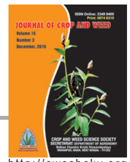
Journal of Crop and Weed, 17(3): 206-213 (2021)

ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Interpretation of mean value and extent of heterosis in fodder and grain yield with associated traits of sorghum [*Sorghum bicolor* (L.) Moench]

A. H. JOSHI, [1*]R. A. GAMI, [2]R. N. PATEL AND ARVINTH S.

Department of Genetics and Plant Breeding, CPCA, S.D. Agricultural University, Sardarkrushinagar (Gujarat)
[1]Sorghum Research Station, [2]Potato Research Station,
S.D. Agricultural University, Deesa-385 535 (Gujarat)

Received : 12.08.2021; Revised : 29.11.2021 ; Accepted : 27.12.2021

DOI: https://doi.org/10.22271/09746315.2021.v17.i3.1511

ABSTRACT

The study was undertaken to reveal mean and percent heterosis level in sorghum [Sorghum bicolor (L.) Moench]. The 28 (F_1) hybrids generated using seven females as a line and four males as a tester through L × T fashion. An examination of mean data of parents with (F_1) hybrids for different yield and associated traits revealed that GJ 43 amongst females and SPV 2573 amongst males, while SR 3019 × SPV 2573, SR 2980 × CSV 31 and SR 3019 × CSV 17 amongst hybrids exhibited higher mean value for grain yield plant^{-1} with some of its associated traits. Looking to dry fodder yield plant^{-1}, the female DSF 168, the male SPV 2682 and crosses DS 156 × SPV 2682, DS 156 × CSV 31 and SR 3048 × CSV 31 recorded higher dry fodder yield plant^{-1}. The significant heterobeltiosis and standard heterosis was perceived in many hybrids for different components traits. The F_1 hybrids, SR 2980 × CSV 31 (40.38 & 50.61 %), DSF 168 × CSV 31 (28.66 and 28.66 %) and SR 3019 × SPV 2573 (28.34 and 55.48 %) manifested significant and positive heterosis over better parent and the standard check CSV 31 for grain yield plant^{-1}. While SR 2980 × SPV 2682, SR 3048 × CSV 31 and SR 2980 × CSV 31 registered highly significant and positive heterotic effects in terms of heterobeltiosis (i.e., 46.13, 31.24 and 30.87 %), standard heterosis over check GJ 43 (i.e., 28.28, 34.52 and 14.27 %) and CSV 31 (i.e., 85.68, 94.71 and 65.40 %) for dry fodder yield plant^{-1}, respectively. These crosses were also given best per se performance, hence hold promising for commercial exploitation.

Keywords: Forage yield, grain yield, heterobeltiosis, L× T analysis, *per se* performance and standard heterosis

Sorghum is an important *kharif* crop in low rainfall areas, which provides primary food for the needy people and fodder for animals in India. In world, sorghum is considered the fifth major and most important grain crop after wheat, maize, rice, and barley. It is an edible and nourishing fodder crop for animals. There is a massive mandate for green and dry fodder, mostly during slim winter and summer seasons in the semi-arid and arid regions. Sorghum also called 'Global Grain' is a crop of worldwide status due to its versatile use being a 4F (food, feed, fodder and fuel) crop. In addition to grain, sorghum is of utmost importanceas a fodder and silage purpose for animals due to its high palatability and ability to provide green forage for a longer period.

Heterosis is a per cent rise or decline performance of hybrid over the parental performance (Mutazing, 1945; Pal and Singh, 1946). The information on the extent of heterosis for various yield and associated characters is vital to choose better combinations to exploit them through heterosis breeding. Heterosis has been effectively exploited in both allogamous and autogamous crops. One of the present research goals was to evaluate hybrid vigour to recognize the genetic makeup of parents and to create Mendelian variability through segregation or recombination in advanced generations of the crosses. In real plant breeding, the heterosis estimated over better parent and standard parent is more accurate and more practical.

MATERIALS AND METHODS

The study was undertaken to reveal mean and per cent heterosis level in sorghum. The 28 (F_1) hybrids were generated through L × T fashion during early summer, 2020 at Sorghum Research Station, S.D. Agricultural University, Deesa (Gujarat) using seven females (DSF 117, DSF 168, DS 156, GJ 43, SR 2980, SR 3048 and SR 3019) and four males (CSV 31, CSV 17, SPV 2682 and SPV 2573). The resulting 28 hybrids with eleven parents (including two checks. *i.e*., GJ 43 and CSV 31) were evaluated in Randomized Block Design (RBD), replicated thrice during *Kharif*, 2020. The observations were recorded from five randomly selected competitive plants from each entry in each replication for all yield and associated traits except days to flowering which were recorded on a plot basis. The dry fodder yield measured after leaves including leaf sheath and stem were chopped after dried at 100º C for 48 hours in a hot air oven. Based on mean data, the analysis of variance (ANOVA) was carried out as per the method suggested by Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1985). The percent heterosis was estimated as increase or decrease

Email: ramangami@gmail.com

in the mean value of F_1 hybrid over better parent, *i.e.,* heterobeltiosis (Fonesca and Patterson, 1968) and over standard check, *i.e.,* standard heterosis (Meredith and Bridge, 1972) for each trait.

Heterobeltiosis was measured in percentage by using following formula

$$Heterobeltiosis\ (\%) = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

The standard heterosis was measured in percentage by using following formula

$$Standard\ heterosis\ (\%) = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{BP}$ = Mean performance of better parent

$\overline{SC}$ = Mean performance of standard check *i.e.,* GJ 43 and CSV 31.

$\overline{F_1}$ = Mean value of F_1.

The significance of heterosis value was tested using 't' test

$$t = \frac{\overline{F_1} - \overline{BP}\ OR\ \overline{SC}}{\text{Standard error of heterosis over } BP \text{ or } SC}$$

Calculated 't' value was equated with table't' values at error degree of freedom for test of significance.

The heterosis can be classified as low, moderate and high based on estimates. The level of heterosis varies from trait to trait. In the present study following criteria was used to classify heterosis level, *i.e.,* low, moderate and high.

Lowest range = X + lowest value,
Moderate range = 2X + lowest value, and
High range = 3X + lowest value (rest upper).
Where,
X= Mean value obtained by total range value divided by three

RESULTS AND DISCUSSION

The analysis of variance for all the characters studied is presented in Table 1. The analysis of variance revealed that significant differences among the parents for all traits. This indicated an adequate amount of variability in the parents (*i.e*., lines and testers) for all the traits. The mean sum of squares due to lines *vs* testers was significant for total plant height, the number of leaves plant^{-1}, stem girth, grain yield plant^{-1}, dry fodder yield plant^{-1}, grain protein content and fodder protein content. The mean sum of squares due to testers (males) were significant for days to flowering, number of leaves plant^{-1} and panicle length. Mean sum of squares due to parents *vs* hybrids were significant for all the traits except stem girth, *i.e*., days to flowering, total plant height, the number of leaves plant^{-1}, leaf length of blade, leaf width of blade, panicle length, grain yield plant^{-1}, dry fodder yield plant^{-1}, grain protein content, fodder protein content, Brix content and HCN content which indicated the presence of enormous heterosis for these traits.

The *per se* performance of parents and hybrids for yields and their traits is presented in Table 2. None of the parents (*i.e*., females or males) shows consistently good performance for all the traits. Considering the primary breeding objectives, *i.e.,* high yielding, earliness and quality parameters, the parental genotype GJ 43 was rewarded higher grain yield plant^{-1}(g) and grain protein content (%). In addition, it was also performed considerably good for panicle length (cm) and Brix content (%). The parent DSF 168 was found superior for dry fodder yield plant^{-1}(g), number of leaves plant^{-1}, leaf width of blade (cm) and fodder protein content (%). However, it stood second for total plant height (cm) and grain protein content (%). The parent CSV 17 was the earliest and had minimum stem girth (mm).

In case of hybrids, the cross SR 3019 × SPV 2573 was exhibited its superiority for grain yield plant^{-1}(g), leaf width of blade (cm) and grain protein content (%). On the other hand, the hybrid GJ 43 × CSV 31 showed better mean performance for total plant height (cm) and the number of leaves plant^{-1}. The hybrids SR 3019 × CSV 31, DS 156 × CSV 17, DSF 117 × SPV 2682, DS 156 × SPV 2682 and GJ 43 × SPV 2682 were found better for stem girth (mm), leaf length of blade (cm), panicle length (cm), dry fodder yield plant^{-1}(g) and fodder protein content (%), respectively. The cross-combination SR 3048 × SPV 2682 took a minimum days to attain flowering. The cross SR 2980 × SPV 2682 was superior for Brix content (%). The cross-combination DS 156 × SPV 2573 shows minimum HCN content (ppm).

In practical plant breeding, the heterosis measured over better parent and popular cultivar is more realistic and is of more practical importance. Hence in the present study, the heterosis was measured over better parent (Fig. 1) and standard checks, *i.e.,*GJ 43 (Fig. 2a) and CSV 31(Fig. 2b) (Table 3). In the present study, out of 28 hybrids, five and eight hybrids registered significant and positive heterosis over the better parent and the standard check CSV 31 for grain yield plant^{-1}, respectively. The wide range of heterosis over better parent and the standard checks was recorded, *i.e.*, -50.20 to 40.38 per cent over the better parent (heterobeltiosis), -51.16 to 4.56 per cent over GJ 43 and -27.37 to 55.48 per cent over CSV 31 for grain yield plant^{-1}. The hybrids SR 2980 × CSV 31 (40.38 & 50.61 %), DSF 168 × CSV 31 (28.66 & 28.66 %) and SR 3019 × SPV 2573 (28.34 & 55.48 %) manifested significant and positive

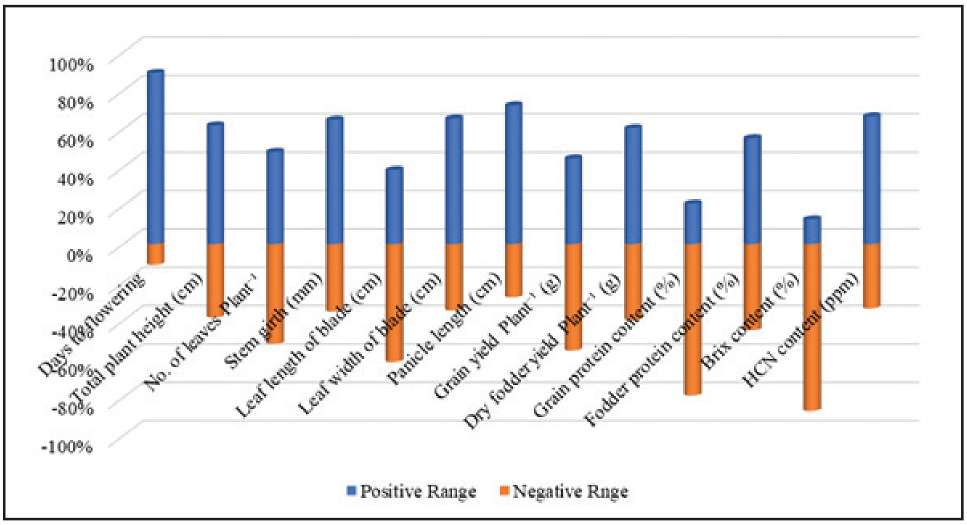


Fig. 1: The extent of heterobeltiosis in sorghum.

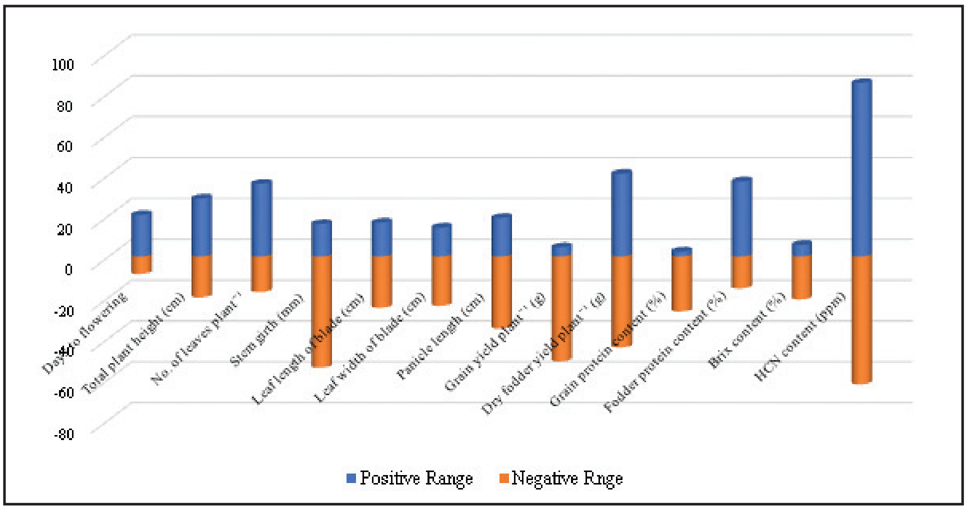


Fig. 2a: The extent of standard heterosis over check GJ 43.

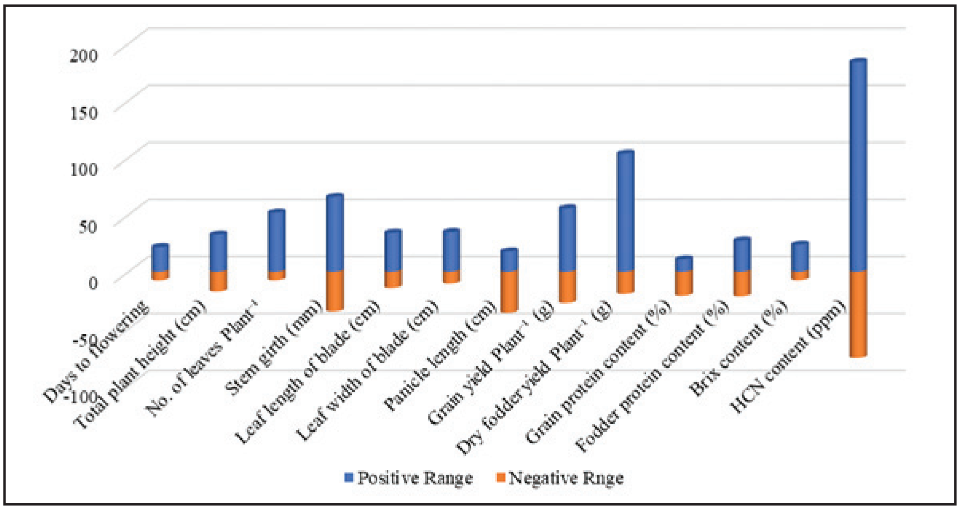


Fig. 2b: The extent of standard heterosis over check CSV 31.

Table 1: Analysis of variance showing mean sum of squares for various traits in sorghum

Sources of variation	d.f.	Days to flowering	Total plant height (cm)	No. of leaves plant^{-1}	Stem girth (mm)	Leaf length of blade (cm)	Leaf width of blade (cm)	Panicle length (cm)
Replications	**2**	5.91	171.50	0.005	0.53	10.35	0.54	5.98
Parents	**11**	82.09**	3958.35**	11.13**	20.61**	72.98**	2.01**	29.14*
(Female) Lines	**6**	31.75	1027.60	8.77	5.37	71.35	2.87	24.18
(Male) Testers	**3**	208.67**	8334.73	18.81*	18.32	100.54	0.95	36.57*
Lines *vs.* Testers	**1**	4.43	8413.79**	2.26*	118.87**	0.02	0.05	36.56
Parents *vs.* Hybrids	**1**	40.43**	11857.53**	12.46**	4.45	108.06**	2.60**	64.95*
Hybrids	**27**	70.46**	5561.24**	10.15**	37.82**	149.59**	2.24**	18.17
Error	**76**	2.15	201.82	0.43	5.08	15.08	0.22	11.95
Sources of variation	**d.f.**	**Grain yield plant^{-1} (g)**	**Dry fodder yield plant^{-1} (g)**	**Grain protein content (%)**	**Fodder protein content (%)**	**Brix content (%)**	**HCN content (ppm)**	
Replications	**2**	0.72	847.43	0.88	0.10	2.39	1.11	
Parents	**11**	169.34**	20482.87**	1.95**	1.82**	8.23**	269.57**	
(Female) Lines	**6**	190.05	11857.94	2.06	1.50	7.66	326.41	
(Male) Testers	**3**	20.34	24995.50	1.35	0.95	11.97	244.24	
Lines *vs.* Testers	**1**	88.45**	12727.93**	3.04**	6.41**	0.39	4.54	
Parents *vs.* Hybrids	**1**	57.70**	50945.98**	4.84**	0.40**	17.08**	106.92**	
Hybrids	**27**	151.07**	15385.91**	2.43**	2.93**	5.22**	428.32**	
Error	**76**	8.05	563.71	0.35	0.04	0.77	5.50	

* $P \leq 0.05$, ** $P \leq 0.01$.

heteros is over better parent and the standard check CSV 31 forgrain yield plant^{-1}. The positive and significant heterotic values were also reported by Chikuta *et al.* (2017), Khadi *et al*. (2018), Rathod *et al*. (2020) and Patel *et al*. (2020) for grain yield plant^{-1}. In the case of dry fodder yield plant^{-1} total of 10, 8 and 24 hybrids evinced significant and positive heterosis over the better parent, standard checks GJ 43 and CSV 31, respectively. Out of total significant hybrids, eight were common for heterobeltiosis and standard heterosis. The wide spectrum of heterobeltiosis and standard heterosis was recorded, *i.e.,* -45.70 to 69.52 per cent (heterobeltiosis), -44.35 to 40.55 per cent over checks GJ 43 and 19.44 to 103.44 per cent over CSV 31. Best three hybrids SR 2980 × SPV 2682,SR 3048 × CSV 31 and SR 2980 × CSV 31 registered highly significant and positive heterotic effects in terms of heterobeltiosis (*i.e.,* 46.13, 31.24 and 30.87 %), standard heterosis over check GJ 43 (*i.e.,* 28.28, 34.52 and 14.27 %) and CSV 31 (*i.e.,* 85.68, 94.71 and 65.40 %), respectively. The wide range of heterobeltiosis and standard heterosis for fodder yield was also reported earlier by Naik *et al*. (2018), Patel *et al*. (2018), Parmar *et al*. (2019) and Patel *et al*. (2020).

A comparative study of best heterotic hybrid revealed that SR 2980 × CSV 31, DSF 168 × CSV 31 and SR 3019 × SPV 2573 for grain yield plant^{-1} and SR 2980 × SPV 2682, SR 3048 × CSV 31 and SR 2980 × CSV 31 for dry fodder yield plant^{-1} revealed significant positive heterosis over both better parent and standard checks. These hybrids also showed significant and positive heterosis over better parent or combination of standard check for various component characters *viz*., total plant height, number of leaves plant^{-1}, stem girth, leaf length of blade, leaf width of blade, Brix content, grain protein content, fodder protein content and HCN content (Table 4).

The results revealed that the extent of heterosis varied from the cross to cross for all the traits. For any one trait, certain hybrids expressed considerable high heterosis, while it was low in other hybrids, suggesting that the selection of parents has an important bearing on the performance of any hybrid. The superiority of hybrids over better parents indicates the parental combinations' ability to throw high levels of trans gressive segregation (Fonseca and Patterson, 1968). Such hybrids might be exploited as a basic material for breeding purposes (Table 5).

Table 2 : Mean performance of parents and their hybrids for various characters in sorghum

Genotypes	Days to flowering	Total plant height (cm)	No. of leaves plant^{-1}	Stem girth (mm)	Leaf length of blade (cm)	Leaf width of blade (cm)	Panicle length (cm)	Grain yield plant^{-1} (g)	Dry fodder yield plant^{-1} (g)	Grain protein content (%)	Fodder protein content (%)	Brix content (%)	HCN content (ppm)
Parents: Females/Lines													
DSF 168	78.33	291.00	17.65	17.73	68.60	8.29	23.21	33.68	343.55	11.10	8.66	20.05	40.41
DSF 117	69.33	260.83	13.58	18.87	78.90	5.87	20.03	31.24	316.82	10.87	8.65	22.63	32.63
SR 2980	69.33	294.75	14.50	19.85	64.70	8.22	23.03	37.13	269.91	10.57	7.14	21.18	34.02
SR 3048	72.33	264.00	13.17	16.90	66.90	7.60	23.29	50.47	316.84	10.50	8.38	20.83	28.00
SR 3019	74.33	243.83	13.17	18.02	66.60	8.25	21.94	41.93	159.97	10.18	8.37	19.24	23.66
GJ 43	72.00	286.17	13.08	20.17	70.93	8.19	26.01	51.46	309.13	11.49	6.98	21.88	28.59
DS 156	70.00	270.75	12.75	20.36	73.38	6.54	28.76	45.35	332.17	8.91	7.73	17.94	54.98
Males/Testers													
CSV 31	71.33	277.17	11.70	14.14	62.03	6.94	26.28	34.61	213.57	10.63	7.50	18.69	43.85
CSV 17	62.33	173.50	11.32	12.53	75.73	7.39	19.89	30.15	73.38	10.00	7.44	19.89	26.30
SPV 2682	82.00	286.92	16.75	18.36	70.47	8.27	21.90	33.27	271.37	9.92	6.28	23.37	28.99
SPV 2573	76.33	221.83	14.00	14.56	72.00	7.33	18.19	36.30	261.51	9.00	7.07	21.09	42.40
Hybrids:													
DSF 168 × CSV 31	72.67	264.08	16.42	20.09	67.33	7.79	25.49	44.53	344.07	11.32	6.07	18.71	36.11
DSF 168 × CSV 17	68.67	268.50	13.08	18.67	68.36	8.63	25.21	33.20	264.78	8.71	7.70	20.46	38.11
DSF 168 × SPV 2682	77.67	250.67	10.83	14.87	65.88	7.03	22.77	34.43	260.94	10.63	7.17	19.41	29.57
DSF 168 × SPV 2573	75.33	257.10	13.67	17.34	65.51	7.00	22.78	32.37	370.81	9.88	6.98	20.74	40.99
DSF 117 × CSV 31	68.33	264.42	12.82	18.71	79.73	9.31	23.09	35.19	280.31	10.20	7.61	20.75	81.13
DSF 117 × CSV 17	68.00	255.83	11.72	16.50	53.27	6.33	23.09	34.68	259.90	10.49	8.14	20.19	55.40
DSF 117 × SPV 2682	67.67	248.42	15.50	19.53	64.40	7.87	30.93	38.77	375.21	9.18	6.31	20.51	34.44
DSF 117 × SPV 2573	81.33	236.17	12.83	10.73	66.13	8.17	16.85	29.40	172.04	9.51	8.12	17.96	45.34
SR 2980 × CSV 31	70.67	270.83	14.00	20.05	59.07	6.84	25.25	52.12	353.25	8.61	6.92	18.33	24.76
SR 2980 × CSV 17	67.33	260.17	13.17	14.68	71.40	9.14	23.48	32.33	230.53	9.78	7.13	19.24	29.12
SR 2980 × SPV 2682	78.33	273.42	16.17	20.30	68.57	8.67	24.16	32.60	396.56	10.03	7.54	23.11	41.16
SR 2980 × SPV 2573	78.00	263.58	14.83	19.97	71.77	8.57	25.75	36.43	297.34	11.18	7.80	19.55	36.19
SR 3048 × CSV 31	72.00	367.17	15.58	21.61	79.71	8.55	25.94	39.62	415.83	10.48	7.23	21.41	44.38
SR 3048 × CSV 17	71.67	256.67	14.25	13.77	71.60	8.11	25.41	34.69	186.42	10.12	7.89	21.61	35.16
SR 3048 × SPV 2682	86.67	314.08	17.42	16.03	63.00	6.86	24.72	30.33	324.74	9.21	7.55	17.41	29.39
SR 3048 × SPV 2573	76.33	261.00	12.83	9.23	58.67	6.23	20.03	25.13	173.79	9.77	7.07	21.23	41.45
SR 3019 × CSV 31	74.00	262.00	13.00	23.39	80.17	8.43	24.77	45.63	276.13	10.81	8.69	18.83	39.62
SR 3019 × CSV 17	69.33	257.92	12.92	19.03	74.73	7.97	26.05	51.81	271.18	8.40	5.89	19.67	35.41

Contd.

Table 2 contd.

Genotypes	Days to flowering	Total plant height (cm)	No. of leaves plant^{-1}	Stem girth (mm)	Leaf length of blade (cm)	Leaf width of blade (cm)	Panicle length (cm)	Grain yield plant^{-1} (g)	Dry fodder yield plant^{-1} (g)	Grain protein content (%)	Fodder protein content (%)	Brix content (%)	HCN content (ppm)
SR 3019 × SPV 2682	78.67	229.25	12.67	12.38	64.00	7.26	25.17	39.63	273.49	8.71	6.63	20.68	36.44
SR 3019 × SPV 2573	75.00	265.58	14.42	13.05	72.03	9.35	25.13	53.81	303.03	11.77	9.23	19.68	38.10
GJ 43× CSV 31	72.33	367.42	17.75	18.90	65.27	8.23	24.37	38.81	256.13	9.91	6.28	20.17	26.71
GJ 43× CSV 17	66.00	258.25	16.25	16.83	66.50	8.23	24.36	36.64	303.57	9.30	6.02	19.38	29.19
GJ 43× SPV 2682	77.67	366.67	16.67	20.54	63.17	6.80	23.51	40.88	328.81	10.80	9.54	20.00	30.24
GJ 43× SPV 2573	74.67	301.75	16.17	19.87	67.50	8.06	25.04	39.01	378.90	10.37	8.81	19.09	27.91
DS 156× CSV 31	77.67	270.17	15.08	20.29	58.33	7.91	28.03	29.89	427.25	9.27	8.28	18.11	40.28
DS 156× CSV 17	70.00	323.75	14.17	20.96	82.70	8.11	27.35	32.26	327.69	9.50	8.72	19.39	35.41
DS 156× SPV 2682	76.67	365.00	17.67	21.54	69.17	7.99	24.80	34.67	434.48	8.86	8.48	20.55	43.74
DS 156× SPV 2573	74.33	353.92	14.50	20.67	62.87	6.81	25.57	30.71	312.15	8.59	6.88	17.33	10.74
Parental mean	**72.51**	**260.98**	**13.79**	**17.41**	**70.02**	**7.54**	**22.96**	**38.69**	**260.75**	**10.29**	**7.65**	**20.62**	**34.89**
Hybrid mean	**73.82**	**283.35**	**14.51**	**17.84**	**67.89**	**7.87**	**24.61**	**37.13**	**307.12**	**9.84**	**7.52**	**19.77**	**37.02**
General mean (i)	**73.45**	**277.04**	**14.31**	**17.72**	**68.49**	**7.77**	**24.14**	**37.57**	**294.04**	**9.96**	**7.56**	**20.01**	**36.42**
Range (overall)	**62.33 to 86.67**	**173.50 to 367.42**	**10.83 to 17.75**	**9.23 to 23.39**	**53.27 to 82.70**	**5.87 to 9.35**	**16.85 to 30.93**	**25.13 to 53.81**	**73.38 to 434.48**	**8.40 to 11.77**	**5.89 to 9.54**	**17.33 to 23.37**	**10.74 to 81.13**
SEm (±)	**0.85**	**8.20**	**0.38**	**1.30**	**2.24**	**0.27**	**2.00**	**1.64**	**13.71**	**0.34**	**0.12**	**0.51**	**1.35**
LSD (0.05)	**2.39**	**23.10**	**1.07**	**3.67**	**6.32**	**0.76**	**5.62**	**4.61**	**38.61**	**0.97**	**0.32**	**1.43**	**3.81**
CV %	**2.00**	**5.13**	**4.60**	**12.72**	**5.67**	**6.00**	**14.32**	**7.55**	**8.07**	**5.98**	**2.64**	**4.38**	**6.44**

Table 3: Number of (F_1) hybrids depicted significant heterotic effect in sorghum

Characters	Over better parent				Over standard check (GJ 43)				Over standard check (CSV 31)			
	+ve	-ve	Total	Range	+ve	-ve	Total	Range	+ve	-ve	Total	Range
Days to flowering	19	0	19	-2.40 to 19.82	13	7	20	-8.33 to 20.37	15	6	21	-7.48 to 21.50
Total plant height(cm)	6	10	16	-20.10 to 32.47	7	12	19	-19.89 to 28.39	8	4	12	-17.29 to 32.56
No. of leaves plant^{-1}	7	10	17	-38.62 to 35.67	16	2	18	-17.20 to 35.67	25	0	25	-7.41 to 51.71
Stem girth (mm)	17	4	21	-36.63 to 67.35	0	9	9	-54.26 to 15.96	17	1	18	-34.75 to 65.42
Leaf length of blade (cm)	3	12	15	-32.49 to 20.37	4	9	13	-24.91 to 16.59	12	1	13	-14.13 to 34.10
Leaf width of blade (cm)	6	8	14	-18.07 to 34.10	3	9	12	-23.94 to 14.17	19	0	19	-10.28 to 34.68
Panicle length (cm)	1	0	1	-15.85 to 41.22	0	2	2	-35.20 to 18.92	0	2	2	-35.87 to 17.68
Grain yield plant^{-1}(g)	5	14	19	-50.20 to 40.38	0	25	25	-51.16 to 4.56	8	3	11	-27.37 to 55.48
Dry fodder yield plant^{-1}(g)	10	8	18	-45.70 to 69.52	8	8	16	-44.35 to 40.55	24	2	26	-19.44 to 103.44
Grain protein content (%)	1	13	14	-21.56 to 5.74	0	22	22	-26.89 to 2.41	1	12	13	-20.95 to 10.73
Fodder protein content (%)	9	18	27	-29.95 to 36.79	15	6	21	-15.53 to 36.79	10	12	22	-21.42 to 27.24
Brix content (%)	0	16	16	-25.50 to 3.78	0	18	18	-20.81 to 5.64	12	0	12	-7.31 to 23.64
HCN content (ppm)	17	4	21	-74.66 to 148.62	19	2	21	-62.42 to 85.04	2	19	21	-75.50 to 183.82

Table 4: Comparative study of heterotic crosses in sorghum for grain yield plant^{-1} and dry fodder yield plant^{-1} with other components

Sr. No.	Heterotic crosses	Heterosis over Better parent		Standard checks GJ 43	Standard checks CSV 31	Desired and significant heterobeltiosis and/or standard heterosis registered in component traits
GRAIN YIELD PLANT^{-1} WITH OTHER COMPONENT TRAITS						
1	SR 2980 × CSV 31	40.38**	(52.12)	-	50.61**	NLP, DFY,HCN
2	DSF 168 × CSV 31	28.66**	(44.53)	-	28.66**	NLP, LWB, DFY, HCN
3	SR 3019 × SPV 2573	28.34**	(53.81)	-	55.48**	NLP, SG, LLB, LWB, DFY, GPC,FPC, HCN
DRY FODDER YIELD PLANT^{-1} WITH OTHER COMPONENT TRAITS						
1	SR 2980 × SPV 2682	46.13**	(396.56)	28.28**	85.68**	NLP, LLB, LWB, BR, FPC
2	SR 3048 × CSV 31	31.24**	(256.13)	34.52**	94.71**	TPH, NLP, LLB, LWB, BR, GYP
3	SR 2980 × CSV 31	30.87**	(353.25)	14.27*	4.40**	NLP, GYP, HCN

Figure in the parentheses indicated mean performance.*$P \leq 0.05$, **$P \leq 0.01$.

Where,

TPH	:	Total plant height (cm)	NLP	:	Number of leaves plant^{-1}
LLB	:	Leaf length of blade (cm)	LWB	:	Leaf width of blade (cm)
SG	:	Stem girth (mm)	BR	:	Brix content (%)
GYP	:	Grain yield plant^{-1} (g)	DFY	:	Dry fodder yield plant^{-1}(g)
GPC	:	Grain protein content (%)	FPC	:	Fodder protein content (%)
HCN	:	Hydrogen cyanide content (ppm)			

The analysis of variance revealed that significant differences among the parents for all traits. This indicated a sufficient variability in the parents (*i.e.*, lines and testers) for all the traits.The parental genotype GJ 43 was rewarded higher grain yield plant^{-1} (g) and grain protein content (%), also performed considerably good for panicle length (cm) and Brix content (%). The parent DSF 168 was found superior for dry fodder yield plant^{-1} (g) , number of leaves plant^{-1}, leaf width of blade (cm) and fodder protein content (%). It stood second for total plant height (cm) and grain protein content (%). The parent CSV 17 was the earliest and had minimum stem girth (mm). A comparative study of best heterotic hybrid indicated that the crosses SR 2980 × CSV 31, DSF 168 × CSV 31 and SR 3019 × SPV 2573 for grain yield plant^{-1}and SR 2980 × SPV 2682,SR 3048 × CSV 31 and SR 2980 × CSV 31 for dry fodder yield plant^{-1}revealed significant positive heterosis over both better parent and standard checks.

Table 5: The overall picture of heterosis level in promising heterotic crosses of sorghum for yield (*i.e.*, grain & dry fodder) and its attributes

Sr. No.	Hybrids	GYP	DFY	TPH	NLP	LLB	LWB	SG	BR	GPC	FPC	HCN
1	SR 2980 × CSV 31	High	High	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Moderate	High
2	DSF 168 × CSV 31	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low	Moderate
3	SR 3019 × SPV 2573	High	High	Moderate	Moderate	Moderate	High	Moderate	Moderate	High	High	Low
4	SR 2980 × SPV 2682	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low
5	SR 3048 × CSV 31	Low	High	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low	Low
6	SR 2980 × CSV 31	High	Moderate	Low	Moderate	Low	Low	Low	Low	Low	Low	High

Where,

TPH	:	Total plant height (cm)	**NLP**	:	Number of leaves plant^{-1}
LLB	:	Leaf length of blade (cm)	**LWB**	:	Leaf width of blade (cm)
SG	:	Stem girth (mm)	**BR**	:	Brix content (%)
GYP	:	Grain yield plant^{-1}(g)	**DFY**	:	Dry fodder yield plant^{-1}(g)
GPC	:	Grain protein content (%)	**FPC**	:	Fodder protein content (%)
HCN	:	Hydrogen cyanide content (ppm)			

REFERENCES

Chikuta, S., Odong, T., Kabi, F. and Rubaihayo, P. 2017. Combining ability and heterosis of selected grain and forage dual purpose sorghum genotypes. *J. Agril Sci.,***9**(2): 1916-9752.

Fonseca, S. and Patterson, F.L. 1968. Hybrid vigour in a seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). *Crop Sci.*, **8**: 85-88.DOI: 10.2135/cropsci1968.0011183x000800010025x

Khadi Prateeksha, S., Biradar, B.D. and Pattanashetti, S.K. 2018. Heterosis studies for yield and yield components in *rabi* sorghum [*Sorghum bicolor* (L.) Moench]. *J. farm Sci.,***31**(3): 342-343.

Meredith, W.R. and Bridge, R.R. 1972. Heterosis and gene action in cotton, *Gossypium hirsutum* L. *Crop Sci.*, **12**: 304-310.DOI: 10.2135/cropsci1972.0011183X001200030015x

Mutazing, A. 1945. Hybrid vigour in crosses between purelines of Galeopsis and tetrant. *Hereditas*, **31**: 391-398.

Naik Ramesh, R., Davda, B.K., Patel, A.R., Patak, V.D., Nagaraju, Y. and Bhamini, V.P. 2018. Heterosis for yield and its component characters in fodder sorghum [*Sorghum bicolor* (L.) Moench]. *J. Pharm., Phytochem.*, **7**(1): 2839-2844.

Pal, B.P. and Singh, H. 1946. Studies in hybrid vigour in brinjal and bitter gourd. *Indian J.Gene.*, **6**: 19-33.

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical methods for agricultural workers*. 4th edition. ICAR, New Delhi, pp. 97-156.

Parmar, N.R., Patel, M.P. Patel, P.R. and Patel, N.B. 2019. Study of Heterosis for Yield and Yield Attributes Characters in Forage Sorghum [*Sorghum Bicolor* (L.) Moench]. *Forage Res.*, **44**(4): 247-250.

Patel Priyanka, S., Patel, N.B., Gami R.A., Kugashiya, K.G and Patel, P.R. 2020. Elucidation of *per se* performance and heterosis for forage yield and its related traits in sorghum [*Sorghum bicolor* (L.) Moench]. *Forage Res.*, **46**(2): 141-147.

Patel, Y.D., Patel, R.N., Gami, R.A., Patel, P.R. and Parmar, N.R. 2018. Study of *perse* performance and heterosis for yield and its attributing traits in forage sorghum [*sorghum bicolor* (L.) Moench]. *Forage Res.*, **44**(2): 81-85.

Rathod, D.P., Gami, R.A., Chauhan, R.M., Kugashiya, K.G. And Patel, R.N. 2020. Study of *per se* performance and heterosis for forage yield and its attributing in sorghum [*Sorghum bicolor* (L.) Moench]. *Forage Res.*, **45** (4): 258-263.

Snedecor, G.W. and W.G. Cochran. 1967. *Statistical methods*. 6th edition. Ames, The Iowa State University Press, Ames, Iowa.