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STUDIES ON COMBINING ABILITY OF LEAF BLIGHT EXSEROHILUM TURCICUM) RESISTANCE IN SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH)

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ABSTRACT

Sorghum hybrids of 20 cytoplasmic-male steriles and six restorers and the parents were evaluated in 1996 and 1997 for leaf blight disease resistance parameters (disease damage score, and length, width and area of the lesions, and number of lesions and flecks), and yield components (days to flower, plant height, agronomic desirability, grain yield plant, and test weight). Combining ability analysis revealed significant genetic variation among the parental lines and the hybrids for various characters studied. The significant line x tester mean squares indicated that the A-lines do not appear to behave consistently over different R -lines and *vice versa.* Specific combining ability (SCA) variances played an important role in the inheritance of various disease related characters and yield attributes. These results indicate that scope exists for producing superior hybrids with heterotic effects for

these traits. The parents and the hybrids with significant favorable general combining ability *(CGA)* and SCA contributions for area of the lesion, number of lesions and number of flecks coupled with desirable mean performance are useful. The most desirable male-sterile lines having desirable effects for more than one disease resistance parameters and yield components are: MS 7, MS 9, MS 11 and MS 16 and the restorer Rl. The hybrids, MS 16 and Rl and MS 15 x R6 were found desirable as they possessed desirable SCA effects for resistance in both the years for more than one trait.

Key words: Combining ability, disease related parameters, *Exserohilum turcicum*, leaf blight, sorghum and yield attributes.

INTRODUCTION

Sorghum *(Sorghum bicolor* (L.) Moench) is extensively cultivated in semi-arid tropics in India and Africa. Its grain is used as food, and its dried stalks as fodder to feed cattle (Rooney & Waniska, 2000). Leaf blight caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs (1974) is one of the extensively distributed (Tarumoto *et al.*, 1997), and at times most damaging foliar pathogens of sorghum (Fredericksen, 1980). The safest and the most economical way of combating disease is through the development of the resistant varieties. No concerted effort has been made to study the combining ability of the parents and the hybrids for various disease related characters besides disease damage score. In order to develop disease resistant and high yielding cultivars it is imperative to identify and select potential combiners, which can produce hybrids superior to the existing ones. Hence, in this paper, the combining ability of the parents and hybrids in sorghum for various blight resistant parameters and yield contributing characters is summarized.

MATERIALS AND METHODS

Materials and field evaluation:

In the present study, 20 CMS (CYtoplasmic male-sterile i.e., A) lines were crossed with six restorer (testers ie., R) lines in a line x tester fashion during the rainy seasons of 1996 and 1997. The resultant 120 cross combinations (A x R hybrids), along with their respective parents and checks, were sown in a randomised complete block design replicated three times during the post rainy seasons of 1996 and 1997, for ieaf blight disease related parameters and yield

contributing characters under artificial disease epiphytotic conditions at ICRISAT Asia Center, Patancheru, Hyderabad, Andhra Pradesh, India. Plot size in both the seasons consisted of 2 rows each of 4m length with 75 cm between rows and 12 cm spacing within the row. Spraying with fungicides was avoided immediately after the inoculation to prevent its adverse effect on the spread of the inoculum. However, plant protection measures were applied as required at the initial stages of the crop to safeguard the crop from the incidence of shoot fly. Highly leaf blight susceptible entries such as *Kundi Jowar* and H 112 were planted in two rows each as infestor rows all round the field and after every 1 0 rows and 12 rows of the test material during first and second years, respectively.

Inoculum preparation:

The leaves affected with leaf blight *(Exserohilum turcicum* (Pass.) were collected from the field and cut into small pieces and surface sterilized with 0.1 % mercuric chloride for one minute followed by washing with sterile distilled water. Leaf pieces were aseptically transferred to sterilized petri plates containing 20 ml of sterilized Potato Dextrose Agar media (PDA) and incubated at 20°C for encouraging the fungal growth. The fungal growth was aseptically transferred to flasks containing sterilized sorghum grains and incubated at 20°C for 15 days. Sorghum grains covered with mycelia and the conidia of the fungus were removed from the flasks, allowed to air dry and separated as far as possible.

Inoculation:

Sorghum plants were artificially inoculated following the whorl-drop method of inoculation (Frederiksen & Franklin, 1978). The inoculation was carried out 21 and 30 days after emergence of the coleoptile during the post rainy seasons of 1996 and 1997, respectively. The second inoculation was given one week after the first inoculation. All the plants in each entry were inoculated by placing two or three grains of seed inoculum in the whorl. High humidity conditions were created by providing overhead sprinklers on the day after inoculation until the disease has spread. It took 40 days for the disease to spread.

Observations:

The observations were recorded for the following characters: Disease damage score (DDR) (scored on a 1-9 scale on plot basis where 1 highly resistant and 9 highly susceptible), length of the lesion (cm), width of the lesion (em), area of the lesion (cm^2), number of lesions, number of flecks, days to 50% flowering, plant height (cm), agronomic desirability (scored on a 1-5 scale on plot basis where l=excellent and 5=poor), grain Yield plant^{-1} (g) and test weight (g 100 grains^{-1}). The genotypes were grouped into six disease reaction groups viz., highly resistant

(HR), resistant (R), moderately resistant (MR), less susceptible (LS), susceptible (S), and highly susceptible (HS) reaction groups taking overall disease damage score as the basis for Presentation of the data.

The results of the pooled analysis of variance for all the entries i.e., A x R hybrids for two consecutive years revealed non-significant differences among the years and significant differences among the genotypes and year x genotype interaction at both levels of significance. Though years were found non-significant, and year x genotype interaction was significant, since the error degrees of freedom was only four (4), the grouping of genotypes based on the disease damage score was handled separately for two consecutive years. The genotypes were therefore grouped into various disease reaction (score) groups separately for each year taking standard deviation into consideration.

Highly resistant (HR)	=	<(x - 2 S.D.)
Resistant (R)	=	(x - 2 S.D.) to (x - S.D.)
Moderately resistant (MR)	=	(x - S.D.) to x
Less susceptible (LS)	=	(x) to (x + S.D.)
Susceptible (S)	=	(x + S.D.) to (x + 2 S.D.)
Highly susceptible (HS)	=	>(x + 2 S.D.)

Where S.D. = standard deviation; x = mean of the trial.

RESULTS AND DISCUSSIONS

Analysis of variance for line x tester mating design revealed significant differences among male-sterile lines, restorer lines, and their F_1 S in both the seasons indicating genetic differences among male-sterile lines as well as restorer lines for all the characters under study (Table 1). The significant line x tester mean squares indicated that the male-sterile lines do not appear to behave consistently over different restoreres and *vice versa.* The data on variance estimates over two years indicated that specific combining ability (SCA) variance was more than general combining ability (GCA) variance for all the characters under study indicating that non-additive gene action played an important role in the inheritance of these characters. This finding is in conformity with the findings

Table 1: Anova tor combining ability analysis tor various disease resistant parameters and yield contributing characters ot sorghum, rabi season.

Characteristic	Year	Replication mean squares d.f. = 2	Line mean squares d.f. = 2	Tester mean squares d.f. = 2	Line x Tester mean squares d.f. = 2	Error mean squares d.f. = 2
DISEASE PARAMETERS						
Disease score[1]	1996	0.210	9.69**	39.83**	1.60**	0.520
	1997	10.250	5.41 **	2.68**	1.72**	0.440
Length of the lesion (cm)	1996	1.090	2.14**	6.66**	1.33**	0.100
	1997	0.070	5.11 **	1.54 **	2.36**	0.180
Width of the lesion (cm)	1996	0.010	0.02**	0.06**	0.01 **	0.001
	1997	0.001	0.02**	0.01**	0.01 **	0.002
Area of the lesion (cm^2)	1996	0.230	0.41 **	1.00**	0.22**	0.020
	1997	0.020	0.89**	0.27**	0.63**	0.050
Number of lesions	1996	9.930	189.79**	214.34**	64.46**	1.230
	1997	1.300	36.45**	68.36**	29.18**	0.680
Number of flecks	1996	313.000	52619.20**	20701.70**	16181.10**	362.000
	1997	841.730	68217.94**	189803.49**	70539.77**	1477.200
GRAIN YIELD COMPONENTS						
Days to 50% flowering	1996	29.410	126.20**	193.04**	25.90**	4.860
	1997	6.690	86.45**	33.42**	34.37**	1.170
Plant height (cm)	1996	8.470	2595.58**	18532.38**	307.11**	24.630
	1997	159.090	14281 .42**	2223.36**	2321.06**	40.600
Agronomic score2.	1996	0.770	1.56**	3.80**	0.59**	0.320
	1997	6.390	1.96**	1.13**	1.03**	0.290
Grain yield $plant^{-1}$ (g)	1996	17.280	327.39**	682.89**	130.61**	15.830
	1997	3.010	307.51 **	216.62**	307.66**	5.140
100 seed weight (g)	1996	0.450	0.85**	0.31 **	0.11 **	0.040
	1997	0.020	0.85**	0.19**	0.40**	0.030

1. Scored on a (1-9) scale. 2. Scored on a (1-5) scale. ** Significant at 1%. * Significant at 5%.

of Khehra *et al.*, (1984) for reaction of *Dreschlera maydis* and Kukadia *et al.*, 1983 for plant height and grain yield plant^{-1} in maize. However, Weiji *et al.*, 1956 reported the importance of both additive and non-additive gene effects for number of lesions, area of lesions and amount of spores per lesion area against *Helminthosporium maydis* in maize. GCA variance was of higher magnitude than SCA variance indicating the importance of additive component than the dominance component for disease reaction against leaf blight in maize (Hughes & Hooker, 1971 and Ramamurthy *et al.*, 1980). Sigulas *et al.* (1988) also reported that in maize GCA effects were much larger than SCA effects for mean lesion area, lesion expansion rate and the shape of the lesion area expansion curve. The relative importance of non-additive gene effects was generally small and varied with the population involved and to a lesser extent, with the year of study (Hughes & Hooker, 1971).

The high SCA variance observed in these studies may be due to the fact that male-sterile lines and restorers were bred separately in different programmes ensuring diversity, and they also support the possibility of selecting highly heterotic hybrids.

The results of GCA effects of selected parents are presented in Table 2 for 1996 and Table 3 for 1997 for disease related and Yield contributing characters. The values with negative estimates are desirable considering the scale in describing the trait. For e.g.: One (1) is desirable because we defined it as resistant and 9 as susceptible. So the estimates with lower values are considered desirable.

The male-sterile lines, MS 7, MS 9 and MS 13, and the restorer line, R3 in the first year (Table 2) were found to be superior with negative GCA effects for DDR, length of the lesion, width of the lesion, area of the lesion, number of lesions and number of flecks coupled with low mean values for the above characters. In the following year, the male-sterile parent, MS 9 exhibited desirable GCA effects for DDR, and length, width and area of the lesion, and number of lesions, while MS 7, MS 1 0 and MS 16 for DDR, and length, width and area of the lesion. These season specific response changes need to be investigated further. These parents (hereafter referred to as group I) are considered to be highly desirable and can be preferably used as donors in the future line-improvement breeding programmes or as the parents in developing leaf blight resistant hybrids as the spread of the pathogen at each and every site of infection is minimum in both the years.

The next set of parents (called hereafter as group II) from the point of desirability are the ones with desirable GCA effect for area of the lesion but undesirable GCA effects for number of lesions and flecks. These are: MS 3, MS

Table 2. General combining ability (GCA) effects of selected sorghum parents for various disease resistant parameters and yield contributing characters, post rainy season, 1996, ICRISAT, Patancheru.

Genotypes	Disease Damage score)	Length of lesion (cm)	Width of lesion (cm)	Area of the lesion (cm²)	Number of lesions (no)	Number of Decks (no)	Days to 50% flowering	Plant height (cm)	Agrono mie seore1	Grain Yield plant⁻¹	100 seed weight (g)
Lines Resistant[3]											
MS 4	-0.22	0.81**	0.07**	0.40**	-4.31**	-61.08**	1.93**	-4.79**	0.31*	-2.21*	-0.14
MS 7	-1.22**	-0.25**	-0.02*	-0.10**	-4.46**	-58.45**	2.10**	-9.18**	0.25*	1.50	0.08*
MS 9	-0.99**	-0.21**	-0.03**	-0.12**	-0.67**	-13.39**	-0.46	0.88	-0.31*	6.89**	0.10**
MS 10	-0.33*	-0.35**	0.01	-0.02	3.91**	122.ot**	1.60**	-9.18**	0.08	1.71	0.14**
MS 11	-1.11**	-0.46**	-0.03**	-0.14**	2.15**	10.77.	2.43**	-8.57**	-0.08	-0.23	-0.06
MS 15	0.23	0.35**	0.06**	0.19**	-5.59**	-83.12**	2.43**	-28.07**	0.47**	-5.19**	0.21**
Moderately Resistant[3]											
MS 3	0.34*	-0.21**	0.00	-0.08**	4.63**	63.90**	1.82**	-1.62	0.14	1.51	-0.06
MS 6	0.06	-0.24**	-0.02*	-0.12**	-2.54**	-70.43**	3.21**	-1.40	0.42*	-5.88**	0.04
MS 16	-0.88**	-0.03	-0.02*	-0.06*	U8**	25.51**	-4.18**	-2.79*	-0.14	4.84**	0.04
Less Susceptible[3]											
MS 14	0.78**	0.38**	0.06**	0.17**	-2.10**	20.68**	1.32.	16.54**	0.42*	-3.33**	0.20**
MS 24	0.17	-0.25**	-0.03**	-0.13**	3.42**	50.20**	-3.46**	-11.34**	-0.03	2.17*	-0.05
Susceptible[3]											
MS 13	0.34*	-0.31**	-0.03**	-0.14**	-3.01**	-41.77**	1.49**	19.93**	0.03	-2.47**	0.33**
S.E. (Line)	0.17	0.07	0.01	0.03	0.26	4.48	0.52	1.17	0.13	0.94	0.04
S.E.(G(I)-G(J)) Line	0.24	0.11	0.01	0.04	0.37	6.34	0.73	1.65	0.19	1.33	0.06
Testers Resistant[3]											
R 1	-0.64**	-0.44**	-0.04**	-0.17**	3.36**	3.56	2.01**	30.71**	-0.18**	3.95**	0.03
Moderately Resistant											
R 3	-1.29**	-0.39**	-0.04**	-0.15**	-0.85**	-19.82**	0.01	-23.03**	0.38**	-3.86**	-0.07**
Less Susceptible[3]											
R 5	0.89**	0.29**	0.04**	0.14**	-0.48**	24.47**	-0.39	-6.66**	0.13	-1.21*	0.03
Susceptible[3]											
R 6	0.13	0.14**	0.08**	0.06**	-2.22**	-15.84**	2.11**	3.36**	-0.18**	-3.13**	-0.09**
S.E. (Tester)	0.09	0.04	0.01	0.02	0.14	2.46	0.28	0.64	0.07	0.52	0.02
S.E. (G(I)-G(J)Tester	0.13	0.06	0.01	0.02	0.20	3.47	0.40	0.91	0.10	0.73	0.03

1. Scored on a (1-9) scale, 2. Scored on a (1-5) scale, 3. The groups are based on disease score, .. Significant at 1 %,' Significant at 5%.

Table 3. General combining ability (GCA) effects of selected sorghum parents for various disease resistant parameters and yield 2 contributing characters, post rainy season 1997, ICRISAT, Patancheru.

Genotypes	Disease damage score[1]	Length of the lesion (cm)	Width of lesion (cm)	Area of the lesion (cm^2)	Number of lesions (no)	Number of flecks (no)	Days to 50% flowering	Plant height (cm)	Agrono mie seore[2]	Grain yield plant^{-1}(g)	100 seed Weight (g)
LINES											
Moderately Resistanf											
MS 4	0.37*	0.20*	0.02*	0.16**	-0.69**	-11.56	-1.71**	-7.37**	-0.07	4.93**	-0.04
MS 7	-0.85**	-1.18**	-0.07**	-0.47**	1.19**	179.82**	1.13**	35.13**	-0.18	-4.65**	-0.05
MS 10	-0.46**	-0.80**	-0.05**	-0.37**	0.69**	-7.69	-0.37	31.80**	-0.46**	8.68**	0.17**
MS 11	-0.07	-0.37**	0.00	-0.14**	3.02**	151.46**	0.52*	-14.04**	0.27*	-5.10**	0.25**
MS 16	-0.41 **	-0.34**	-0.03**	-0.18**	0.89**	100.85**	0.85**	-38.76**	0.16	-7.91 **	0.18**
MS 25	0.43**	0.70**	0.04**	0.30**	-2.17**	-90.58**	-0.26	-8.48**	-0.07	0.64	0.15**
Less Susceptible[3]											
MS 9	-0.79**	-0.88**	-0.03**	-0.30**	-0.68**	36.3**	2.85**	25.96**	0.32*	0.21	0.06
MS 14	-1.02**	0.19	0.02*	0.16**	-0.98**	-6.65	0.68**	-42.73**	0.21	1.55**	0.09*
MS 21	0.65**	0.40**	0.03**	0.19**	0.20	-41.52**	2.07**	52.07**	-0.29*	5.15**	-0.42**
MS 22	0.48**	0.71**	0.01	0.19**	-0.46*	-121.59**	-2.71 **	21.52**	-0.07	2.49**	-0.33**
MS 24	-0.13	-0.06	-0.01	-0.08	-1.65**	-127.3**	-2.26**	-25.15**	-0.29*	0.91	0.14**
S.E. (Lines)	0.16	0.10	0.01	0.05	0.19	9.06	0.25	1.50	0.13	0.53	0.04
S.E. (G(I)-G(J) Lines	0.22	0.14	0.01	0.07	0.27	12.81	0.36	2.12	0.18	0.76	0.06
TESTERS											
Resistant											
R 1	0.24**	-0.10*	-0.01	-0.07*	0.36**	29.66**	0.09	-8.7**	0.11	-3.14**	-0.05**
Susceptible[3]											
R 4	-0.29**	-0.19**	0.00	-0.06*	1.27**	19.46**	0.53**	10.19**	-0.11	2.10**	-0.06**
R 6	0.03	0.11*	0.01	0.04	-1.18**	-92.26**	-1.31 **	-1.29	-021 **	1.43**	0.09**
S.E. (Testers)	0.09	0.05	0.01	0.03	0.11	4.96	0.14	0.82	0.07	0.29	0.02
S.E.(G(I)-G(J)Testers	0.12	0.08	0.01	0.04	0.15	7.02	0.20	1.16	0.10	0.41	0.03

1. Scored on a (1-9) scale, 2. Scored on a (1-5) scale, 3. The groups are based on disease score, **Significant at 1%, *Significant at 5%

11, MS 16 and MS 24 among male-sterile lines and RI among restorers in the first year (Table 2), while MS 7, MS 11 and MS 16 among male-sterile lines and RI and R4 among restorers in the second year (Table 3). Weji *et al.*, (1956) also observed similar GCA effects for resistant and susceptible lines in corn.

In 1996 season, the hybrids 4 x RI, MS 15 x R6, MS 19 x R3 and MS 22 x R4 exhibited desirable SCA effects for DDR as well as for all other disease parameters (Table 4). In 1997 season, the hybrids 16 x RI, MS 4 x R5, MS 6 x R2, MS 21 x R6, MS 14 x R5 and MS 12 x R4 recorded desirable SCA effects for DDR as well as for all other disease parameters (Table 5). These are referred to as group I. In 1996 season, the hybrids 10 x Rl, MS 10 x R3, MS 11 x R5, MS 25 x R3 and MS 25 x R5 exhibited desirable SCA effects for DDR, and length, width and area of the lesion, but not the number of lesions and flecks (Table 4). In 1997 season, the hybrids that belong to this group are 15 x R1, MS 7 x R3, MS 11 x R6, MS 16x R6, MS 11 x R5, MS 3 xR1, MS 14 x R2, MS 9 x R3, MS 19 x R4 and MS 22 x R6 (Table 5). These hybrids are hereafter reported to as group II.

The negative (desirable) effect of SCA usually occurred in crosses involving resistant and susceptible parents indicating that resistance is partly dominant.

In the parents and hybrids in group II, the pathogen causes minimum leaf damage, in spite of the presence of more infection sites on the leaf One of the defensive mechanisms like localized infections (hypersensitive reaction) might be responsible for the restricted growth of the pathogen. These genotypes could be considered as tolerant varieties, as they resist the spread of the pathogen and may produce normal yield. Bergquist & Masias, 1973 and Frederiksen *et al.*, 1975 reported that hypersensitive reactions characterize varietal resistance in seedlings and mature plants. Muller (1959) viewed hypersensitivity as the resistant response of the host plant. It is useful in a long epidemic in which disease increases with small beginnings to a relatively great amount. The effect of horizontal resistance is enhanced when the entire area is covered with crop varieties showing horizontal resistance. The amount of inoculum will be slow and consequently, the development of the disease will be slow. Thus horizontal resistance may be preferable as it is stable and considemble amount of yield is expected in spite of widespread disease. The rate and the extent of necrosis or horizontal resistance in leaf tissue appear to measure quantitatively the resistance to sorghum leaf blight.

The genotypes with positive GCA/SCA effects for area of the lesion and negative GCA/SCA effects for number of lesions and number of flecks and those with positive GCA/SCA effect for area of the lesion, number of lesions and number of flecks are not useful to the breeding programmes. In the former case, though

Table 4. Specific combining ability (SCA) effects of selected sorghum hybrids for various disease resistant parameters and yield contributing characters, post rainy season 1996, ICRISAT, Patancheru

Disease	Damalfe score	Lengthof lesion (cm)	Width of the lesion (cm)	Area of lesion (cm^2)	Number of lesions	Number of flecks	Days to 50% flowering	Plant Height (cm)	Agrono -mic score[2]	Grain yield plant^{-1}(g)	100 seed weigh t (g)
Hybrids											
RxR3											
MS 4 x Rl	-0.25	-0.53**	-0.06**	-0.37**	-5.76**	-66.01**	-7.01**	-0.09	0.63	4.46	0.00
MS 10 x Rl	-0.81	-0.50**	-0.07**	-0.18**	9.42**	109.56**	-1.35	2.63	0.18	-7.20**	0.14
R x MR3											
MS 10 x R3	-0.49	-0.29	-0.06**	-0.15*	7.43**	101.48**	-4.35**	-0.31	-0.05	4.48	0.11
R x LS3											
MS 11 x R5	0.54	-0.68**	-0.06**	-0.24**	5.76**	48.94**	-1.95	-8.63**	-0.65*	-2.37	0.06
RXS3											
MS 15 xR6	-1.23**	-1.85**	-0.11**	-0.65**	-0.57	- 72.87**	-1.78	2.22	1.14**	-2.33	-0.23*
MS lOx R2	0.33	-0.10	-0.03	-0.15*	-5.55**	-92.54**	-2.03	2.11	-0.40	-4.46	-0.06
MR x R3											
MS 16 x Rl	0.75	0.55**	0.05**	0.20**	-8.37**	-131.26**	8.43**	1.24	0.07	13.14**	-0.29**
MR x MR3											
MS 19 x R3	-0.43	-0.82**	-0.05**	-0.25**	-0.88	-53.34**	2.10	3.86	-0.22	3.30	-0.05
MR x LS3											
MS 22 x R4	-0.90*	-0.30	-0.04*	-0.15*	-4.28**	-99.42**	0.12	-6.52*	0.55	2.74	0.03
LS x MR3											
MS 25 x R3	1.29**	-1.12**	-0.04*	-0.40**	5.97**	59.28**	0.76	4.08	0.17	-6.50**	0.10
LS x LS3											
MS 25 x R5	0.54	-1.01**	-0.1 **	-0.52**	1.94**	28.50**	2.00	-8.97**	0.41	0.64	0.01
Sx S3											
MS lAxR2	0.44	-0.63**	-0.04*	-0.23**	-2.57**	-69.45**	6.91**	-2.06	-0.01	-9.11**	0.10
MS 13 x R2	-0.67	-0.25	-0.06**	-0.14*	6.00**	165.01**	-3.92**	4.67	-0.68*	2.19	0.22*
S.E. (Crosses)	0.42	0.18	0.02	0.07	0.64	10.98	1.27	2.87	0.33	2.30	0.11
S.E. (S(IJ)-S(JK) Crosses	0.59	0.26	0.03	0.10	0.91	15.53	1.80	4.05	0.46	3.25	0.15

1. Scored on a (1-9) scale, 2. Scored on a (1-5) scale, 3. The groups are based on disease score, **Significant at 1%, *Significant at 5%

R = Resistant, MR = Moderately Resistant, LS = Less Susceptible, S = Susceptible

Table 5. Specitic combining ability (SCA) etlects of-selected sorghum hybrids tor various disease resistant parameters and yield contributing characters, post rainy season 1997, ICRISAT, Patancheru

Hybrids	Disease damage score1	Length of lesion (cm)	Width of lesion (cm)	Area of lesion (cm^2)	Number of lesions (no)	Number of flecks (no)	Days to 50% flowering	Plant Height (cm)	Agronomic score[2]	Grain yield $plant^{-1}$(g)	100 seed weight (g)
MR x R[3]											
MS 15 x Rl	-0.80*	-1.63**	-0.12**	-0.59**	5.14**	107.28**	-0.15	-9.63**	-0.61**	5.74**	-0.09
MS 16 x Rl	-0.91*	-1.00**	-0.07**	-0.36**	-0.10	-73.34**	-2.15**	25.09**	0.23	10.52**	-0.33.*
MR x MR3											
MS 7 x R3	0.17	-1.05**	-0.10**	-0.36**	1.55**	73.65**	2.07**	-22.13**	-0.77*	16.41**	0.35**
MR x S[3]	0.51	-0.80**	-0.80	-0.40**	2.03**	178.88**	1.31*	1.48	0.00	23.38**	0.04
MS 11 x R6	-0.69	-0.67**	-0.02	-0.26*	3.25**	145.18**	1.2S*	-17.05**	-0.90**	18.07**	-0.26**
MS IS x R6	0.42	0.88**	0.10**	0.52**	-3.52**	-103.13**	-0.08	-23.71**	-0.29	3.84**	-0.23**
MS 16 x R6	-0.36	-0.98**	-0.09**	-0.43**	1.18*	98.98**	-3.42**	1.01	0.21	-6.32**	-0.26**
MR x HSJ											
MS 4 xR5	-1.34**	-1.2S**	-0.10**	-0.67**	-2.87**	-65.57**	0.16	-30.13**	0.10	-19.10**	-0.61*
MS 11 x R5	0.11	-0.86**	-0.06**	-0.39**	2.10**	141.28**	0.93	9.87**	0.43	-8.88*	0.13
LS x R[3]											
MS 3 x Rl	-1.30**	-1.36**	-0.12**	-0,72**	2.07**	344.55**	0.74	-4.63	0.12	0.57	-0.55**
LS x MR[3]											
MS 6 xR2	-0.01	-0.73**	-0.03	-0.28**	-1.34**	-151.83**	-8.30**	20.51**	-0.38	20.08**	0.66**
MS 14 x R2	0.43	-1.33**	-0.11**	-0.67**	4.88**	261.82**	-1.97**	23.64**	-0.71*	6.54**	-0.30**
MS 9 x R3	0.11	-1.1S**	-0.13**	-0.50**	3.48**	53.04*	-0.98	43.70**	-0.61*	-2.78*	-0.28**
LS x S[3]											
MS 19 x R4	-0.04	-1.40**	-0.10**	-0.64**	6.84**	79.13**	0.97	6.48	-0.28	-10.5**	-0.40**
MS 21 x R6	-0.42	-0.75**	-0.05**	-0.40**	-2.13**	-63.64**	0.69	0.18	-0.01	-6.97**	0.17
MS 22 xR6	0.42	-1.18**	-0.05**	-0.48**	1.06*	IS2.69**	6.81**	-69.27**	1.43**	-5.05**	-0.02
LS x HS[3]											
MS 14 x R5	-0.95*	-0.41	-0.02	-0.26*	-2.58**	-141.17**	2.43**	-4.77	0.49	-1.73	-0.34**
MS 21 x R5	0.38	-1.14**	-0.08**	-0.58**	7.49**	396.13**	-0.29	-9.57**	-0.68*	21.54**	0.43**
S x S[3]											
MS 12 xR4	-0.66	-0.49*	-0.05**	-0.31**	-1.33**	-59.95**	-1.19	-2.41	0.00	-10.26**	-0.43**
S.E. (Crosses)	0.38	0.24	0.02	0.13	0.48	22.19	0.62	3.68	0.31	1.31	0.10
S.E. (S(IJ)-S(JK) Crosses	0.54	0.34	0.03	0.18	0.67	31.38	-1.14	5.20	0.44	1.85	0.17

I. Disease score, 2. Agronomic score., .. Significant at 1%, . Significant at 5%, R = Resistant, MR = Moderately Resistant, LS = Less Susceptible, HS = Highly Susceptible, S = Susceptible.

the number of infection sites is minimum, the spread of the pathogen at every site of infection is rapid; consequently the total leaf area damage increases. In the latter case, the number of infection sites are more and the spread at each site is also rapid resulting in total leaf area damage and yield loss.

Considering the favourable mean performance and the disease reaction for the respective characters for both the years, the following parental lines showed favourable mean performance coupled with desirable and consistent GCA effect for various disease-related characters including disease damage score. These are: the male-sterile lines MS 7, MS 9, MS 11 and MS 16 and the restorer line Rl. The hybrids, MS 16 and Rl and MS 15 x R6 were found desirable as they possessed desirable SCA effects for resistance in both the years for more than one trait.

Among the parents selected for disease resistance, the male-sterile lines MS 7 and MS lOin 1996 and MS 9 and MS 14 in 1997 season were considered to be more desirable considering the favourable GCA effects for agronomic desirability and grain Yield plant^{-1}. Among the hybrids selected for resistance parameters, the hybrids MS 4 x Rl and MS 22 x R4 in 1996 and MS 16 x Rl in 1997 (falling in group I) had desirable effects for the above traits.

Thus, the favourable GCA effects for different parameters were located in different parents. A breeding programme may be designed with multiple crosses to breed favourable GCA alleles for several resistance characters together into a few genotypes.

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