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RESEARCH ARTICLE :

Heterosis for grain yield and its parameters in *Kharif* sorghum [*Sorghum bicolor* (L.) Moench] hybrids

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SUMMARY : The present investigation was to estimate heterosis for grain yield and grain mould resistance parameters in 24 *Kharif* sorghum [*Sorghum bicolor* (L.) Moench] hybrids. Six male sterile lines and four testers were crossed in line x tester mating design to obtain 24 hybrids during *Rabi* 2012 and these crosses along with parents and two checks PVK 801 and CSH 25 were evaluated for eight grain yield and mould parameters in RBD design during *Kharif* 2013. The analysis of variance for line x tester design indicated significant differences due to the parents and crosses and the significant variances due to parents vs crosses indicated occurrence of substantial heterotic response for all the traits under study. Range of heterosis for grain yield ranged from -8.24 to 70.30, 11.95 to 122.36 and 0.99 to 100.60 over betterparent and standard checks PVK 801 and CSH 25, respectively. Significantly high heterobeltiosis and standard herterosis over both the checks was observed in crosses 372 A x C 43, DNA 10 x KR 196, IMS 12 x KR 196 and PMS 98 A x KR 199 for grain yield while in crosses DNA 10 x C43, DNA 10 x SUS 8-4, 372 A x C 43 and PMS 98A x C43 for fodder yield. Almost all the crosses based on IMS 12 and AKMS 85 A showed negative heterosis for days to 50 per cent flowering suggesting use of these lines to breed short duration hybrids. Significantly high heterosis in desirable direction for grain mould attributes *viz.*, field grade score and threshed grade score exhibited by cross combinations AKMS 85 x KR-196, PMS 98A x C43, AKMS 85 x C-43, AKMS 85 x SUS-8-4 and DNA 10 x KR-196. from present investigation it was evident that the crosses PMS 98A x C43, DNA 10 x KR 196, DNA 10 x KR 199 MS 372 x C43 and PMS 8A x KR199 exhibiting significantly high heterosis, high per se performance for grain yield along with grain mold score in desirable direction may be exploted for commercial cultivation.

KEY WORDS :
Heterosis, *Kharif* sorghum, Grain mould, Grain yield

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BACKGROUND AND OBJECTIVES

Sorghum is the fifth most important cereal following rice, wheat, maize and barley across the world, which is mostly cultivated in the arid and semi-arid tropics for its better adaptation to various stresses. Area under sorghum in India is 9.1 million hectare with 6.7 million tonnes of production and 783 kg productivity per hectare. In India it is grown as major cereal crop in both *Kharif* and *Rabi* season for food, feed and fodder purpose. Despite decrease in area over the years, production has been sustained at 7.45 million tons. Despite decrease in area over the years from 18.61 m ha in 1969-70 to 7.53 m ha in 2008-09, productivity has been increased from 554 kg/ha to 1055 kg/ha during the same period, mainly due to release of high yielding hybrids and cultivars. The extent of Heterosis has been reported to 9.7 per cent to 50.0 per cent by several workers (Harer and Bapat (1982).

Kulkarni *et al*. (2007) Nandanwankar (1990) and Kulkarni and Patil (2004). However, *Kharif* sorghum fetches low demand for food and low producer prices relatively to oilseeds and pulses due to deteriorated grain quality caused by grain mould. Sorghum grain mould constitutes one of the most important biotic constraints to *Kharif* sorghum improvement and production. Development of grain mould tolerant *Kharif* sorghum varieties is the need of the day, which helps the farmers in reducing the loss of grain quality and fetches him high market price. Hybrids are cultivar options and white grained hybrids are preferred for food but there are no commercial white grained hybrids possessing grain mold resistance (Kumar *et al*., 2011). For improving the genetic architecture of the crop through breeding efforts, utilization of heterosis is important for maximization of yield in sorghum (Agrawal, 2005).Therefore, present study was undertaken to estimate the heterobeltiosis and standard heterosis for grain yield and grain mold resistant parameters in *Kharif* sorghum hybrids.

RESOURCES AND METHODS

Material for present study was comprised of 24 hybrids developed by crossing six diverse male sterile lines (PMS 8A, PMS 98 A, AKMS 85, IMS 12, DNA 10 and MS 372 A) and four restorers (KR 196, KR 199, C43 and SUS 8-4) in line x tester mating design at Sorghum Research Station Parbhani during *Rabi* 2012. These resulted hybrids along with parents and two checks PVK 801 and CSH 25 were evaluated in RBD design with two replications during *Kharif* 2013. Each genotype was planted in two rows of 4 m length with 45 cm x 15 cm spacing between and within rows. The agronomic and plant protection measures were followed as and when required during the period of crop growth. Observations were recorded for eight charecters on five randomly selected plants in each entry from each replication. The heterosis effects in terms of per cent increase or decrease over superior parent (heterobeltiosis) and over standard check (useful heterosis) were measured for days to 50 per cent flowering, plant height, test weight, grain yield per lant, fodder yield par plant, harvest index, field grade score and threshed grade score. The heterosis was calculated as per the procedure suggested by Fonesca and Patterson (1968).

OBSERVATIONS AND ANALYSIS

The analysis of variance for line x tester design presented in Table 1 indicated significant differences due to the parents and crosses for most of the characters under study, in both yield contributing and grain mould resistance traits. The significant variances due to parents vs crosses indicated occurrence of substantial heterotic response for all the traits under study except test weight. These results are in agreement with those published earlier for days to 50 per cent flowering, plant height,

Table 1 : ANOVA for line x tester analysis

Sr. No.	Genotypes	d.f.	Days to 50% flowering	Plant height (cm)	Grain yield/ plant (g)	Fodder yield/ plant (g)	Test weight (g)	Harvest index (%)	Field grade score (FGS)	Threshed grade score (TGS)
1.	Replications	1	1.78	60.24	0.64	0.91	1.47	0.43	0.52	0.05
2.	Genotypes	33	41.48**	3218.80**	127.15**	505.59**	24.73**	29.24**	1.25**	0.63**
3.	Crosses	23	39.21**	2880.82**	99.06**	581.07**	9.35*	25.24**	0.94**	0.60**
4.	Parents	9	21.38**	2732.80**	44.68*	186.39**	58.65**	35.09**	2.20**	0.68**
5.	Parents vs. Cross	1	274.35**	15366.35**	1515.31**	1642.23**	73.07**	68.56**	0.06	0.82**
6.	Lines	5	130.38**	6342.58*	124.09	1060.16	9.70	47.90	1.03	1.08
7.	Testers	3	12.81	3009.69	31.72	4.25	16.36	7.65	0.38	0.47
8.	Line x tester	15	14.11**	1701.13**	104.18**	536.74**	7.85	21.21**	1.02**	0.47**
9.	Error	33	4.14	61.11	16.98	55.82	4.31	6.60	0.13	0.14

* and ** indicate significance of values at P=0.05 and 0.01, respectively

test weight and grain yield per plant, (Maheshwari *et al*., 1993) and days to 50 per cent flowering, plant height, grain yield per plant and test weight (Khapre *et al.*, 2000).

The heterosis calculated as percentage increase or decrease exhibited by hybrids better parent (heterobeltiosis) and over standard checks for eight characters is presented in Table 2. Results revealed that heterobeltiosis and standard heterosis over checks PVK 801 and CSH 25 for grain yield/ plant was ranged from -8.24 to 70.30, 11.95 to 122.36 and 0.99 to 100.60, respectively. Among 24 crosses; 8,19 and 13 crosses exhibited significant and positive heterosis over better parent, checks PVK 801 and CSH 25. The crosses 372 A x C43 (70.30 and 100.60), DNA 10 x KR 196(52.69 and 42.72), IMS 12 x KR 196(48.29 and 38.61), DNA 10 x KR199 (45.72 and 45.93) and PMS 98A x KR 199 (35.14 and 48.94) recorded significantly highest positive heterobeltiosis and standard heterosis for grain yield per plant over hybrid check CSH 25. Significant heterobeltiosis and standard heterosis for grain yield was also reported by Nirmala *et al.* (2004); Patel *et al.* (1990) and Premalatha *et al*. (2006). Extent of heterosis for fodder yield was ranged from -36.59 to 43.61, -21.21 to 54.55 and -39.53 to 18.60 over better parent, checks PVK 801 and CSH 25. The cross DNA 10 x C-43 (43.61) recorded highest significant and positive heterobeltiosis closely followed by 372A x C-43 (40.98) and 372A x SUS-8-4 (36.77) while cross PMS-98A x C-43 recorded significantly highest positive standard heterosis. Bhatt (2008); Tarique *et al.* (2012) and Prakash *et al.* (2010) also recorded heterobeltiosis and standard heterosis for fodder yield. Almost all the hybrids based on IMS 12 and

Table 2a: Estimation of heterosis over better parent and standard check (PVK 801, CSH 25) for grain yield and grain mold parameters

Sr. No.	Genotypes	Days to 50% flowering			Plant height			Grain yield			Fodder yield		
		BP	PVK-801	CSH-25	BP	PVK-801	CSH-25	BP	PVK-801	CSH-25	BP	PVK-801	CSH-25
1.	PMS-8A x KR-196	-3.27	-1.33	-6.33*	13.86**	26.72**	5.02	8.04	11.95	0.99	27.94**	31.82**	1.16
2.	PMS-8A x KR-199	-10.97**	-8.00**	-12.66**	24.44**	38.57**	14.84**	29.75*	44.03**	29.93*	16.67	27.27**	-2.33
3.	PMS-8A x C-43	-0.65	1.33	-3.80	31.28**	29.48**	7.31	-5.78	23.92	10.98	-3.08	-4.55	-26.74**
4.	PMS-8A x SUS-8-4	-1.31	0.67	-4.43	53.02**	25.62**	4.11	19.59	45.16**	30.95*	32.31**	30.30**	0.00
5.	PMS-98A x KR-196	-11.84**	-10.67**	-15.19**	16.34**	29.48**	7.31	11.74	36.51**	23.15	-13.16	0,00	-23.26**
6.	PMS-98A x KR-199	-10.32**	-7.33*	-12.03**	15.46**	27.55**	7.31	35.14**	65.09**	48.94**	23.68**	42.42**	9.30
7.	PMS-98A x C-43	-2.61	-0.67	-5.70*	70.27**	73.55**	43.84**	12.69	47.14**	32.74*	34.21**	54.55**	18.60*
8.	PMS-98A x SUS-8-4	-12.50**	-11.33**	-15.82**	-14.32**	-12.67**	-27.63**	14.95	40.44**	26.70*	-23.68**	-12.12	-32.56**
9.	CMS-11-6 x KR-196	-9.21**	-8.00**	-12.66**	-13.37**	-3.58	-20.09**	48.29**	3.65**	38.61**	-16.67	-9.09	-30.23**
10.	CMS-11-6 x KR-199	-5.81*	-2.67	-7.59**	-11.47**	-2.20	-18.95**	30.59*	4.97**	30.78*	-12.50	-4.55	-26.74**
11.	CMS-11-6 x C-43	-3.27	-1.33	-6.33*	-4.20	0.55	-16.67**	-8.24	19.81	8.09	-13.89	-6.06	-27.91**
12.	CMS-11-6 x SUS-8-4	-4.03	-4.67	-9.49**	6.30	11.57*	-7.53*	13.99	38.36**	24.82*	-11.11	-3.03	-25.58**
13.	CMS-11-8 x KR-196	-14.47**	-13.33**	-17.72**	8.48*	33.88**	10.96**	-7.76	13.71	2.58	-6.10	16.67	-10.47
14.	CMS-11-8 x KR-199	-9.68**	-6.67*	-11.39**	-24.11**	-6.34	-22.37**	-3.06	19.50	7.80	-36.59**	-21.21*	-39.53**
15.	CMS-11-8 x C-43	-16.99**	-15.33**	-19.62**	5.80	30.58**	8.22**	2.84	34.28*	21.13	-30.49**	-13.64	-33.72**
16.	CMS-11-8 x SUS-8-4	-13.42**	-14.00**	-18.35**	-3.35	19.28**	-1.14	8.93	34.28*	21.13	3.66	28.79**	-1.16
17.	CMS-11-13 x KR-196	-15.13**	-14.00**	-18.35	-11.88**	-1.93	-18.72**	52.69**	58.21**	42.72**	25.00**	28.79**	-1.16
18.	CMS-11-13 x KR-199	-16.13**	-13.33**	-17.72**	015.71**	-6.89	-22.83**	45.72**	61.76**	45.93**	22.22*	33.33**	2.33
19.	CMS-11-13 x C-43	-15.69**	-14.00**	-18.35**	1.68	0.28	-16.89**	2.48	33.81*	20.71	43.61**	32.73**	1.86
20.	CMS-11-13 x SUS-8-4	-4.35	-12.00**	-16.46**	28.75**	-14.88*	-29.45**	22.69*	48.93**	34.35**	35.48**	27.27**	-2.33
21.	CMS-11-15 x KR-196	-0.66	0.67	-4.43	-3.71	7.16	-11.19**	30.24*	39.25**	25.62*	17.65	21.21*	-6.98
22.	CMS-11-15 x KR-199	-1.94	1.33	-3.80	-9.48*	0.00	-17.12**	23.23	36.79**	23.40	5.56	15.15	-11.63
23.	CMS-11-15 x C-43	-1.31	0.67	-4.43	10.06*	8.54	-10.05**	70.30**	122.36**	100.60**	40.98**	30.30**	0.00
24.	CMS-11-15 x SUS-8-4	-5.92*	-4.67	-9.49**	7.26	-6.34	-22.37**	10.62	34.28*	21.13	36.77**	28.48**	-1.40
	Minimum	-16.99	-15.33	-19.62	-14.32	-14.88	-29.45	-8.24	11.95	0.99	-36.59	-21.21	-39.53
	Maximum	-0.66	1.33	-3.80	70.27	73.55	43.84	70.30	122.36	100.60	43.61	54.55	18.60

* and ** indicate significance of values at P=0.05 and 0.01, respectively

AKMS 85 A recorded significant negative heterosis for days to 50 per cent flowering, suggesting use of these line to breed early duration hybrids. Maheshwari *et al.* (1993); Prabhakar (2001) and Premalata *et al.* (2006) also obtained negative heterosis for days to 50 per cent flowering. Highly significant heterobeltiosis and standard heterosis was found in cross PMS 98A x C43 for plant height, 372A x SUS 8-4 and IMS 12 x SUS 8-4 for test weight and AKMS 85A x KR 199 and PMS 98A x KR 196 for harvest index.

Significantly high heterotic effect in desirable direction was recorded in crosses PMS 98A x C43, AKMS 85A x KR 196, AKMS 85A x SUS 8-4, AKMS 85A x C43 and DNA 10 x KR 196 for both the grain mould attributes *viz.*, field grade score and threshed grade score. While crosses 372A x SUS 8-4 and PMS 8A x KR 196 showed significantly negative heterobrltiosis and standard heterosis over resistant check PVK 801 only for field grade score. All the crosses exhibiting significant heterosis in desirable direction had also recorded significant *per se* performance for all these traits. Importance of *per se* performance along with heterosis in selecting better hybrids has also been noted by Meshram *et al.* (2005) and Rao (1968).

It is evident from the present study that top ranking crosses showing highly desirable heterosis for mould parameters recorded non significant heterosis for grain yield. However, crosses PMS 8A x KR 199, PMS 98A x C43, DNA 10 x KR 196, DNA 10 x KR 199 and MS 372 A x C43 exhibited significant heterotic effect, high per se performance for grain yield over high yielding commercial hybrid CSH 25 and significantly negative heterosis over tolerant check PVK 801 for field and threshed grade score may be evaluated in multilocation

Table 2b: Estimation of heterosis over better parent and standard check (PVK 801, CSH 25) for grain yield and grain mold parameters

Sr. No.	Genotypes	Test weight			Harvest index			Field grade score			Threshed grade score		
		BP	PVK-801	CSH-25	BP	PVK-801	CSH-25	BP	PVK-801	CSH-25	BP	PVK-801	CSH-25
1.	PMS-8A x KR-196	-6.78	-12.70	12.24	-6.01	-8.32	17.61	-16.67	-28.57*	-37.50**	-12.50	-12.50	-12.50
2.	PMS-8A x KR-199	1.61	0.00	28.57**	28.39*	30.55*	67.46**	0.00	-14.29	-25.00*	0.00	0.00	0.00
3.	PMS-8A x C-43	-11.67	-15.87*	8.16	-7.85	29.05*	65.54**	0.00	-14.29	-25.00*	0.00	0.00	0.00
4.	PMS-8A x SUS-8-4	18.00*	-6.35	20.41*	-12.29	16.14	48.98**	-14.29	-14.29	-25.00*	-12.50	-12.50	-12.50
5.	PMS-98A x KR-196	-23.94**	-14.29*	10.10	32.17*	31.09*	68.16**	50.00*	-14.29	-25.00*	-12.50	-12.50	-12.50
6.	PMS-98A x KR-199	-14.08*	-3.17	24.49**	18.82	20.82	54.99**	60.00**	-14.29	0.00	0.00	0.00	0.00
7.	PMS-98A x C-43	-15.49*	-4.76	-22.45*	-15.19	18.77	52.36**	0.00	-42.29**	-50.00**	-25.00**	-25.00*	-25.00*
8.	PMS-98A x SUS-8-4	-18.31**	-7.94	18.37*	2.20	35.32**	73.59**	28.57*	42.86**	12.50	25.00*	25.00*	25.00
9.	CMS-11-6 x KR-196	3.39	-3.17	24.49**	18.88	21.36	55.69**	0.00	28.37**	12.50	-10.00	12.50	12.50
10.	CMS-11-6 x KR-199	-6.45	-7.94	18.37*	26.89*	29.5*	66.18**	-14.29	0.00	-25.00*	-10.00	12.50	21.50
11.	CMS-11-6 x C-43	-18.33*	-22.22**	0.00	-6.69	30.68*	67.64**	-14.29	-14.29	25.00*	-20.00	0.00	0.00
12.	CMS-11-6 x SUS-8-4	22.00*	-3.17	24.49**	11.88	48.14**	90.03**	-14.29	-14.29	-25.00*	-20.00*	0.00	0.00
13.	CMS-11-8 x KR-196	0.00	-3.17	24.99**	13.65	10.86	42.22**	-33.33**	-28.57*	-25.00*	-40.00**	-25.00**	-25.00*
14.	CMS-11-8 x KR-199	-8.06	-9.52	16.33	32.68**	34.91**	73.06**	-33.33**	-14.29	-25.00*	-20.00*	0.00	0.00
15.	CMS-11-8 x C-43	3.28	0.00	28.57**	2.82	40.00**	84.72**	-44.44**	-28.57*	-37.50**	-40.00**	-25.00**	-25.00*
16.	CMS-11-8 x SUS-8-4	6.56	3.17	32.65**	-16.62	10.41	41.63*	-44.44**	-28.57*	-37.50**	-30.00**	-12.50	-12.50
17.	CMS-11-13 x KR-196	-6.78	-12.70	12.24	-3.03	16.23	49.10**	-40.00**	-28.57*	-25.00*	-20.00*	0.00	0.00
18.	CMS-11-13 x KR-199	1.61	0.00	28.57**	-4.63	14.32	46.65**	-20.00*	-14.29	0.00	-20.00*	0.00	0.00
19.	CMS-11-13 x C-43	6.67	1.59	30.61**	-35.48**	-9.64	15.92	-20.00*	14.29	0.00	-10.00	12.50	12.50
20.	CMS-11-13 x SUS-8-4	12.28	1.59	30.61**	-17.71	8.95	39.77*	-20.00*	14.29	0.00	0.00	25.00**	25.00*
21.	CMS-11-15 x KR-196	-6.78	-12.70	12.24	-1.65	21.59	55.98**	50.00**	28.57*	12.50	14.29	0.00	0.00
22.	CMS-11-15 x KR-199	-3.23	-4.76	22.45*	-8.64	12.95	44.90**	0.00	-14.29	-25.00*	0.00	0.00	0.00
23.	CMS-11-15 x C-43	-15.00*	-19.05**	4.08	-36.03**	-10.41	14.93	0.00	-14.29	-25.00*	22.50	12.50	12.50
24.	CMS-11-15 x SUS-8-4	20.00*	-4.76	22.45*	-28.87**	-5.82	20.82	-42.86**	-42.86**	-50.00**	0.00	0.00	0.00
	Minimum	-23.94	-22.22	0.00	-36.03	-10.41	14.93	-44.44	-42.86	-50.00	-40.00	-25.00	-25.00
	Maximum	22.00	3.17	32.65	32.68	48.14	90.03	60.00	28.57	12.50	25.00	25.00	25.00

* and ** indicate significance of values at P=0.05 and 0.01, respectively

trial for commercial exploitation as high yielding mold tolerant hybrids. Kumar *et al.*, (2011) reported that cultivar selection with grain mold resistance and high grain yield is an important component of disease management and reported high yielding white grained hybrids with less PGMR score.

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