1.7	2.5	3.0	2.4	3.0
41695	IS 30469C 1649D	Ethiopia	80	195	3.5	3.1	2.5	3.3	3.0	3.0
41696	IS 30469C I649T	Ethiopia	61	145	3.5	5.2	3.0	2.7	3.6	2.2
41703	IS 24695C 1679T	Ethiopia	79	195	3.5	2.3	2.3	2.5	2.4	2.0
41706	IS 24695C - 1695	Ethiopia	75	205	3.5	2.2	2.7	2.3	2.4	2.0
9471	(Resistant check)	S. Africa	60	245	3.2	2.3	2.1	1.8	2.1	2.0
18452	SPV 104 (Susceptible check)	India	63	190	8.5	3.5	6.7	8.2	6.1	8.0
		SE±	1.14	60.1	0.13	0.13	0.14	0.18	0.11	0.16

Mean of two repetitions each with 10 plants in 4-m long plots in field screening

1. DTF = Days to 50% flowering in the rainy season
2. PLHT=Plant height (cm) in rainy season
3. Mean of two replications, each of a petridish containing 25 grains using three fungi (*Fusarium moniliforme* , *F. pallidoroseum,* and *Curvular ia lunata*)
4. Mold scores on 1-9 scale, where 1= no mold, and 9 - > 75% mold
5. Threshed grain mold score was recorded only at Patancheru

Materials and methods

The most predominantly occurring grain mold fungi *Fusarium moniliforme* J. Sheld. *F pallidoroseum* (Cooke) Sacc. and *Curvularia lunata* (Wakker) Boedijn] were isolated on oatmeal agar and multiplied on presoaked autoclaved sorghum grains at 28±1°C under 12 h light cycles for 10 days. A spore suspension (1 *x* 10^6 spores mL^{-1}) prepared by mixing equal volumes of spore suspension of each of the three fungi was used for in vitro tests.

A total of 347 selections derived from 12 photoperiod sensitive Zerazera accessions [IS 956, IS 2579, IS 3443 and IS 6928 (Sudan), IS 18758, IS 24695 and IS 30469 (Ethiopia), IS 6248, IS 18484, IS 18790 and IS 18791 (India) and IS 18522 (USA)] through a conversion program were used for in vitro screening. IS 9471 a resistant cultivar with brown pericarp and IS 18452 a susceptible cultivar with straw-colored pericarp were included as checks in all the tests.

A preliminary evaluation of 347 selections was carried out in 1992 following an in vitro screening technique developed at ICRISAT (Singh and Navi 2001). Twenty-five seeds of each selection were dipped in a spore suspension described above for 1-2 min. They were air dried and transferred to a 9-cm pre-sterilized petridish humid chambers and incubated at 28±1°C for 5 days. Seeds were evaluated on a 1 9 mold severity rating scale where 1 = no mold, 2 = 1-5, 3 = 6 10, 4 = 11-20, 5 = 21 30, 6 = 31-40, 7 = 41- 50, 8 = 51-75 and 9 = >75% grain surface areas covered by the mold).

Forty-three resistant selections made from in vitro tests were evaluated in a field grain mold nursery using overhead sprinklers during the 1993 and 1994 rainy seasons at Patancheru in Andhra Pradesh, and under natural conditions at Bhavanisagar in Tamil Nadu and Mysore in Karnataka. In each selection 10 panicles with uniform flowering were tagged and were evaluated for mold resistance using the 1-9 rating scale at grain maturity, and again 14 days after maturity. All the tagged panicles were harvested, threshed, and threshed grain mold scores were recorded on a 1 -9 scale.

Results and discussion

Under in vitro test, none of the selections was totally free from mold, while 43 showed mean mold ratings between 2.2 and 3.5, 88 were rated between 3.7 and 4.5, and 216 had ≥ 4.7 mold ratings. The 43 selections with ≤3.5 ratings from in vitro screening were tested in sorghum grain mold nurseries during the rainy seasons 1993 and 1994 the mean mold rating across the locations was ≤4 on 1 -9 scale for most test entries (Table 1). The mean mold score of susceptible check IS 18452 was 6.1 and that of a resistant check IS 9471 with brown pericarp was 2.1. The threshed mold scores of the 43 selections were below 4 and that of resistant check 2 and the susceptible check 8. The days to 50% flowering (DTF) ranged from 54 to 87 while plant height varied from 90 to 220 cm in the selected 43-converted zerazera selections. Eight accessions with in vitro mold ratings of ≤3.7-4 and field mold ratings of <4 at Patancheru were selected as

Table 2. Evaluation of eight Zerazera sorghum selections for resistance to grain molds both in vitro and a field grain mold nursery at Patancheru during the 1994 rainy season

IS No.	Pedigree	Origin	DTK[1]	PLHT[2]	Mean mold score[4] LAB'	PTN	TGMR[5]
41720	IS 18758C -618-2	Ethiopia	54	125	2.1	2.2	2.0
41720	IS 18758C-618-3	Ethiopia	54	125	2.4	2.4	2.0
40657	IS 18758C-710-4	Ethiopia	-[6]		2.5	2.3	2.0
40657	IS 18758C-710-5	Ethiopia	-	-	2.5	2.3	2.0
41397	IS 30469C-140-2	Ethiopia	79	130	3.0	3.9	3.5
41397	IS 30469C 140-4	Ethiopia	79	130	3.0	3.9	3.2
41618	IS 30469C - 1187-5	Ethiopia	79	205	3.0	3.9	3.4
41675	IS 30469C 1508T-2	Ethiopia	80	235	3.0	3.9	3.3
9471	(Resistant check)	S. Africa	60	245	3.2	1.8	2.0
18452	[SPV 104 (Susceptible check)]	India	63	190	8.5	8.2	8.0
	SEf±	3.75	16.32	0.59	0.59	0.58	

1 5 See Table 1 footnotes

6. = Data not available

promising. Two selections each of IS 18758C--618 , IS 18758C-710, and IS 30469C-140, and one selection each of IS 30469C-1187, and IS 30469C-1508T showed consistently high levels of mold resistance (<3) in both the tests (Table 2). Additionally, these selections were also found to have very high levels of resistance to anthracnose [*Colletotrichum graminicola* (Ces.) GW. Wilson] and leaf blight [*Exserohilum turcicum* (Pass.) Leonard & Suggs] at all the three locations (data not reported).

Several sources of resistance have been reported in late-maturing white-straw, brown-, and red-pericarp sorghums (Bandyopadhyay and Mughogho 1988b) and in photoperiod-sensitive germplasm accessions (Singh et al. 1995; Singh and Navi 2001). These new sources identified are photoperiod-insensitive, early to medium-maturing with straw-colored grain. Therefore, it is proposed to further test them in variable environments to determine their resistance stability.

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