E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(11): 628-633
Received: 16-08-2025
Accepted: 22-09-2025

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Estimation of economic heterosis for grain yield and it's attributing traits in sorghum [*Sorghum bicolor* (L.) Moench]

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DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i11i.4239

Abstract
The present investigation was undertaken in order to estimate the heterosis for grain yield and its attributing traits in sorghum. The crosses were attempted by using half diallel mating design using ten parents during kharif 2023. The resultant 45 crosses together with 10 parents and 2 standard checks (CSV 17 and CSV 23) were tested using randomized block design with three replications at three locations *viz*., Instructional Farm RCA, Udaipur, Instructional Farm CTAE and Krishi Vigyan Kendra, Badgaon during kharif 2024. A total of 38 and 5 crosses exhibited significant desirable heterobeltiosis and economic heterosis respectively for grain yield per plant. The heterobeltiosis for grain yield per plant ranged from 4.97% to 120.07% while economic heterosis ranged from 17.97% to 31.83%. The maximum heterosis over better parent in the desirable diection was recorded by cross CSV 28 X SPV 96 (120.07%). The maximum heterosis towards positive direction over standard check was recorded by CSV 23 X SPV 2510 (31.83%). Crosses with desirable traits for yield components showed increased grain yield likely due to the combined effect of improved traits.

Keywords: Sorghum, half diallel mating design, heterobeltiosis and economic heterosis

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is a major millet crop that belongs to the grass family poaceae. It is the fifth most important cereal crop grown in a wide range of agro ecologies and plays an important role in global food security (Boyles *et al*. 2016) [1]. Sorghum is highly adaptable crop in moisture stressed areas where other crops have the lowest chances of surviving because of its great photosynthetic efficiency. As a C4 plant, it has high photosynthetic efficiency and can tolerate different environmental stresses *viz*., drought, salinity and high temperature. Sorghum's high drought tolerance is crucial for its adaptation to arid and semi arid environments around the world. Therefore, sorghum is the crop of choice for Climate Smart Agriculture in the context of climate change. The nation's economic sorghum area is estimated to be approximately 14.21 lakh hectares, with an annual yield of 17.54 lakh tonnes and a productivity of 1170 kg/ha. Sorghum was one of the first crop to achieve hybrid advantage and the successful selection of CMS lines for sorghum lines for sorghum opened up a wide range of prospects for the application of hybrids (Stephens and Hollard, 1954) [11]. Sorghum hybrids are widely adaptable, high yielding, and disease resistant, and play an important role in improved sorghum yields (Rakshit *et al* 2014) [10].
The choice of parents to be incorporated in hybridization programme is a crucial step for breeders, particularly if the aim is improvement of complex quantitative characters, such as grain yield and its components. The use of parents of known superior genetic worth ensures much better success. Nature and magnitude of heterosis is one of the most important aspects for selection of right parents for crosses and also help in identification of superior cross combinations that produce desirable transgressive segregants in advanced generations.

Statistical Analysis

Heterobeltiosis and economic heterosis, expressed as per cent deviation in a desirable direction over better parent and standard check, respectively. Heterosis, heterobeltiosis and economic heterosis were calculated according to the methods suggested by Shull (1908) [12], Fonseca and Patterson (1968) [5] and Meredith and Bridge (1972) [9], respectively for individual as well as over the environments.

Materials and Methods

The field experiment was conducted in Udaipur, Rajasthan situated at 24°58' N Latitude, 73°68' E Longitude with an Altitude of 582.17 m above mean sea level. The climatic conditions of the area represent subtropical humid with annual rainfall 637 mm. The experimental material of present study was comprised of 45 elite crosses developed by crossing ten parents in half diallel mating design along with two standard checks (CSV 17 and CSV 23). CSV 17, CSV 27, CSV 15, CSV 39, CSV 23, CSV 28, AKR 150, SPV 96, CSV 10 and SPV 2510 used as parents, from the AICRP, Sorghum, Udaipur.

The crossing programme was carried out during kharif 2023 at Instructional Farm, RCA, Udaipur. At the same time, the parents were selfed to get pure seeds of parents for the experiment. The experimental material consisting of total 57 entries including 45 crosses, 10 parents and 2 checks were tested in randomized block design with three replications at three locations *viz*., E1- Instructional Farm, RCA, Udaipur; E2- Instructional Farm, CTAE, Udaipur and E3- KVK, Badgaon, Udaipur during kharif 2024. A single row plant of 3m was allotted randomly to each entry. The space between plants was maintained at 45 cm x 15 cm.

Ten competitive plants per genotype in each replication in each environment were selected randomly for recording observation on panicle length (cm), plant height (cm), no. of primaries per panicle, no. of seeds per panicle, grain yield per plant (g), dry fodder yield per plant (g), test weight (g), protein% (grain), protein% (fodder) and harvest index (%) while for days to 50% flowering and days to maturity observations were recorded on plot basis and their average values were used in the statistical analysis.

Results and Discussion

Analysis of variance

The genotypes used in this experiment showed significant differences across all traits, confirming that the presence of enough genetic variations to study. The genotype variance was further subdivided into parents, crosses and parents v/s crosses variance. For every character under study, it was also determined that the difference between the crosses and parents were highly significant. Mean squares due to parents v/s crosses were found highly significant for all the characters except plant height (Table 1). These differences in parents and hybrids were found significant due to recombination of genes derived from diverse parents leading to generation of an array of variability for different traits. This suggested the existence of overall heterosis and the chance of significant differences between the parents and crosses with respect to these characters. By seeing possibility of heterosis among these selected genotypes further analysis was needed.

Heterosis

Heterobeltiosis

The percentage increase or reduction in F1 over the better parent for twelve characters was used to measure heterobeltiosis. Characterwise results on heterosis over better parent (heterobeltiosis) on pooled basis were presented in Table 2 to Table 5 and described as under.

For sorghum days to 50% flowering and days to maturity the heterotic effect in a negative direction was preferable. Heterobeltiosis for days to 50% flowering ranged from -9.22% (CSV 17 × CSV 27) to -2.92% (CSV 27 × CSV 23) Thus, the earliest crosses were CSV 17 × CSV 27 (-9.22%) followed by CSV 17 × CSV 39 (-8.20%) Out of 45 crosses, 8 crosses manifested significant and desirable (negative) estimate of heterobeltiosis while for days to maturity, heterosis ranged from -2.39% (CSV 23 x CSV 28) to -7.69 (CSV 17 x CSV 27). 17 crosses manifested significant and desirable (negative) estimates.

For grain yield per plant heterobeltiosis ranged from 4.97% (CSV 17 x SPV 2510) to 120.07% (CSV 28 x SPV 96). 38 crosses exhibited significant positive heterosis for grain yield. For traits like no. of seeds per panicle, ranged from 3.87% (AKR 150 X SPV 2510) to 91.00% (CSV 23 X SPV 2510). For no. of primaries per panicle minimum and maximum values recorded were 7.49% (CSV 27 X CSV 39)% to 41.17% (CSV 39 X CSV 10). 2.83% (CSV 15 X CSV 39 and CSV 15 X SPV 2510) to 36.77% (CSV 28 X SPV 96) for test weight. For panicle length, heterosis over better parent ranged from 6.97% (CSV 28 X AKR 150) to 21.17% (CSV 27 X CSV 23). For plant height heterosis ranged from 2.56% (CSV 15 X SPV 2510) to 13.60% (CSV 28 X SPV 96). The magnitude of heterobeltiosis ranged from 3.24% (CSV 17 X CSV 27) to 29.57% (SPV 96 X SPV 2510) for dry fodder yield per plant. The range of heterosis over better parent was recorded 4.18% (CSV 15 x AKR 150) to 43.63% (CSV 28 x SPV 96) for harvest index.

Economic heterosis

The percentage increase or reduction in F1over the standard check for twelve characters was used to measure standard heterosis. Standard heterosis is more useful than the measure of heterosis over superior parents. Characterwise results on heterosis over standard checks, CSV 17 and CSV 23 (economic heterosis) were presented in Table 2 to Table 5 and described as under.

The range of standard heterosis for days to 50% flowering varied from -4.76% (CSV 17 x CSV 15 and x CSV 17 x CSV SPV) to -8.28% (CSV 17 × CSV 27). Out of 45 crosses 7 crosses exhibited significant negative heterosis. Cross CSV 17 X CSV 27 (-7.02%) was found earliest in maturity followed by CSV 17 X CSV 39(-6.66%). 7 crosses manifested significant negative heterosis for maturity.

For grain yield per plant minimum economic heterosis observed 17.97% (CSV 27 x CSV 39) and maximum 31.83% (CSV 23 x SPV 2510) followed by crosses CSV 39 X SPV 2510 (31.40%) and CSV 28 X SPV 96 (27.64%). 5 crosses exhibited significant positive heterosis for grain yield. For traits like no. of seeds per panicle, economic heterosis ranged from 4.92% (CSV 17 X CSV 27) to 97.33% (CSV 23 X SPV 2510) followed by CSV 39 X SPV 2510 (71.48%).

For no. of primaries per panicle minimum and maximum values recorded were 6.11% (CSV 39 X SPV 2510)% and 11.01% (CSV 23 X SPV 2510). Cross CSV 23 X SPV 2510 exhibited maximum value of economic heterosis 34.85% for test weight followed by CSV 39 X SPV 2510 (30.77%), CSV 28 X CSV 10 (26.63%). For panicle length, economic heterosis ranged from 6.49% (CSV 23 X AKR 150) to 18.77% (CSV 27 X CSV 23). For plant height maximum value exhibited by cross CSV 23 X CSV 2510 (3.66%) followed by CSV 39 X SPV 2510 (3.12%).

The magnitude of economic heterosis ranged from 2.96% (CSV15 X CSV 39) to 15.08% (SPV 96 X SPV 2510) for dry fodder yield per plant. Cross CSV 23 X SPV 2510 (13.41%) exhibited maximum value for harvest index followed by CSV 28 X SPV 96 (12.29%). 5 crosses exhibited significant positive heterosis.

Similar trends of results for yield and yield contributing traits were also reported by Dardeer *et al*. (2011) [3], Kale and Desai (2016) [6], Chaudhari (2016) [2], Khadi (2018) [8], Kalpande (2019) [7], Vinoth (2021) [14], Tambe (2021) [13] and Elraheem (2023) [4].

It was revealed that high, significant and positive heterosis for grain yield per plant in these crosses were not accompanied by single unique trait. These crosses also exhibited significant and desirable heterosis for component traits.

For grain yield, the best-performing crosses were CSV- 23× SPV 2510, CSV 39 × SPV 2510, CSV 28 × SPV 96 and CSV 27 × CSV 23 all of which significantly outperformed both their parent lines and the standard varieties. These crosses also showed significant and desirable heterobeltiosis and standard heterosis for grain yield and attributing traits *viz*., panicle length, no. of primaries per panicle, no. of seeds per panicle, test weight and harvest index.

Table 1: Analysis of variance (mean squares) for grain yiels and its attributing traits in Sorghum

S. N.	Characters	Env	Rep/Env	Genotype	Parents	F1	P vs F1	Pool Error
	d.f.	2	6	54	9	44	1	324
1	Days to 50% Flowering	4909.97**	1.73	668.36**	550.80**	706.79**	35.20**	3.09
2	Days to maturity	7681.48**	2.45	771.32**	663.01**	768.87**	1853.66**	7.44
3	Panicle length	629.69**	0.75	41.25**	23.03**	42.88**	133.52**	2.30
4	Plant height	11255.94**	23.60	9151.84**	8262.63**	9541.72**	0.33	30.06
5	No. of primaries per panicle	2988.92**	15.51	468.16**	433.62**	351.84**	5896.70**	12.27
6	No. of seeds per panicle	26655.21**	2.37	1073.12**	107.32**	972.49**	14192.78**	4.53
7	Grain yield per plant	7233.60**	4.55	2778.20**	1472.26**	2501.77**	26694.43**	3.78
8	Dry fodder yield per plant	19422.50**	20.75	859.92**	665.03**	429.23**	21564.04**	18.10
9	Test weight	2.61**	0.00	0.67**	0.21**	0.67**	4.82**	0.00
10	Protein% (Grain)	44.15**	0.14	27.42**	11.54**	19.74**	508.00**	0.07
11	Protein% (Fodder)	75.44**	0.02	3.27**	3.01**	0.52**	126.53**	0.03
12	Harvest index	117.83**	1.12	145.11**	103.00**	141.31**	691.59**	0.88

Table 2: Per cent heterobeltiosis (HB) and economic heterosis (EH) for days to 50% flowering, days to maturity and panicle length in Sorghum

S. n.	Genotype			Days to 50% flowering		Days to maturity		Panicle length	
				HB (%)	EH (%)	HB (%)	EH (%)	HB (%)	EH (%)
1	CSV- 17	X	CSV- 27	-9.22**	-8.28**	-7.69**	-7.02**	-	-
2	CSV- 17	X	CSV- 15	-5.74**	-4.76**	-6.25**	-5.57**	-	-
3	CSV- 17	X	CSV-39	-8.20**	-7.25**	-7.33**	-6.66**	-	-
4	CSV- 17	X	CSV- 23	-5.33**	-4.35**	-5.65**	-4.96**	-	-
5	CSV- 17	X	CSV- 28	-6.76**	-5.80**	-5.29**	-4.60**	-	-
6	CSV- 17	X	AKR-150	-6.35**	-5.38**	-5.89**	-5.21**	-	-
7	CSV- 17	X	SPV-96	-5.74**	-4.76**	-6.73**	-6.05**	-	-
8	CSV- 17	X	CSV-10	-	-	-	-	-	-
9	CSV- 17	X	SPV-2510	-	-	-	-	-	-
10	CSV- 27	X	CSV- 15	-	-	-	-	-	-
11	CSV- 27	X	CSV-39	-	-	-	-	-	-
12	CSV- 27	X	CSV- 23	-2.92**	-	-7.46**	-	21.17**	18.77**
13	CSV- 27	X	CSV- 28	-1.31	-	-1.44	-	-	-
14	CSV- 27	X	AKR-150	-	-	-	-	6.33	-
15	CSV- 27	X	SPV-96	-	-	-	-	2.74	3.01
16	CSV- 27	X	CSV-10	-	-	-	-	14.90**	3.16
17	CSV- 27	X	SPV-2510	-	-	-	-	-	4.43
18	CSV- 15	X	CSV-39	-2.08	-	-3.12*	-	3.17	2.86
19	CSV- 15	X	CSV- 23	-	-	-	-	3.20	1.16
20	CSV- 15	X	CSV- 28	-	-	-4.48**	-	3.14	-
21	CSV- 15	X	AKR-150	-1.05	-	-5.10**	-	4.51	0.26
22	CSV- 15	X	SPV-96	-	-	-	-	0.01	0.28
23	CSV- 15	X	CSV-10	0.00	-	-4.29**	-	5.87	1.57
24	CSV- 15	X	SPV-2510	-	-	-2.40*	-	-	0.78
25	CSV-39	X	CSV- 23	-	-	-0.54	-	11.41**	11.07**
26	CSV-39	X	CSV- 28	-0.52	-	-1.51	-	8.65**	8.31**
27	CSV-39	X	AKR-150	-	-	-0.75	-	8.94**	8.61**
28	CSV-39	X	SPV-96	-	-	-	-	1.53	1.80
29	CSV-39	X	CSV-10	-	-	-	-	7.75*	7.42*
30	CSV-39	X	SPV-2510	-	-	-0.97	-	5.19	11.29**
31	CSV- 23	X	CSV- 28	-1.16	-	-2.39*	-	11.02**	8.82**
32	CSV- 23	X	AKR-150	-	-	-	-	8.64**	6.49*

33	CSV- 23	X	SPV-96	-	-	-	-	4.48	4.75
34	CSV- 23	X	CSV-10	-	-	-	-	7.90*	5.76
35	CSV- 23	X	SPV-2510	-	-	-1.85	-	11.65**	18.13**
36	CSV- 28	X	AKR-150	-	-	-	-	6.97*	2.66
37	CSV- 28	X	SPV-96	-	-	-	-	14.78**	15.08**
38	CSV- 28	X	CSV-10	-	-	-	-	6.31	2.03
39	CSV- 28	X	SPV-2510	-	-	-3.90**	-	5.41	11.52**
40	AKR-150	X	SPV-96	-	-	-	-	-	-
41	AKR-150	X	CSV-10	-	-	-1.57	-	4.46	-
42	AKR-150	X	SPV-2510	-	-	-5.00**	-	-	-
43	SPV-96	X	CSV-10	-	-	-0.33	-	5.20	5.48
44	SPV-96	X	SPV-2510	-	-	-2.11	-	8.95**	15.27**
45	CSV-10	X	SPV-2510	-2.09	-	-7.33**	-	0.85	6.69*

Table 3: Per cent heterobeltiosis (HB) and economic heterosis (EH) for plant height, no. of primaries per panicle and no. seeds per panicle in Sorghum

S. n.	Genotype			Plant height		No. of Primaries per panicle		No. of seeds per panicle	
				HB (%)	EH (%)	HB (%)	EH (%)	HB (%)	EH (%)
1	CSV- 17	X	CSV- 27	-	-	20.90**	-	13.51**	4.92*
2	CSV- 17	X	CSV- 15	-	-	23.14**	-	14.95**	0.40
3	CSV- 17	X	CSV-39	-	-	22.59**	-	10.70**	-
4	CSV- 17	X	CSV- 23	-	-	-	-	9.71**	8.91**
5	CSV- 17	X	CSV- 28	-	-	7.77*	-	5.98**	0.37
6	CSV- 17	X	AKR-150	-	-	-	-	9.38**	-
7	CSV- 17	X	SPV-96	3.94*	-	23.10**	-	12.39**	9.48**
8	CSV- 17	X	CSV-10	-	-	7.40	-	3.84	-
9	CSV- 17	X	SPV-2510	-	-	16.29**	-	5.50**	8.99**
10	CSV- 27	X	CSV- 15	7.58**	-	15.48**	-	28.59**	18.85**
11	CSV- 27	X	CSV-39	3.65**	-	7.49*	-	33.03**	22.96**
12	CSV- 27	X	CSV- 23	-	-	5.31	3.93	45.56**	44.50**
13	CSV- 27	X	CSV- 28	-	-	10.42**	-	29.58**	22.72**
14	CSV- 27	X	AKR-150	0.88	-	2.18	-	23.92**	14.54**
15	CSV- 27	X	SPV-96	-	-	10.71**	-	30.54**	27.17**
16	CSV- 27	X	CSV-10	-	-	-	-	26.75**	17.15**
17	CSV- 27	X	SPV-2510	0.71	-	13.19**	-	20.33**	24.30**
18	CSV- 15	X	CSV-39	-	-	16.09**	-	29.85**	13.42**
19	CSV- 15	X	CSV- 23	-	-	-	-	27.06**	26.14**
20	CSV- 15	X	CSV- 28	-	-	20.46**	-	33.37**	26.31**
21	CSV- 15	X	AKR-150	-	-	8.82*	-	33.17**	16.32**
22	CSV- 15	X	SPV-96	-	-	29.73**	-	31.27**	27.88**
23	CSV- 15	X	CSV-10	-	-	8.10*	-	21.04**	5.72**
24	CSV- 15	X	SPV-2510	2.56*	-	20.49**	-	21.16**	25.15**
25	CSV-39	X	CSV- 23	-	-	-	-	29.31**	28.37**
26	CSV-39	X	CSV- 28	-	-	4.12	-	35.77**	28.58**
27	CSV-39	X	AKR-150	0.15	-	9.57*	-	19.13**	3.14
28	CSV-39	X	SPV-96	-	-	24.38**	-	16.88**	13.86**
29	CSV-39	X	CSV-10	6.25**	-	41.17**	-	21.25**	4.97*
30	CSV-39	X	SPV-2510	9.12**	3.12**	30.50**	6.11*	66.00**	71.48**
31	CSV- 23	X	CSV- 28	-	-	2.34	0.99	17.79**	16.94**
32	CSV- 23	X	AKR-150	-	-	0.91	-	3.03	2.28
33	CSV- 23	X	SPV-96	-	-	1.16	-	14.31**	13.48**
34	CSV- 23	X	CSV-10	-	-	3.59	2.23	13.38**	12.55**
35	CSV- 23	X	SPV-2510	3.81**	3.66**	12.49**	11.01**	91.02**	97.33**
36	CSV- 28	X	AKR-150	-	-	-	-	18.49**	12.22**
37	CSV- 28	X	SPV-96	13.60**	2.03	39.36**	6.95*	73.24**	68.76**
38	CSV- 28	X	CSV-10	-	-	-	-	7.93**	2.21
39	CSV- 28	X	SPV-2510	-	-	14.38**	-	14.96**	18.75**
40	AKR-150	X	SPV-96	-	-	9.30*	-	16.75**	13.73**
41	AKR-150	X	CSV-10	3.14*	-	25.95**	-	15.22**	-
42	AKR-150	X	SPV-2510	1.66	-	5.51	-	3.87*	7.30**
43	SPV-96	X	CSV-10	-	-	15.35**	-	30.53**	27.15**
44	SPV-96	X	SPV-2510	3.56**	-	27.00**	3.27	47.34**	52.21**
45	CSV-10	X	SPV-2510	1.43	-	-	-	26.36**	30.53**

*, ** Significant at 5% and 1% levels, respectively

Table 4: Per cent heterobeltiosis (HB) and economic heterosis (EH) for grain yield per plant, dry fodder yield per plant and test weight in Sorghum

S. n.	Genotype			Grain yield per plant		Dry fodder yield per plant		Test weight	
				HB (%)	EH (%)	HB (%)	EH (%)	HB (%)	EH (%)
1	CSV- 17	X	CSV- 27	6.95**	-	3.24*	-	3.52*	-
2	CSV- 17	X	CSV- 15	9.22**	-	6.84**	-	1.40	-
3	CSV- 17	X	CSV-39	7.95**	-	8.59**	-	3.31*	-
4	CSV- 17	X	CSV- 23	-	-	-	-	3.47**	2.09
5	CSV- 17	X	CSV- 28	10.59**	-	8.73**	-	4.83**	-
6	CSV- 17	X	AKR-150	6.92**	-	19.34**	-	7.82**	-
7	CSV- 17	X	SPV-96	15.70**	-	21.68**	0.64	3.04*	-
8	CSV- 17	X	CSV-10	14.03**	-	13.53**	0.22	6.70**	-
9	CSV- 17	X	SPV-2510	4.97**	-	11.99**	-	1.72	4.18**
10	CSV- 27	X	CSV- 15	34.73**	-	16.58**	9.70**	3.89**	-
11	CSV- 27	X	CSV-39	31.61**	-	10.43**	3.91**	8.97**	-
12	CSV- 27	X	CSV- 23	19.02**	17.97**	5.12**	4.33**	25.45**	23.78**
13	CSV- 27	X	CSV- 28	34.34**	-	8.10**	1.72	6.83**	-
14	CSV- 27	X	AKR-150	29.18**	-	8.21**	1.83	1.97	-
15	CSV- 27	X	SPV-96	36.93**	-	1.06	-	3.52*	-
16	CSV- 27	X	CSV-10	26.59**	-	7.62**	1.27	4.37**	-
17	CSV- 27	X	SPV-2510	35.95**	-	12.34**	5.71**	8.59**	11.22**
18	CSV- 15	X	CSV-39	30.02**	-	10.32**	0.95	2.83*	-
19	CSV- 15	X	CSV- 23	-	-	8.55**	7.73**	4.19**	2.81*
20	CSV- 15	X	CSV- 28	30.52**	-	13.80**	3.92**	3.80**	-
21	CSV- 15	X	AKR-150	23.84**	-	12.57**	0.97	3.61*	-
22	CSV- 15	X	SPV-96	31.02**	-	0.48	-	5.44**	-
23	CSV- 15	X	CSV-10	28.39**	-	14.80**	2.96*	3.07*	-
24	CSV- 15	X	SPV-2510	16.95**	-	19.25**	6.96**	2.83*	5.33**
25	CSV-39	X	CSV- 23	-	-	8.68**	7.85**	4.87**	3.47**
26	CSV-39	X	CSV- 28	42.39**	-	11.39**	1.93	4.26**	-
27	CSV-39	X	AKR-150	21.79**	-	10.26**	0.90	1.57	-
28	CSV-39	X	SPV-96	27.82**	-	-	-	4.14**	-
29	CSV-39	X	CSV-10	19.39**	-	10.02**	0.67	2.36	-
30	CSV-39	X	SPV-2510	90.23**	31.40**	17.68**	7.69**	27.67**	30.77**
31	CSV- 23	X	CSV- 28	-	-	-	-	2.46	1.09
32	CSV- 23	X	AKR-150	-	-	0.24	-	2.22	0.86
33	CSV- 23	X	SPV-96	-	-	-	-	3.76**	2.38
34	CSV- 23	X	CSV-10	-	-	2.43	1.66	2.55*	1.19
35	CSV- 23	X	SPV-2510	33.00**	31.83**	5.82**	5.02**	31.66**	34.85**
36	CSV- 28	X	AKR-150	38.70**	-	8.06**	-	4.62**	-
37	CSV- 28	X	SPV-96	120.07**	27.64**	13.41**	3.56*	36.77**	26.63**
38	CSV- 28	X	CSV-10	40.33**	-	8.53**	-	25.94**	16.60**
39	CSV- 28	X	SPV-2510	16.86**	-	12.54**	2.76	10.12**	12.79**
40	AKR-150	X	SPV-96	29.60**	-	14.15**	-	4.89**	-
41	AKR-150	X	CSV-10	18.70**	-	14.22**	0.82	9.00**	-
42	AKR-150	X	SPV-2510	14.06**	-	20.36**	6.89**	5.06**	7.61**
43	SPV-96	X	CSV-10	62.94**	-	9.62**	-	3.31*	-
44	SPV-96	X	SPV-2510	83.27**	26.59**	29.57**	15.08**	19.17**	22.06**
45	CSV-10	X	SPV-2510	7.73**	-	18.87**	5.57**	3.30**	5.80**

Table 5: Per cent heterobeltiosis (HB) and economic heterosis (EH) for protein content in grain, protein content in fodder and harvest index in Sorghum

S. n.	Genotype			Protein content in grain		Protein content in fodder		Harvest index	
				HB (%)	EH (%)	HB (%)	EH (%)	HB (%)	EH (%)
1	CSV- 17	X	CSV- 27	-	-	-	-	-	-
2	CSV- 17	X	CSV- 15	-	-	-	-	-	-
3	CSV- 17	X	CSV-39	-	-	-	-	-	-
4	CSV- 17	X	CSV- 23	-	-	-	-	-	-
5	CSV- 17	X	CSV- 28	-	-	-	-	-	-
6	CSV- 17	X	AKR-150	-	-	-	-	-	-
7	CSV- 17	X	SPV-96	-	-	-	-	-	-
8	CSV- 17	X	CSV-10	-	-	-	-	-	-
9	CSV- 17	X	SPV-2510	-	-	-	-	-	-
10	CSV- 27	X	CSV- 15	-	-	-	-	9.46**	-
11	CSV- 27	X	CSV-39	-	-	-	-	11.82**	-
12	CSV- 27	X	CSV- 23	-	-	-	-	7.40**	7.27**
13	CSV- 27	X	CSV- 28	-	-	-	-	14.80**	-
14	CSV- 27	X	AKR-150	-	-	-	-	9.39**	-
15	CSV- 27	X	SPV-96	-	-	-	-	20.75**	-

16	CSV- 27	X	CSV-10	-	-	-	-	11.26**	-
17	CSV- 27	X	SPV-2510	-	-	-	-	8.56**	-
18	CSV- 15	X	CSV-39	-	-	-	-	9.84**	-
19	CSV- 15	X	CSV- 23	-	-	-	-	-	-
20	CSV- 15	X	CSV- 28	-	-	-	-	8.10**	-
21	CSV- 15	X	AKR-150	-	-	-	-	4.18**	-
22	CSV- 15	X	SPV-96	-	-	-	-	18.21**	-
23	CSV- 15	X	CSV-10	-	-	-	-	7.60**	-
24	CSV- 15	X	SPV-2510	-	-	-	-	-	-
25	CSV-39	X	CSV- 23	-	-	-	-	-	-
26	CSV-39	X	CSV- 28	-	-	-	-	17.63**	-
27	CSV-39	X	AKR-150	-	-	-	-	0.12	-
28	CSV-39	X	SPV-96	-	-	-	-	15.66**	-
29	CSV-39	X	CSV-10	-	-	-	-	6.09**	-
30	CSV-39	X	SPV-2510	-	-	-	-	30.47**	11.68**
31	CSV- 23	X	CSV- 28	-	-	-	-	-	-
32	CSV- 23	X	AKR-150	-	-	-	-	-	-
33	CSV- 23	X	SPV-96	-	-	-	-	-	-
34	CSV- 23	X	CSV-10	-	-	-	-	-	-
35	CSV- 23	X	SPV-2510	-	-	-	-	13.55**	13.41**
36	CSV- 28	X	AKR-150	-	-	-	-	11.00**	-
37	CSV- 28	X	SPV-96	-	-	-	-	43.63**	12.29**
38	CSV- 28	X	CSV-10	-	-	-	-	18.83**	-
39	CSV- 28	X	SPV-2510	-	-	-	-	0.89	-
40	AKR-150	X	SPV-96	-	-	-	-	7.48**	-
41	AKR-150	X	CSV-10	-	-	-	-	-	-
42	AKR-150	X	SPV-2510	-	-	-	-	-	-
43	SPV-96	X	CSV-10	-	-	-	-	24.24**	-
44	SPV-96	X	SPV-2510	-	-	-	-	23.25**	5.50**
45	CSV-10	X	SPV-2510	-	-	-	-	-	-

Conclusion

The majority of the crosses for yield and yield related traits exhibited positive significant heterosis, thereby indicating that for these traits the genes with positive effect were dominant. While for maturity related traits, the hybrids that exhibited negative significant heterosis, indicating that for these traits the genes with negative effect were dominant. High heterotic crosses had also shown high mean performance. Per se performance may not be a reliable indicator of genetic potential while, heterotic potential is more reliable. Genetic expression of heterozygosity can be obtained through hybridization with the help of the magnitude of heterosis. On the basis of per se performance and heterotic response involved in the inheritance of grain yield and its attributing traits, the three crosses *viz*., CSV 23 × SPV 2510, CSV 39 × SPV 2510 and CSV 28 × SPV 96 appeared to be the most superior cross combinations. These crosses recorded 126.67, 126.26 and 122.65 per cent higher yield over standard check (CSV 23), respectively. Therefore, these crosses could be exploited for heterosis breeding programme to boost the grain yield in sorghum.

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