a wet control were also tested. After being soaked in solutions containing KCl, $K_2SO_4$, superphosphate, hyperphosphate or mixtures of them for 3 days at 5°C in the dark, seeds were dried (25°C for 3 h) and stored at 25°C for 4 weeks.

### Results

Post-storage germination tests at 39/29°C (day/night temp) and –3.0 bar moisture level revealed that soaking seeds in water or 1g $L^{-1}$ hyperphosphate gave significantly higher final germination percentages and germination index values than untreated seeds (Table 1). Treating seeds with KCl either alone or in combination with another salt significantly reduced the germination percentage due to toxic effect of the $Cl^-$ ion.

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# Pathology

## Grain Mold Resistance in Advanced Sorghum B-lines

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### Introduction

Grain mold, caused by a complex of pathogenic and saprophytic fungi, is a highly destructive disease of sorghum [*Sorghum bicolor* (L.) Moench] and is widely distributed in the semi-arid tropics of Africa and India. Annual global losses due to grain mold have been estimated at US$ 130 million (ICRISAT 1992). Improved cultivars, particularly hybrids bred for early to medium maturity to escape terminal drought stress in India are normally more vulnerable to the disease than late maturing cultivars (Bandyopadhyay et al. 1988). Major efforts in breeding cytoplasmic-nuclear male sterility-based sorghum seed parents (A/B-lines) for grain mold resistance at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, and other locations in India as well as in the US have met with partial success (Reddy et al. 2000). Therefore, efforts were made to improve sorghum B-lines for grain mold resistance through a specific breeding approach and the outputs of these efforts, along with future perspectives of breeding for grain mold resistance, are reported here.

### Materials and Methods

The material for the study consisted of 28 promising grain mold resistant B-lines developed at ICRISAT, Patancheru, during the past six years using pedigree selection among segregating progenies derived from crosses between grain mold resistant lines and high-yielding bold grain B-lines. These were evaluated along with three controls (IS 14384 as grain mold resistant, and Bulk Y and 296B as grain mold susceptible) during the 2003 rainy season in a randomized complete block design (RCBD) with 2 replications. Sprinkler irrigation was provided for 30 min per day on dry days during flowering to physiological maturity of sorghum to create high humidity (>90% relative humidity) congenial to the development of adequate and uniform disease pressure. Ten panicles of uniformly flowering plants were tagged in each replication for recording grain mold infection at

**Table 1. Performance of advance sorghum B-lines for grain mold resistance and agronomic traits during the 2003 rainy season, ICRISAT, Patancheru.**

| Designation | DTF[a] | Plant heigh (m)[a] | Grain mass (g $100^{-1}$) | Grain yield (t $ha^{-1}$) | PGMR[b] | TGMR[b] | Grain hardness[c] (kg $seed^{-1}$) | Panicle type[d] | Glume color[e] | Glume cover[e] | Grain color[e] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SGMR 03-1 | 74 | 1.9 | 2.37 | 1.54 | 5.6 | 6.4 | 5.1 | SC | W | 50 | W |
| SGMR 03-2 | 72 | 1.9 | 2.13 | 1.57 | 4.0 | 4.3 | 4.8 | SC | R | 25 | W |
| SGMR 05-1 | 71 | 1.7 | 2.20 | 2.35 | 6.4 | 6.0 | 3.9 | SC | R | 50 | W |
| SGMR 05-2 | 72 | 1.7 | 2.13 | 1.52 | 6.7 | 7.3 | 3.7 | SC | R | 25 | W |
| SGMR 07-1 | 71 | 1.9 | 2.35 | 2.29 | 4.4 | 5.2 | 3.9 | SC | R | 25 | W |
| SGMR 07-2 | 74 | 1.8 | 2.22 | 1.83 | 4.9 | 5.4 | 4.3 | SC | R | 25 | W |
| SGMR 08-1 | 79 | 1.7 | 2.34 | 1.09 | 7.4 | 8.4 | 4.8 | SC | W | 50 | W |
| SGMR 08-2 | 77 | 1.9 | 2.55 | 1.14 | 7.7 | 8.4 | 4.9 | SC | W | 50 | W |
| SGMR 09-1 | 77 | 1.7 | 2.20 | 0.58 | 6.1 | 8.1 | 4.9 | SC | W | 50 | W |
| SGMR 09-2 | 77 | 1.8 | 2.21 | 0.92 | 7.3 | 8.2 | 5.9 | SC | W | 25 | W |
| SGMR 10-1 | 75 | 1.9 | 1.99 | 1.56 | 5.1 | 4.9 | 4.6 | L | W | 50 | R |
| SGMR 10-2 | 74 | 2.0 | 1.81 | 1.19 | 6.0 | 5.9 | 3.5 | SC | R | 50 | R |
| SGMR 11-1 | 74 | 1.9 | 2.13 | 1.14 | 3.6 | 3.8 | 5.0 | SC | R | 50 | R |
| SGMR 11-2 | 77 | 1.8 | 2.01 | 0.98 | 4.6 | 4.2 | 5.1 | SC | W | 50 | R |
| SGMR 12-1 | 71 | 2.0 | 2.46 | 1.82 | 4.4 | 5.1 | 3.9 | SC | R | 50 | R |
| SGMR 12-2 | 70 | 2.0 | 2.51 | 2.68 | 4.3 | 5.4 | 4.0 | SC | R | 25 | R |
| SGMR 21-1 | 78 | 1.7 | 1.97 | 0.73 | 3.4 | 3.6 | 5.4 | SC | R | 50 | R |
| SGMR 21-2 | 81 | 1.7 | 2.12 | 0.50 | 5.3 | 5.5 | 3.8 | SC | W | 50 | R |
| SGMR 21-3 | 81 | 1.6 | 1.57 | 0.29 | 5.5 | 6.1 | 3.9 | SC | R | 50 | R |
| SGMR 21-4 | 78 | 1.7 | 1.88 | 0.77 | 3.2 | 2.8 | 5.6 | SC | B | 50 | B |
| SGMR 23-1 | 79 | 1.9 | 1.51 | 0.74 | 5.4 | 6.1 | 1.7 | SC | R | 50 | B |
| SGMR 23-2 | 77 | 1.9 | 1.60 | 1.39 | 3.8 | 4.4 | 1.9 | SC | R | 75 | R |
| SGMR 24-1 | 70 | 1.7 | 2.34 | 2.25 | 4.3 | 5.1 | 4.0 | SC | W | 50 | B |
| SGMR 24-2 | 71 | 1.7 | 2.26 | 1.78 | 6.8 | 7.5 | 3.0 | SC | W | 50 | B |
| SGMR 33-1 | 70 | 1.9 | 1.95 | 2.62 | 1.7 | 2.3 | 3.8 | C | R | 75 | B |
| SGMR 33-2 | 70 | 2.0 | 2.01 | 2.69 | 1.8 | 2.2 | 3.3 | C | R | 50 | B |
| SGMR 40-1 | 62 | 1.9 | 2.51 | 2.50 | 1.7 | 3.2 | 4.4 | SC | B | 25 | B |
| SGMR 40-2 | 62 | 1.6 | 2.41 | 2.31 | 2.3 | 4.5 | 4.4 | SC | B | 25 | B |
| IS 14384 (C) | 71 | 2.8 | 1.99 | 3.63 | 1.2 | 1.3 | 8.3 | L | B | 25 | R |
| Bulk Y (C) | 56 | 1.3 | 3.63 | 2.09 | 8.2 | 9.0 | 7.6 | L | B | 25 | W |
| 296 B (C) | 73 | 1.1 | 1.88 | 1.57 | 8.4 | 8.7 | 2.3 | C | W | 50 | W |
| Mean | 73 | 1.8 | 2.17 | 1.58 | 4.9 | 5.5 | 4.4 | - | - | 45 | - |
| MSS | 92.83** | 0.22** | 0.44** | 1.96** | 75.63** | 81.72** | 3.73** | - | - | - | - |
| LSD($P$=0.05) | 2.49 | 0.19 | 0.31 | 0.32 | 1.1 | 0.9 | 1.5 | - | - | - | - |

[a]Mean of three replications. DTF=Days to 50% flowering

[b]PGMR=Grain mold reaction at grain physiological maturity and TGMR=Grain mold reaction on threshed grain. Mean of 2 replications, 10 panicles/rep., based on 1-9 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% mold infection

[c]Mean of two replications, 25 grains/rep

[d]C=Compact; SC=Semicompact; L=Loose

[e]W=White; R=Red; B=Brown

**Significant at $P$<0.01

**Table 2. Influence of grain and glumes colors on grain mold reactions in advanced sorghum B-lines.**

| | Grain color | | | Glume color | | | Glume coverage (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| Moldreaction | White (10) | Red (10) | Brown (8) | White (10) | Red (15) | Brown (3) | 25 (8) | 50 (18) | 75 (2) |
| PGMR | 6.1 | 4.6 | 3.4 | 6.0 | 4.4 | 2.4 | 4.4 | 5.1 | 2.8 |
| TGMR | 6.8 | 4.9 | 4.2 | 6.7 | 4.9 | 3.5 | 5.4 | 5.6 | 3.2 |

Figures in parentheses represent the number of B-lines.
PGMR=Grain mold reaction at grain physiological maturity and TGMR=Grain mold reaction on threshed grain.

physiological maturity (PM) and on threshed grain (TG) using the 1-9 progressive 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% mold. Grain (20 g from each panicle) threshed from all the panicles were pooled and mold infection was recorded as TGMR using the same 1-9 scale.

A separate trial was conducted with the same set of entries during the 2003 rainy season at ICRISAT, Patancheru in RCBD for agronomic evaluation. The observations were recorded on 10 randomly selected plants in the middle two rows for growth and yield traits; days to 50% flowering (DTF), plant height, grain yield, panicle type (compact, semi-compact and loose), grain mass, glumes and grain color (white, red, and brown), glumes cover on grains, and grain hardness (at 7% grain moisture).

## Results and Discussion

Significant differences were observed among the 28 lines for PGMR and TGMR scores, and DTF, plant height, grain hardness, grain mass, and grain yield (Table 1). None of the entries showed significantly higher levels of PGMR and TGMR than the resistant control IS 14384, which showed PGMR and TGMR scores of 1.2 and 1.3, respectively. Nevertheless, SGMR 33-1, SGMR 33-2, SGMR 40-1 and SGMR 40-2 had PGMR score less than 2.3 and were at par with the resistant check IS 14384, and produced significantly higher grain yield (2.31-2.69 t $ha^{-1}$). These B-lines, besides flowering early (<70 days), had semi-compact to compact panicles and red/brown grains with 25-75% coverage by red/brown glumes. These lines had 1.95–2.51 g $100^{-1}$ grain mass and moderate grain hardness of 3.3–4.4 kg $seed^{-1}$ compared with 1.88 g $100^{-1}$ grain mass and 2.3 $kg^{-1}$grain hardness of 296 B, a susceptible control.

**Relationship of PGMR and TGMR with grain and glumes traits.** The results indicated that grain and glume color (red or brown) appeared to contribute to grain mold resistance (Table 2). The lines with brown grain and glumes showed higher grain mold resistance than those with red grain and glumes or white grain and glumes as evident from mean PGMR and TGMR scores (Table 2). The earlier reports on the contribution of grain color (Menkir et al. 1996) and glume color (Audilakshmi et al. 1999) to grain mold resistance in sorghum support the present findings. Three lines [SGMR 3-2 (PGMR: 4.0 and TGMR: 4.3) and SGMR 7-1 (PGMR: 4.4 and TGMR: 5.2) and SGMR 7-2 (PGMR: 4.9 and TGMR: 5.4)] in white grain background had moderate mold resistance levels, although they had pigmented (red) glumes. All white-grain B-lines with white glume color were susceptible (Table 1). The glume cover on the grain also appeared to provide some protection to grains from mold infection. Two lines (SGMR 23-2 and SGMR 33-1) with more than 75% glume coverage showed much higher grain mold resistance than those with 25 and 50% glume coverage (Table 2). However, no definite relationship was observed between the extent of glume coverage and mold resistance levels. For example, lines, such as SGMR 05-1, SGMR 08-1, SGMR 08-2, SGMR 09-1 and SGMR 24-2 with 50% glume coverage were more susceptible (PGMR and TGMR scores >6.0), than SGMR 40-1 and SGMR 40-2 with 25% glume coverage (PGMR< 2.0 and TGMR<4.5) (Table 1). The higher mold resistance levels in some of these lines with less glume coverage is encouraging considering farmers' preferences for cultivars with less glume coverage, which reduces postharvest processing cost.

A significant positive correlation between PGMR and early flowering and significant negative correlation between PGMR and TGMR scores with grain yield implied that it is necessary to maintain a balance between maturity, mold resistance levels, and grain yield. A weak correlation between mold resistance levels and grain mass and grain hardness was observed, which is contrary to earlier reports of significant negative correlation between mold resistance and grain mass (Reddy et al. 2000) and positive correlations between mold resistance and grain hardness

(Audilakshmi et al. 1999). These results indicate better prospects for developing mold resistant B-lines without compromising grain size (one of the important traits preferred by farmers). Concerted breeding efforts involving diverse sources of mold resistance and high-yielding bold grain lines are essential for the development of B-lines with enhanced mold resistance levels under desirable agronomic background.

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# Variability in Target Leaf Spot Pathogen *Bipolaris sorghicola* of Sorghum in Rajasthan, India


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## Introduction

Target leaf spot, caused by *Bipolaris sorghicola* (Lefebvre & Sherwin) Alcorn, is known to be prevalent and occasionally severe in the US since 1939 (Dalmacio 2000) and was reported from India by Munjal and Kapoor (1960). Limited information is available on this disease, probably due to its misidentification since its symptoms closely resemble those of other foliar diseases such as zonate leaf spot and gray leaf spot (Dalmacio 2000; Leslie 2002). Target leaf spot was observed to be widely prevalent in southern Rajasthan during 2001-2004, and critical studies of its symptoms and morphological and cultural characteristics were made to provide dependable identification of the disease in the field. The results of this study are presented and discussed here.

## Materials and Methods

The leaves infected by symptoms of target leaf spot collected from different places and cultivars (Table 1) were studied in detail and the pathogen was isolated on potato dextrose agar (PDA) medium. Important morphological characteristics *viz.*, conidial development on 0.5% PDA (by slide-culturing method), germination of conidia (in slide-germination tests), and cultural characteristics were studied, and compared with the available literature (Dalmacio 2000). The pathogen collected from various regions was identified as *Bipolaris sorghicola.* The cultures were maintained on PDA slants at 4°C.

Comparative pathogenic potential of five isolates of *B. sorghicola* was studied by inoculating 28-day–old pot-grown plants of four cultivars *Kekri* local, S Path-97, IS-164 and SU-45 with spore suspensions ($1 \times 10^5$ conidia $ml^{-1}$), prepared from 10-day-old cultures of *B. sorghicola* isolates. Each isolate was maintained in three replicated pots, each with five plants. Pots were separated by polythene sheets to avoid drift of inoculum from other pots while spray inoculating. The inoculated plants were kept in humid chambers for 24 hours and then transferred to the cagehouse and high humidity was maintained throughout the disease development period by regular irrigations. Observations were recorded 30 days after inoculation on a 1-5 disease rating scale. Number of plants in each score was recorded and percent disease index (PDI) was calculated as:

$$\text{Percent disease index} = \frac{\text{Sum of all disease ratings}}{\text{Total number of ratings} \times \text{maximum score}} \times 100$$

## Results and Discussion

The symptoms of target leaf spot on different cultivars consisted of yellow, diffused spots on cultivars with tan reaction (Fig. 1) or straw-colored spots with or without red-brown margins, or bright red to purple brown (Figs. 4-6). The shape of the spots varied from elongated pointed or round, or cylindrical lesions (Figs. 3, 7, 8) to