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Original Research Article

Studies on Combining Ability for Grain Mould Resistance Parameters in Sorghum (*Sorghum bicolor* (L.) Moench)

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A B S T R A C T

In all sorghum (*Sorghum bicolor* (L.) Moench) production systems, grain molds can reduce the yield and quality of short duration cultivars if they mature in wet and humid weather. In the present study, a set of 10 x 10 diallel consisting of F_1& F_2 progenies, along with their parents were evaluated to study the inheritance of some mould resistance traits, to identify useful parents and also efficient breeding methodology for overall improvement. Among the parents, GNM 14-7, PMS 74B, PMS 71B, IS 14332 and AKGMR 110 were identified as a good general combiners for grain mold resistance. These parents can be utilized for the development of grain mold resistant hybrids. Positive and significant sca effects for germination percentage were obtained in 13 crosses of F_1diallel. Among them, the crosses B 58586 x MS 296B, AKGMR 110 x IS 14332, MS 296B x PVK 801 and GNM 14-7 x MS 296B were most superior.

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal crop in India. The crop is grown predominantly by subsistence farmers in the areas subjected to low rainfall and drought, where it is mostly used as food. Many of the improved sorghum varieties and hybrids mature earlier than local varieties, often before the end of the rainy season. This results in increased exposure of the developing and maturing grain to conditions of high humidity and wetness. Grain mold develops under these conditions and results in decreased filling and size of the grain and chalky endosperm, which disintegrates during harvest and threshing.

A number of pathogenic and saprophytic fungi are involved in the sorghum grain mold complex. Fungi belonging to more than 40 genera are reported to be associated with sorghum grain mold (Navi *et al.,* 1999). Of these, only a few fungi infect sorghum flower tissues during early stages of grain development. These include Fusarium monaliforme sheld; Curvularialunata (Walker) Boedjin and Phomasorghi (Sacc.) (Bandyopadhyay *et al.,* 2000; Thakur *et al.,* 2003). Sorghum research workers identified grain mold as one of the most vexing problems in sorghum. In most cases, avoidance or chemical control in farmers field is impracticable and therefore major research efforts have been focused on development of resistant cultivars for which knowledge of combining ability is necessary in selection of appropriate parents for hybridization. The general combining ability (GCA) and specific combining ability (SCA) are suitable genetic components for unbiased estimation to develop an efficient breeding procedure. Hence, this study was undertaken to study the combining ability for grain mold resistance by using diallel mating system to generate the information on combining ability of parents to select better parents and develop superior cross combinations

Materials and Methods

The present field study was undertaken at Sorghum research station, Vasantrao Naik Marathwada Agricultural University, Parbhani (Maharashtra) during *rabi* season 2015-16 The experimental material comprised of 10 divergent parents and their 45 F_1hybrids in half-diallel fashion. The Randomized block design was used with three replication and the plant spacing within a row was 15 cm and row to row spacing was 45 cm. Recommended package of practices were followed to raise the good crop.

The data were recorded on five competitive fertile plants for field grade score, threshed grade score, grain hardness, grain density, germination percentage, glume coverage percentage, water absorption capacity, fungal load *of Fusarium* spp., Fungal load of *Curvularia* spp. and fungal load of other mould spp. The concept of general and specific combining ability as a measure of type of gene action was proposed by Sprague and Tatum (1942). Griffing (1956[b]) has described the methods of analysis for combining ability.

Results and Discussion

The mean square for ten characters of F_1 crosses under study are presented in Table 1. It is seen from Table 1 that, mean squares due to replication were non-significant for all the characters germination percentage, water absorption capacity and fungal load of *fusarium spp*. Treatment differences were highly significant for all the traits studied.

Further partitioning of treatment variance into components viz., parents, hybrids and parents vs hybrids revealed that parents significantly differed among themselves for all the characters. Similarly, hybrids also showed highly significant differences for all the traits. Whereas, the parents vs hybrids comparison was significant for all the characters except 100 seed weight and germination percentage.It may, thus be concluded that the parents included in this investigation possessed sufficient variability for the characters studied.

The significant general combining ability effects in desirable direction for the traits studied are extracted and presented in Table 3.It is seen from the Table 3 that, none of the parents proved to be best general combiner for all the traits under study. However, the parents GNM 14-7 has been found to possess desirable gca for seven out of 10 characters such as germination percentage and its nine important component characters in F_1diallel progenies. The parent GNM 14-7 minimum threshed grade score, more grain hardness, higher germination percentage, minimum glume coverage, minimum fungal load of *Fusarium* spp., *Curvularia* spp. and other mould spp. in F_1diallel set. Parent PMS 74B, transmitted genes for more grain hardness, higher germination percentage, minimum fungal load of *Fusarium* spp., *Curvularia* spp. and other mould spp. in F_1diallel set. Another parent PMS 42B, transmitted favourable genes for minimum field grade score, minimum threshed grade score, more grain hardness, more grain density and higher germination percentage in F_1diallel set. Parent IS 14332 also showed desirable gca effect for four important characters viz. more grain hardness, higher grain density, higher germination percentage, minimum fungal load of other mould spp. in F_1diallel set. Thus, from summary performance indicated above for mould characters and grain yield, the above mentioned five parents can also be categorized as good general combiners i.e. GNM 14-7, PMS 74B, PMS 71B, IS 14332 and AKGMR 110. Since a high general combining effects correspond with additive and for additive x additive interaction (Griffing 1956[b]) and represents the fixable genetic component of variation, these parents appear to be worthy of exploitation in recombination breeding programme.

Table.1 Analysis of Variance of parents and F_1 hybrids in 10 x 10 diallel of sorghum

Sr. No.	Characters	Source					
		Replication	**Treatments**	**Parents**	**F_1 hybrids**	**Parents Vs. F_1 hybrids**	**Error**
Degrees of freedom		**2**	**54**	**9**	**44**	**1**	**108**
1	Days to 50% flowering	53.49**	74.17**	60.88**	76.80**	78.22**	1.96
2	Days to maturity	44.04**	52.31**	59.18**	49.10**	131.94**	0.96
3	Plant height (cm)	55.01	9558.92**	915**	9043**	35910**	44.66
4	Number of primaries per panicle	6.36	459.32**	241.11**	489.07**	1113.80**	2.78
5	Panicle length (cm)	4.21	73.97**	69.05**	75.49**	51.52**	1.98
6	Panicle width (cm)	0.10	2.89**	1.81**	3.18**	0.14	0.04
7	Number of grains per primary branch	26.18	1003.12**	275.65**	1062.03*	4958.12*	13.27
8	100 grain weight (gm)	0.63*	0.885**	1.12**	0.84**	0.35	0.15
9	Grain yield/ plant (g)	47.67**	1359.88**	985.56**	1462.91**	194.88**	7.99
10	Field grade score	0.67	9.42**	18.96**	6.98**	30.70**	1.37
11	Threshed grade score	1.71	11.83**	25.49**	9.06**	10.42*	0.96
12	Grain hardness (kg/cm^2)	0.21	4.93**	3.69**	5.24**	2.60**	0.19
13	Grain density (g/ml)	0.003	0.014**	0.02**	0.012**	0.002	0.0019
14	Germination percentage	98.53*	319.60**	447.68**	278.45**	977.53**	25.72
15	Glume coverage (%)	2.38	602.85**	823.70**	570.75**	27.90	18.37
16	Water absorption capacity (g)	0.003**	0.051**	0.031**	0.049**	0.28**	0.0006
17	Fungal load of *Fusarium*spp. (%)	5.44*	98.19**	86.50**	99.47**	147.30**	1.52
18	Fungal load of *Curvularia*spp. (%)	16.75	113.32**	70.97**	122.68**	82.27*	8.63
19	Fungal load of Other mold spp. (%)	0.80	64.15**	21.17**	61.56**	564.81**	3.26

* Significant at 5% level and ** Significant at 1% level

Table.2 Estimates of general combining ability effects of parents from F_1 crosses

Characters	Field grade score	Threshed grade score	Grain hardness (kg/cm^2)	Grain density (g/ml)	Germination (%)	Glume coverage (%)	Water absorption capacity (g)	Fungal load of Fusarium spp. (%)	Fungal load of Curvularia spp. (%)	Fungal load of Other mold spp. (%)
Parents										
GNM 14-7	-0.63**	-0.27	0.66**	0.003	3.05**	-3.04**	-0.01*	0.10	-0.05	0.10
AKGMR110	-0.52*	-0.46*	-0.04	-0.01	-1.05	1.03	-0.007	-0.34	-0.52	-1.32**
B 58586	-1.77**	-2.02**	-0.07	0.02**	1.86*	20.39**	-0.08**	-2.64**	0.56	0.43
MS 296B	1.11**	1.20**	-0.75**	0.004	-9.55**	-3.06**	0.07**	2.44**	-0.69	-0.12
I 26	0.67**	0.72**	-0.02	-0.01	-6.43**	-2.51**	0.03**	-2.04**	1.04*	2.71**
PMS 74B	0.70**	0.70**	-0.18*	0.007	-1.93*	1.91*	0.03**	0.05	0.20	0.50
PMS 71B	0.67**	0.75**	-0.81**	0.01	1.86*	-2.38**	0.05**	0.88**	1.63**	-2.06**
PMS 42B	0.28	0.28	0.34**	0.04**	6.58**	-1.37*	0.02**	2.51**	1.67**	0.82*
PVK 801	0.22	0.17	0.30**	-0.01*	0.28	-3.40**	-0.01*	-0.18	-2.29**	-1.20**
IS14332	-0.74**	-1.07**	0.59**	-0.05**	5.33**	-7.54**	-0.08**	-0.78**	-1.56*	0.15
SE (m) (gi)	0.18	0.15	0.06	0.006	0.80	0.67	0.004	0.19	0.46	0.28
CD 5% (gi)	0.42**	0.35**	0.15**	0.01**	1.81**	1.53**	0.009**	0.44**	1.05**	0.64**
CD 1% (gi)	0.60**	0.50**	0.22**	0.02**	2.60**	2.20**	0.01**	0.63**	1.51**	0.92**
SE (m) (gi-g))j)	0.27	0.23	0.10	0.01	1.19	1.01	0.006	0.29	0.69	0.42
CD 5% (gi-gj)	0.62**	0.52**	0.23**	0.02**	2.70**	2.28**	0.01**	0.65**	1.56**	0.96**
CD 1% (gi-gj)	0.89**	0.75**	0.33**	0.03**	3.88**	3.28**	0.02**	0.94**	2.25**	1.38**

*Significant at 5% level of significance ** Significant at 1% level of significance and others are non-significant

Table.3 Estimates of specific combining ability effects for F_1 crosses in 10x10 dialle

Sr.No.	Characters	Field grade score	Threshed grade score	Grain hardness (kg/cm^2)	Grain density (g/ml)
	F_1 crosses				
1	GNM14-7XAKGMR110	-0.26	0.13	-0.15	0.04
2	GNM-14-7X B 58586	0.32	1.02	0.27	-0.01
3	GNM14-7 X MS 296B	-2.56**	-1.86**	-1.37**	0.02
4	GNM14-7 X I26	-1.45*	-2.05**	1.89**	0.05*
5	GNM14-7 X PMS74B	-0.81	-1.02	-0.84**	0.01
6	GNM14-7 X PMS71B	0.21	-0.08	0.88**	0.05*
7	GNM14-7 X PMS42B	-1.40*	-0.27	0.29	0.01
8	GNM14-7 X PVK801	2.32**	2.16**	0.60*	-0.10**
9	GNM14-7 X IS14332	0.62	0.08	1.47**	0.09**
10	AKGMR110X B58586	0.21	0.22	-0.05	0.11**
11	AKGMR110XMS296B	-0.34	0.33	1.23**	0.003
12	AKGMR110 X I26	-0.56	-0.86	0.73*	-0.03
13	AKGMR110XPMS74B	0.73	0.83	-0.20	0.04
14	AKGMR110XPMS71B	0.43	1.77*	-1.24**	-0.07 *
15	AKGMR110XPMS42B	-0.51	-1.41*	-1.23**	-0.07 *
16	AKGMR110XPVK801	0.54	0.69	-0.49*	0.05*
17	AKGMR110XIS14332	0.51	0.94	-0.28	-0.02
18	B58586XMS 296B	-1.76*	-2.11**	1.76**	-0.10**
19	B58586 X I26	-0.98	-0.63	-2.66**	0.11**
20	B58586 X PMS74B	0.32	1.05*	-0.61*	-0.10**
21	B58586 X PMS71B	-0.65	-1.00	0.75*	0.02
22	B58586 X PMS42B	0.73	0.80	-0.93**	0.02
23	B58586 X PVK801	-1.20	-1.41*	1.07**	-0.03
24	B58586 X IS-14332	0.76	1.16*	-1.08**	-0.07*
25	MS 296B X I26	-0.20	0.13	-0.21	0.00
26	MS 296B X PMS74B	0.43	0.16	-1.36**	0.09**
27	MS 296B X PMS71B	0.46	0.77	0.37	-0.01
28	MS 296B X PMS42B	0.51	-0.08	0.18	0.05*
29	MS 296B X PVK801	1.57*	2.36**	-0.31	-0.03
30	MS 296B X IS14332	-2.12*	-2.38**	-1.96**	-0.001
31	I 26 X PMS74B	-0.45	-0.02	0.54*	-0.05*
32	I 26 X PMS71B	-0.42	-0.75	0.64*	-0.03
33	I 26 X PMS42B	-0.70	-0.27	1.31**	0.03
34	I 26 X PVK801	0.68	1.50*	0.19	0.05 *
35	I 26 X IS14332	-0.34	-0.25	0.03	-0.01
36	PMS74B X PMS 71B	-2.12*	-1.72*	0.36	-0.01
37	PMS74B X PMS42B	0.59	-0.25	-0.35	-0.06 *
38	PMS74B X PVK801	-1.67*	-3.13**	1.11**	0.008
39	PMS74B X IS14332	1.29*	2.11**	0.55*	0.07*
40	PMS71B X PMS42B	-0.04	-0.63	-0.99**	-0.11**
41	PMS71B X PVK801	0.01	0.13	-0.68*	-0.05*
42	PMS71B X IS14332	-2.34**	-2.94**	1.95**	0.02
43	PMS42B X PVK801	-2.26**	-2.05**	2.12**	0.07*
44	PMS42B X IS14332	0.37	0.52	0.90**	0.06*
45	PVK801X IS14332	2.43s**	2.97**	-1.55**	-0.03
	SE (m) Sij-Sik	0.91	0.76	0.34	0.03
	CD (Sij-Sik) at 5%	1.84	1.545	0.694	0.070
	CD (Sij-Sik) at 1%	2.46	2.064	0.927	0.093

Continues….

Sr.No.	Characters	Germination (%)	Glume coverage (%)	Water absorption capacity (g)	Fungal load of *Fusarium* spp. (%)	Fungal load of *Curvularia* spp. (%)	Fungal load of Other mold spp. (%)
	F_1 crosses						
1	GNM14-7XAKGMR110	0.66	-9.86**	0.03*	-7.98**	0.84	-0.33
2	GNM-14-7X B 58586	-6.13*	-3.46	0.07**	-0.30	-1.22	2.26*
3	GNM14-7 X MS 296B	11.47**	-6.54*	-0.14**	-4.42**	-2.19	-2.80*
4	GNM14-7 X I26	5.67*	-7.69*	-0.13**	1.22	-5.95**	-1.61
5	GNM14-7 X PMS74B	8.53*	-6.10*	0.07**	-0.28	-0.91	-0.74
6	GNM14-7 X PMS71B	-1.87	1.91	0.09**	5.59**	-3.67*	-1.83
7	GNM14-7 X PMS42B	-0.53	0.48	-0.08**	7.41**	-8.96**	-4.33**
8	GNM14-7 X PVK801	-4.88	3.14	0.01	-3.53**	6.56**	1.93
9	GNM14-7 X IS14332	5.50*	0.91	-0.08**	-4.09**	12.36**	-2.32*
10	AKGMR110X B58586	-6.51*	7.45*	0.02	1.69*	-0.56	6.98**
11	AKGMR110XMS296B	-4.46	14.14**	-0.03*	2.48**	3.21*	-3.11**
12	AKGMR110 X I26	0.40	7.84*	0.10**	-1.81*	3.53*	-4.60**
13	AKGMR110XPMS74B	7.62*	-15.40**	-0.06**	-1.40*	-7.39**	-4.12**
14	AKGMR110XPMS71B	2.23	-10.11**	0.008	-4.73**	2.36	1.51
15	AKGMR110XPMS42B	-7.73*	-8.32**	0.04*	0.04	3.92*	-2.32*
16	AKGMR110XPVK801	8.34*	-4.25	-0.13**	10.97**	-3.36*	-3.55**
17	AKGMR110XIS14332	13.81**	2.37	-0.11**	-1.14	6.55**	-0.89
18	B58586XMS 296B	19.17**	-6.44*	-0.09**	-6.87**	10.18**	-2.37*
19	B58586 X I26	-2.782	9.97**	-0.11**	-1.23	2.80	4.53**
20	B58586 X PMS74B	-0.168	-9.43**	0.04*	-0.44	0.30	5.75**
21	B58586 X PMS71B	6.333 *	7.21*	0.04*	-6.27**	9.97**	-3.68**
22	B58586 X PMS42B	1.069	-11.78**	-0.11**	-5.21**	-1.77	-6.57**
23	B58586 X PVK801	-2.494	12.60**	-0.03*	10.41**	-3.67*	-2.05*
24	B58586 X IS-14332	-15.09**	-10.71**	-0.08**	11.42**	-9.60**	-0.14
25	MS 296B X I26	6.84*	-7.07*	0.04*	3.78**	-10.18**	-0.60
26	MS 296B X PMS74B	-13.83**	-7.09*	-0.05**	6.91**	-8.95**	-5.12**
27	MS 296B X PMS71B	-15.29**	11.81**	0.06**	4.45**	-4.01*	-0.64
28	MS 296B X PMS42B	0.24	14.34**	0.20**	-8.37**	9.49**	-3.72**
29	MS 296B X PVK801	12.27**	0.13	0.07**	-9.90**	-2.42	-4.51**
30	MS 296B X IS14332	-14.39**	-4.21	-0.18**	6.12**	-9.68**	7.86**
31	I 26 X PMS74B	-1.22	7.20*	-0.002	-1.82*	6.91**	-1.22
32	I 26 X PMS71B	5.09	-4.96*	0.08**	3.56**	-9.25**	-2.71*
33	I 26 X PMS42B	4.94	-1.90	-0.02	-4.66**	-3.24*	9.58**
34	I 26 X PVK801	2.38	-7.72*	0.06**	-5.80**	-1.23	-1.26
35	I 26 X IS14332	5.20	0.06	-0.007	-4.63**	12.26**	-3.01*
36	PMS74B X PMS 71B	0.55	26.98**	-0.23**	-0.48	-4.51*	-3.75**
37	PMS74B X PMS42B	6.50*	21.32**	-0.05**	-0.35	2.19	9.55**
38	PMS74B X PVK801	-0.46	12.13**	-0.18**	-7.89**	0.99	-1.92
39	PMS74B X IS14332	-3.96	-2.61	0.11**	-5.96**	3.22*	-3.87**
40	PMS71B X PMS42B	0.81	-18.50**	-0.06**	0.19	-3.24*	-3.83**
41	PMS71B X PVK801	4.74	-6.07*	-0.003	-3.92**	3.71*	-2.57*
42	PMS71B X IS14332	7.53*	-2.13	-0.16**	-4.68**	4.19*	0.99
43	PMS42B X PVK801	4.08	0.22	-0.16**	-1.67*	1.74	-4.36**
44	PMS42B X IS14332	-0.42	3.12	0.05**	6.27**	-9.75**	-0.92
45	PVK801X IS14332	1.84	-1.70	0.25**	7.33**	-6.55**	1.30
	SE (m) Sij-Sik	3.96	3.35	0.02	0.96	2.29	1.41
	CD (Sij-Sik) at 5%	7.99	6.75	0.04	1.94	4.63	2.84
	CD (Sij-Sik) at 1%	10.67	9.02	0.05	2.59	6.18	3.80

*Significant at 5% level of significance ** Significant at 1% level of significance and others are non-significant.

Specific combining ability effect is indicative of heterosis and so do the dominance and epistatic gene action. Denis and Girad (1977) regard loss in viability to be so important part of the grain mould syndrome that they recommend a germination test as part of the standard evaluation for identification of grain mould resistance. According to this, the superior parental combinations having significantly high specific combining ability effects for germination percentage and its component traits are presented in Table 4. The crosses B 58586 x MS 296B, AKGMR 110 x IS 14332, MS 296B x PVK 801, GMN 14-7 x MS 296B, GNM 14-7 x PMS 74B, AKGMR 110 x PVK 801, AKGMR 110 x PMS 74B, PMS 71B x IS 14332, MS 296B x I 26, PMS 74B x PMS 42B, B 58586 x PMS 71B, GNM 14-7 x I 26 and GNM 14-7 x IS 14332 with high sca effects along with desirable heterosis and involving parents with high gca effects may be studied in further generations to select better segregates and develop lines with better grain mould resistance and yield potential. The data on the estimates of combining ability variances showed larger values of sca than gca for all the traits under study. This indicated that non-additive gene action was predominant for all these characters. It is therefore, suggested that improvement of all these characters.

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