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HETEROSIS AND COMBINING ABILITY FOR GREEN FODDER YIELD AND ITS CONTRIBUTING TRAITS IN FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

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SUMMARY

Study of combining ability and heterosis was conducted on 45 F_1 hybrids along with fifteen fodder sorghum genotypes (three male sterile lines and fifteen restorer lines) to know the pattern of inheritance of some morphological traits for selecting superior genotypes. The experiment was carried out according to line x tester mating design, during summer 2011. Analysis of variance revealed significant differences among genotypes, parents, hybrids and line x tester interactions for all the traits under study. Variances of SCA were higher than the GCA variances for all traits which indicated predominance of non-additive gene action in the inheritance of the traits. The significant positive standard heterosis over GFSH-1 for green fodder yield per plant was exhibited by SURAT-1 x C-10-2 (42.53 %). This hybrid also exhibited high heterosis and *per se* performance for yield attributing traits *viz.*, days to 50 per cent flowering, plant height at 50 % flowering and dry matter yield per plant. It was followed by SURAT-1 x GUNDRI (24.34 %) and SURAT-4 x AFS-30 (22.50 %). Within CMS parents, SURAT-2 and SURAT-1 and among male parents, C-10-2, GUNDARI, AFS-30 and S-1049 were observed to be good general combiners for most of the characters studied. The cross combinations SURAT-1 x C-10-2, surat-4 x UP CHARI and surat-2 x phule amruta were found to be the best specific crosses for green fodder yield per plant. The hybrid SURAT-1 x C-10-2 and surat-4 x UP CHARI were also found to be the best specific crosses for days to 50% flowering and number of tillers per plant, therefore, these can be further exploited for selection of transgressive segregants.

Key words : Forage sorghum, heterosis, combining ability, green fodder yield, yield components

Sorghum [*Sorghum bicolor* (L.) Moench] is the fifth most important crop in the world. Major sorghum producing countries are USA, India, Nigeria, China, Mexico, Sudan and Argentina Sorghum is the most important fodder crop in the northern and central parts of India. Sorghum ranks first among the cereal fodder crops. It is because of its growing ability in poor soil, faster growth habit, higher yield, palatability and nutritious quality. It gives almost uniform green fodder yield throughout the year. For developing high yielding varieties/hybrids through hybridization, the choice of the right type of parents is of paramount importance, hence the importance of testing parents for their combining ability. Further, for the system of breeding to be employed, the knowledge of gene action is of immense value which varies depending on the genetic variation as well as genetic divergence in the material. The information on these aspects is limited in forage sorghum. Accordingly, the present investigation aims to estimate heterosis, combining ability and the nature of gene action for fodder yield and its attributing traits in forage sorghum.

MATERIALS AND METHODS

The hybrids were developed by crossing 3 male sterile lines (SURAT-1, SURAT-2 and SURAT-4) and 15 testers (S 1049, GFS-5, SSG-59-3, COFS-29, MP CHARI, GUNDRI, UP CHARI, C-10-2, SRF-286, PHULE AMRUTA, AFS-28, AFS-30, AFS-14, AFS-15 and AFS-18) in line x tester mating design during summer 2011. The experimental material for the present investigation consisted of 18 parents (3 lines + 15 testers), 45 hybrids with one check GFSH-1. The experiment

TABLE 1

Analysis of variance (mean squares) for parents and hybrids for various traits studied

Source	D. F.	Days to 50% flowering	Plant height (cm) at flowering	No. of tillers/plant	No. of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Stem girth (cm)	Green fodder yield/plant (g)	Dry matter content (DM %)	Dry matter yield/plant (g)
Replications	2	153.31**	92.25	0.063	2.76*	2.00	0.48*	0.001	0.017*	88.50**	28.26**	89.76**
Genotypes (G)	63	126.34**	584.37**	0.353**	2.58**	44.64**	1.18**	0.01**	0.035**	4003.83**	18.43**	218.08**
Parents (P)	17	136.28**	533.71**	0.368**	2.78**	54.03**	1.36**	0.015**	0.049**	3160.15**	12.47**	215.27**
Females (F)	2	55.44**	183.70**	0.054	0.53	15.32	0.22	0.0046	0.013*	1588.78**	1.21	111.65**
Males (M)	14	136.97**	620.80**	0.434**	2.95**	58.29**	1.52**	0.0074**	0.055**	2827.71**	14.84**	202.25**
F *vs* M	1	288.29**	14.59	0.093	5.02*	71.86**	1.35**	0.14**	0.047**	10957.05**	1.70	604.79**
Hybrids (H)	44	124.58**	574.36**	0.349**	2.53**	37.51**	1.09**	0.0081**	0.028**	4382.90**	21.34**	220.89**
Parents *vs* Hybrids	1	109.55**	2424.75**	0.118	2.31	240.34**	3.08**	0.053**	0.11**	3676.56**	0.00	135.56**
Check *vs* Hybrids	1	40.26**	111.31	0.54*	0.95	0.32	0.18	0.0042	1.43**	1579.62**	10.48*	197.02**
Error	126	4.45	34.38	0.081	0.739	7.42	0.116	0.0016	0.003	39.57	2.36	5.79

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

TABLE 2

Analysis of variance (mean squares) and variance components for combining ability for various traits studied

Source	Days to 50% flowering	Plant height (cm) at flowering	No. of tillers/plant	No. of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Stem girth (cm)	Green fodder yield/plant (g)	Dry matter content (DM %)	Dry matter yield/plant (g)
ó^{2}gca	11.16	37.32**	0.023	-0.11	-0.014	0.12	-0.0003**	-0.0013	177.63	1.07	17.97
ó^{2}sca	27.79**	113.64**	0.06**	0.72**	8.94**	0.20**	0.002**	0.01**	1271.40**	5.17**	52.76**
Error	4.67	32.65	0.072	0.75	7.82	0.10	0.002	0.0035	41.43	2.68	6.47
ó^{2}gca/ ó^{2}sca	0.40	0.033	0.38	0.15	0.002	0.60	0.15	0.13	0.14	0.21	0.34

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

was conducted at the research farm of Main Forage Research Station, Anand Agricultural University, Anand (Gujarat). Each experimental plot consisted of two rows of 4 m length each. The inter-row and intra-row spacing were 30 and 10 cm, respectively. The experiment was evaluated in a randomized block design with three replications. The recommended agronomic practices were followed for raising a normal crop.

For recording observations, 5 competitive plants were randomly selected from each treatment in each replication and the average value per plant was computed for various yield and its attributing traits *viz.*, days to 50 per cent flowering, plant height at 50 % flowering, number of tillers per plant, number of leaves per plant, leaf length, leaf width, leaf: stem ratio, stem girth, green fodder yield per plant, dry matter content and dry matter yield per plant.

Magnitude of relative heterosis, heterobeltiosis and standard heterosis was computed as per procedure suggested by Turner (1953), Fonesca and Patterson (1968) and Meredith and Bridge (1972), respectively. Analysis of variance and estimation of combining ability effects were made as per Kempthorne (1957).

RESULTS AND DISCUSSION

Analysis of variance revealed that the mean squares due to genotypes were significant for all the characters under study (Table 1). Mean squares due to genotypes were further partitioned into mean squares due to parents, hybrids, parents vs. hybrids and check vs. hybrids. The analysis of variance further revealed that parents and hybrids differed significantly for all the characters studied. This revealed the presence of great deal of diversity among the parents and hybrids with respect to majority of the characters under study. Mean squares due to parents *vs* hybrids were significant for all the characters except number of tillers per plant, number of leaves per plant and dry matter content. This suggested the existence of differences between parents and hybrids for majority of the characters.

Analysis of variance for combining ability (Table 2) revealed that the mean squares due lines in respect of their general combining ability was highly significant for plant height at 50 % flowering and leaf: stem ratio, where as variance among testers was significant for days to 50 per cent flowering, leaf width, and dry matter yield per plant. The variance due to line × tester interaction was significant for all the characters indicating differential response of lines with different testers. This indicates that sufficient variability exists for gca effects in the parents and that for the sca effects in the crosses.

The mean square ratio for general combining ability to specific combining ability (gca: sca) is an indication of preponderance of additive and non-additive genetic variance. The selection of female and male parents is of paramount importance so as to have desirable performance in their hybrids. General combining ability effects is one of the major criteria used to judge the performance of parents. The lower estimates of gca: sca ratio for all characters suggested the predominant role of non-additive gene action and greater magnitude of variance due to specific combining ability for inheritance of these traits

The range of heterosis, heterobeltiosis and economic heterosis along with number of significant crosses for heterosis, heterobeltiosis and economic heterosis of different characters are present in Table 3. The result revealed that sixteen, eleven and twelve hybrids expressed significant positive relative heterosis, heterobeltiosis and standard heterosis for green fodder yield, respectively.

Improvement in yield is one of the important objectives, so the superiority of hybrids over the best cultivated hybrid is essential for increasing its commercial value. In present study, well known hybrid GFSH-1 released by Anand Agricultural University in recent past has been used as standard check hybrid in order to obtain information on superiority of hybrids. Five most heterotic crosses (Standard heterosis) for green fodder yield per plant along with *per se* performance and their heterotic effects for component characters are represent in Table 4. The highest yielding hybrid SURAT-1 x C-10-2 had the highest standard heterosis (42.53 per cent) over the best check GFSH-1. The hybrid SURAT-1 x C-10-2 exhibited maximum green fodder yield per plant (232.33 g) and the highest Standard heterosis (42.53 per cent) for green fodder yield over the check GFSH-1. In addition to this the hybrid SURAT-1 x C-10-2 also exhibited significant standard heterosis in desirable direction for other yield attributing characters like days to 50 per cent flowering, plant height at 50 % flowering and dry matter yield per plant (Table 4). Several workers have also reported the presence of considerable degree of heterosis for green fodder yield per plant in sorghum Parmar (1997), Desai *et al.* (1999), Rajguru *et al.* (2005),

TABLE 3

The range of heterosis, heterobeltiosis and economic heterosis and number of crosses showing significant heterosis, heterobeltiosis and economic heterosis for 11 characters in Sorghum

Characters	Range of heterosis and most heterotic cross			Number of hybrids having significant heterotic effect					
	H_1	H_2	H_3	H_1		H_2		H_3	
				+ve	-ve	+ve	-ve	+ve	-ve
Days to 50 per cent flowering	-28.47 to 22.94 (SURAT-1 x AFS-15)	-27.27 to 45.64 (SURAT-4 x S-1049)	-26.21 to 7.28 (SURAT-1 x MP CHARI)	18	13	23	12	3	19
Plant height (cm) at flowering	-31.12 to 13.82 (SURAT-1 x C-10-2)	(SURAT-1 x C-10-2) -32.32 to 11.04	-26.12 to 13.56 (SURAT-1 x C-10-2)	5	26	4	31	5	23
Number of tillers per plant	-20.93 to 37.84 (SURAT-1 x C-10-2)	-29.17 to 34.21 (SURAT-1 x C-10-2)	-33.87 to 8.63 (SURAT-1 x C-10-2)	4	5	4	11	0	26
Number of leaves per plant	-13.93 to 10.46 (SURAT-2 x COFS-29)	-15.85 to 8.64 (SURAT-2 x COFS-29)	-14.81 to 8.64 (SURAT-2 x COFS-29)	2	8	1	13	1	10
Leaf length (cm)	-16.26 to 17.34 (SURAT-4 x SRF-286)	-20.26 to 16.71 (SURAT-4 x SRF-286)	-12.11 to 15.17 (SURAT-4 x SRF-286)	3	12	1	18	3	3
Leaf width (cm)	-33.15 to 35.40 (SURAT-1 x MP CHARI)	-37.63 to 27.10 (SURAT-1 x MP CHARI)	-23.06 to 34.08 (SURAT-1 x MP CHARI)	7	23	2	29	4	15
Leaf: stem ratio	-25.12 to 14.65 (SURAT-1 x SRF-286)	-29.07 to 1.82 (SURAT-1 x SRF-286)	-22.06 to 10.29 (SURAT-1 x SRF-286)	5	9	0	29	2	14
Stem girth (cm)	-30.37 to 44.53 (SURAT-4 x AFS-30)	-17.90 to 73.17 (SURAT-4 x AFS-30)	-25.00 to 26.19 (SURAT-4 x AFS-30)	15	10	21	2	7	11
Green fodder yield per plant (g)	-48.35 to 71.63 (SURAT-4 x AFS-30)	-53.60 to 43.30 (SURAT-4 x AFS-30)	-50.50 to 42.53 (SURAT-1 x C-10-2)	16	19	11	26	12	28
Dry matter content (DM %)	-19.34 to 26.18 (SURAT-1 x GUNDRI)	-25.92 to 21.67 (SURAT-4 x MP CHARI)	24.38 to 14.56 (SURAT-1 x GUNDRI)	7	10	5	15	5	23
Dry matter yield per plant (g)	-42.26 to 73.47 (SURAT-4 x S-1049)	-57.74 to 38.63 (SURAT-4 x S-1049)	-57.57 to 43.08 (SURAT-1 x GUNDRI)	17	21	11	26	4	30

H_1–Relative heterosis, H_2–Better parent and H_3–Standard heterosis.

TABLE 4

Five most heterotic crosses (Standard heterosis) for green fodder yield per plant along with *per se* performance and their heterotic effects for component characters in sorghum

S. No.	Crosses	Mean green fodder yield per plant (g)	Standard heterosis green fodder yield per plant (%)	Also desirable significant for other traits
1	SURAT-1 x C-10-2	232.33	42.53**	Days to 50 per cent flowering, plant height at 50% flowering, dry matter yield per plant
2	SURAT-1 x GUNDRI	202.67	24.34**	Plant height at 50% flowering, dry matter content, dry matter yield per plant, hydrocyanic acid content
3	SURAT-4 x AFS-30	199.67	22.50**	Plant height at 50% flowering
4	SURAT-2 x GUNDRI	195.67	20.04**	-
5	SURAT-2 x PHULE AMRUTA	190.00	16.56**	-

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

Bhatt (2009), Patel (2011) and Sajjanar *et al.* (2011).

The highest magnitude of heterosis in desirable direction was observed for days to 50 per cent flowering (SURAT-1 x AFS-15), plant height at flowering (SURAT-1 x C-10-2), number of tillers per plant (SURAT-1 x C-10-2), number of leaves per plant (SURAT-2 x COFS-29), leaf length (SURAT-4 x SRF-286), leaf width (SURAT-1 x MP CHARI), leaf: stem ratio (SURAT-1 x SRF-286), stem girth (SURAT-4 x GFS-5) green fodder yield per plant (SURAT-4 x AFS-30), dry matter content (SURAT-1 x GUNDRI) and dry matter yield per plant (SURAT-4 x S 1049).

High gca effects are related to additive gene effects or additive × additive effects (Griffing, 1956), which represent the fixable genetic component of variance. It may therefore, be suggested that these parents with high gca effects may be extensively used in hybridization programme for the improvement of these traits. The gca effect of 15 parents are presented in Table 5. The estimates of gca effects revealed that the female parent SURAT-2 was found good general combiner for green fodder yield per plant as well as for dry matter yield per plant. While female parent SURAT-1 was found good general combiner for days to 50 per cent flowering, plant height at flowering, number of leaves per plant, leaf width and leaf: stem ratio. Among the male parents, GUNDRI, C-10-2 was found to be good general combiner for green fodder yield per plant, plant height at flowering, number of tillers per plant, number of leaves per plant and dry matter yield per plant.

The specific combining ability (sca) is the deviation from the performance predicted on the basis of general combining ability (Allard, 1986). The sca effects are important criteria for the evaluation of hybrids. Among crosses, the hybrids SURAT-1 x C-10-2 exhibited significant sca effects in desirable direction for green fodder yield per plant, days to 50 per cent flowering and number of tillers per plant, SURAT-1 x AFS-14 for plant height at flowering, SURAT-2 x COFS-29 for number of leaves per plant, SURAT-2 x AFS-30 for dry matter content, SURAT-1 x GUNDRI for dry matter yield per plant, SURAT-2 x MP CHARI and SURAT-1 x AFS-28 for leaf : stem ratio, SURAT-4 x C-10-2 for stem girth, SURAT-1 x SSG-59-3 for leaf length and SURAT-1 x MP CHARI for leaf width.

The results are in conformity with those obtained earlier by Agarwal *et al.* (2005), Sumalini *et al.* (2005), Singh and Shrotria (2008), Mohammed *et al.* (2008), Mohammed (2009), Prakash *et al.* (2010), *Dara singh* and Sukhchain (2010) and Girma *et al.* (2011). The knowledge of combining ability of parents and hybrids can be of much help in further breeding programmes.

Genetic variance component indicated the involment of non-additive gene action for the inheritance of several characters *viz.*, green fodder yield per plant, number of tillers per plant, number of leaves per plant, leaf length, stem girth and dry matter content, then use of heterosis breeding method is to be followed for improvement of such characters. When both additive and non-additive gene actions were found important in the inheritance of the characters, *viz.*, days to 50 per cent flowering, plant height at flowering, leaf width, leaf : stem ratio and dry matter yield per plant, then recurrent selection method of breeding would be useful for improvement of these traits.

TABLE 5

General combining ability effects of parents for different characters

Source	Days to 50% flowering	Plant height (cm) at flowering	No. of tillers/plant	No. of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Stem girth (cm)	Green fodder yield/plant (g)	Dry matter content (DM %)	Dry matter yield/plant (g)
SURAT-1	-1.41**	8.58**	-0.12**	0.23**	-1.73**	0.15**	0.03**	-0.001	-7.33**	0.19	-1.33**
SURAT-2	0.01	-5.37**	-0.03	-0.10	0.31	-0.02	0.00	-0.003	7.18**	-0.48**	1.02**
SURAT-4	1.39**	-3.20**	0.15**	-0.13	1.42**	-0.14**	-0.03**	0.005	0.16	0.30	0.31
S 1049	4.81**	-0.37	0.41**	0.10	-2.11**	0.23**	-0.01	0.01	16.31**	-1.17**	1.93**
GFS-5	-0.63	1.96	0.03	0.50*	0.89	0.68**	0.01	-0.07**	-7.13**	1.43**	-0.19
SSG-59-3	-5.85**	1.51	-0.06	-0.16	-1.64*	0.11	-0.02*	-0.01	25.42**	1.32**	7.06**
COFS-29	0.70	5.94**	-0.04	0.37	-1.22	-0.23**	0.02*	-0.08**	-14.02**	2.49**	0.17
MP CHARI	-5.07**	0.53	-0.13	0.06	0.14	0.85**	-0.03**	0.00	-1.36	2.86**	2.67**
GUNDRI	2.48**	10.29**	0.36**	0.73**	-1.71*	0.24**	0.01	0.09**	36.20**	1.73**	10.80**
UP CHARI	-3.07**	-9.89**	-0.04	-0.45	-1.42	-0.20*	-0.01	0.03	-6.80**	-0.71	-2.21**
C-10-2	-1.74**	8.76**	0.30**	0.66**	0.45	-0.23**	-0.02*	0.06**	36.53**	0.10	8.27**
SRF-286	4.81**	9.76**	0.03	0.04	4.27**	-0.40**	0.00	-0.001	12.53**	-0.40	2.16**
PHULE AMRUTA	5.93**	-4.36**	-0.24**	-0.07	2.21**	-0.42**	0.03**	0.004	2.64	0.92*	1.47*
AFS-28	-9.30**	-8.57**	0.03	-0.26	-3.08**	-0.11	0.00	-0.01	-8.58**	-0.43	-2.78**
AFS-30	2.15**	14.47**	0.16*	0.24	0.74	0.71**	0.03**	0.03	21.98**	-0.23	3.82**
AFS-14	7.04**	-16.31**	-0.35**	-0.91**	0.44	-0.10	0.00	-0.07**	-34.58**	-3.12**	-10.80**
AFS-15	-3.52**	-8.00**	-0.33**	-0.36	0.67	-0.66**	-0.03**	-0.02	-38.24**	-2.85**	-11.40**
AFS-18	1.26*	-5.71**	-0.15*	-0.47*	1.36	-0.47**	0.02*	0.04*	-40.91**	-1.94**	-10.97**
S.Em. (g i)	0.22	0.59	0.03	0.09	0.29	0.03	0.01	0.01	0.66	0.17	0.26
S.Em. (g j)	0.59	1.56	0.07	0.24	0.76	0.09	0.01	0.02	1.75	0.45	0.69

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

TABLE 6
Specific combining ability effects of crosses for different characters

Source	Days to 50% flowering	Plant height (cm) at flowering	No. of tillers/plant	No. of leaves/plant	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Stem girth (cm)	Green fodder yield/plant (g)	Dry matter content (DM %)	Dry matter yield/plant (g)
SURAT-1 × S 1049	3.96**	-1.64	0.07	1.24**	1.78	0.30*	-0.01	-0.01	7.22**	-1.23*	-0.53
SURAT-1 × GFS-5	5.41**	-16.31**	-0.02	-0.83*	1.11	0.11	-0.01	0.11**	6.00*	-3.16**	-2.44*
SURAT-1 × SSG-59-3	-3.70**	2.93	-0.26**	0.70*	5.78**	-0.45**	-0.02	-0.14**	-26.56**	2.58**	-2.23*
SURAT-1 × COFS-29	-6.59**	-3.42	-0.08	-2.43**	0.09	-0.38**	-0.02	-0.02	-15.44**	-1.39*	-5.58**
SURAT-1 × MP CHARI	-7.81**	-13.54**	-0.06	-0.32	0.73	0.91**	-0.06**	-0.05**	-45.11**	2.15**	-8.63**
SURAT-1 × GUNDRI	5.63**	7.62**	0.18	0.15	-3.36**	0.02	0.01	0.07**	34.00**	3.40**	15.20**
SURAT-1 × UP CHARI	-0.15	-4.47*	-0.35**	-0.54	0.09	0.06	0.02	0.04*	-2.33	-0.95	-1.89
SURAT-1 × C-10-2	-9.48**	14.36**	0.52**	0.21	-1.85	0.32**	0.04*	0.19**	63.33**	-0.56	12.48**
SURAT-1 × SRF-286	4.63**	3.42	-0.22*	0.50	-3.27**	0.02	0.06**	0.09**	16.00**	-0.46	2.62**
SURAT-1 × PHULE AMRUTA	1.19	8.48**	0.25*	1.28**	-2.00	-0.32**	0.00	-0.06**	-33.11**	1.78**	-5.45**
SURAT-1 × AFS-28	3.07**	-5.84**	0.05	0.10	0.89	-0.80**	0.07**	-0.07**	-27.22**	1.00	-4.54**
SURAT-1 × AFS-30	6.63**	4.51*	0.25*	-0.03	1.73	0.31**	0.02	0.00	-9.11**	-2.50**	-5.01**
SURAT-1 × AFS-14	1.07	18.02**	0.03	0.65*	0.17	0.42**	0.01	-0.10**	14.44**	0.23	3.12**
SURAT-1 × AFS-15	-9.37**	-8.89**	-0.19	0.30	0.33	0.06	-0.08**	-0.02	-5.56*	0.86	0.05
SURAT-1 × AFS-18	5.52**	-5.24*	-0.17	-0.99**	-2.22*	-0.60**	-0.02	-0.01	23.44**	-1.75**	2.85**
SURAT-2 × S 1049	-2.46**	0.64	-0.15	-0.43	-3.67**	0.34**	-0.01	-0.05**	-34.96**	-0.36	-8.14**
SURAT-2 × GFS-5	-4.68**	7.64*	-0.17	0.43	-0.40	-0.48**	-0.04*	0.02	28.49**	-0.16	6.68**
SURAT-2 × SSG-59-3	0.87	1.62	0.05	-0.77*	-8.20**	0.52**	0.03	0.01	3.93	2.01**	4.75**
SURAT-2 × COFS-29	3.32**	5.39*	0.29**	1.70**	3.51**	0.16	0.01	0.01	7.71**	0.58	2.64**
SURAT-2 × MP CHARI	5.43**	17.54**	0.05	0.54	0.49	-0.45**	0.07**	0.13**	36.04**	-3.45**	3.45**
SURAT-2 × GUNDRI	-0.79	-9.43**	0.16	-0.46	2.60*	-0.34**	0.03	0.04*	12.49**	-4.06**	-5.29**
SURAT-2 × UP CHARI	5.76**	5.82**	-0.11	0.99**	2.45*	-0.14	0.04*	-0.14**	-45.18**	0.01	-9.70**
SURAT-2 × C-10-2	5.10**	-5.29*	-0.17	1.01**	-0.02	-0.64**	-0.09**	0.03	2.16	1.87**	3.38**
SURAT-2 × SRF-286	-3.13**	-11.23**	-0.17	-1.37**	-2.24*	-0.14	-0.06**	-0.03	-40.18**	-0.03	-8.79**
SURAT-2 × PHULE AMRUTA	-1.24	0.79	-0.17	-0.86**	-1.71	0.38**	0.01	0.03	40.38**	-0.42	8.48**
SURAT-2 × AFS-28	-3.01**	-2.49	0.43**	-0.40	0.98	0.47**	0.00	-0.03	18.93**	-1.80**	1.27
SURAT-2 × AFS-30	-3.46**	-12.94**	-0.31**	-0.10	0.82	0.05	0.01	-0.10**	-28.62**	5.10**	1.32
SURAT-2 × AFS-14	-1.35	-21.43**	-0.13	-0.25	-1.04	0.19	-0.02	0.00	-16.73**	0.06	-3.25**
SURAT-2 × AFS-15	3.54**	9.79**	0.18	-0.70*	1.22	-0.07	0.02	0.02	20.60**	-0.54	2.98**
SURAT-2 × AFS-18	-3.90**	13.57**	0.21*	0.68*	5.20**	0.14	0.00	0.06**	-5.07*	1.18	0.22
SURAT-4 × S 1049	-1.50	1.00	0.08	-0.80*	1.89	-0.64**	0.02	0.06**	27.73**	1.59*	8.67**
SURAT-4 × GFS-5	-0.73	8.67**	0.19	0.40	-0.71	0.37**	0.06**	-0.13**	-34.49**	3.33**	-4.24**
SURAT-4 × SSG-59-3	2.83**	-4.55*	0.21*	0.07	2.42*	-0.06	-0.01	0.13**	22.62**	-4.60**	-2.53**
SURAT-4 × COFS-29	3.27**	-1.97	-0.21*	0.73*	-3.60**	0.21	0.01	0.02	7.73**	0.80	2.95**
SURAT-4 × MP CHARI	2.39**	-4.00	0.01	-0.22	-1.22	-0.46**	-0.01	-0.08**	9.07**	1.30*	5.18**
SURAT-4 × GUNDRI	-4.84**	1.80	-0.35**	0.31	0.75	0.31**	-0.03	-0.11**	-46.49**	0.66	-9.91**
SURAT-4 × UP CHARI	-5.61**	-1.35	0.45**	-0.45	-2.53*	0.08	-0.06**	0.11**	47.51**	0.94	11.59**
SURAT-4 × C-10-2	4.39**	-9.06**	-0.35**	-1.22**	1.87	0.31**	0.05**	-0.21**	-65.49**	-1.31*	-15.86**
SURAT-4 × SRF-286	-1.50	7.80**	0.39**	0.87**	5.51**	0.11	0.00	-0.06**	24.18**	0.49	6.18**
SURAT-4 × PHULE AMRUTA	0.05	-9.27**	-0.08	-0.42	3.71**	-0.06	-0.01	0.03	-7.27**	-1.36*	-3.03**
SURAT-4 × AFS-28	-0.06	8.34**	-0.48**	0.30	-1.87	0.33**	-0.06**	0.10**	8.29**	0.79	3.27**
SURAT-4 × AFS-30	-3.17**	8.43**	0.05	0.13	-2.56*	-0.36**	-0.03	0.10**	37.73**	-2.61**	3.69**
SURAT-4 × AFS-14	0.27	3.40	0.10	-0.39	0.88	-0.62**	0.00	0.10**	2.29	-0.29	0.13
SURAT-4 × AFS-15	5.83**	-0.91	0.01	0.40	-1.56	0.01	0.06**	0.00	-15.04**	-0.32	-3.02**
SURAT-4 × AFS-18	-1.61	-8.33**	-0.03	0.31	-2.98**	0.46**	0.01	-0.05**	-18.38**	0.57	-3.06**
S.Em. (s ij)	0.83	2.20	0.10	0.33	1.08	0.12	0.02	0.02	2.48	0.63	0.98

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

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REFEERENCES

Agarwal, M., Singh, R. and Shrotria, P. K. 2005. *Forage Res.,* **31** : 8-11.

Allard, R. W. (1986). *Principles of Plant Breeding.*

Bhatt, A. 2009. *Agricultural Science Digest,* **28** : 245-249.

Dara singh and Sukhchain 2010. *Range Mgmt. & Agroforestry,* **31** : 125-127.

Desai, S. A., Singh, R. and Shorotria, P. K. 1999. *J. Maharastra agric. Univ.,* **24** : 138-142.

Fonseca, S. and Patterson, F. 1968. *Crop Sci.,* **8** : 85-88.

Girma, M., Ayana A. and Ketema B. 2011. *E.A.J.S.,* **4** : 34-40.

Griffing, B. 1956. *Aust. J. Bio. Sci.,* **9** : 63-93.

Maarouf I. Mohammed 2009. *Crop Sci.,* **1** : 311-319.

Meredith, W. R. and Bridge, R. R. 1972. *Crop Sci.,* **12** : 304-310.

Mohammed Maarouf I. and Talib Nuha H. 2008. *Australian Journal of Basic and Applied Sci.,* **2** : 99-104.

Parmar, H. P. (1997). L x T analysis in forage sorghum. Unpublished M. Sc. (Agri.) Thesis, Gujarat Agricultural University, Anand Campus, Anand.

Patel, V. K. 2011. Heterosis and combining ability studies in forage sorghum. Unpublished M. Sc. (Agri.) Thesis, Gujarat Agricultural University, Anand Campus, Anand.

Prakash, R., Ganesamurthy, K., Nirmalakumari, A. and Nagarajan, P. 2010. *Electronic Journal of Plant Breeding,* **1** : 124-128.

Rajguru, A. B., Kashid, N. V., Kamble, M. S., Rasal, P. N. and Gosavi, A. B. 2005. *J. Maharastra agric. Univ.,* **30** : 292-295.

Sajjanar, G. M., Biradar, B. D. and Biradar, S. S. 2011. *Karnataka J. agric. Sci.,* **24** (2): 227-229.

Singh R. K. and Shrotria P. K. 2008. *Forage Res.,* **34** : 79-82.

Sumalini, K., Desale, J. S. and Gulia, S. K. 2005. *Forage Res.,* **31** : 30-32.

Turner, J. H. 1953. *Agron. J.,* **45** : 487-490.