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GENETIC ANALYSIS IN FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

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SUMMARY

The experiment in sorghum [*Sorghum bicolor* (L.) Moench] was carried to study gene action and combining ability of 27 hybrids were generated by L×T fashion during early summer, 2018 at Sorghum Research Station, SDAU, Deesa. The 27 hybrids along with 12 parents and two standard checks (GJ 39 and CSH 30) were evaluated in randomized block design with three replications at Sorghum Research Station, SDAU, Deesa (Gujarat) during *kharif*, 2018. The ratio of σ2gca/σ2sca being more than unity was found for days to flowering, stem girth and leaf width which suggested greater role of additive genetic variance in the inheritance of these traits. Based on the *gca* effect, the parents DS 173, DS 156 and DS 155 were good general combiners for green fodder yield per plant and the parent DS 137, DS 149 and DS 155 were found good general combiners for grain yield per plant.. The hybrids 7A × DS 161, 296A × DS 137 and 7A × DS 149 for grain yield per plant and 296A × DS 161, 7A × DS 156 and 2219A × DS 155 for green fodder yield per plant were the most promising hybrids on the basis of significant positive *sca* effect. These crosses also exhibited positive significant *sca* effect for other contributing traits *viz.*, plant height, leaf length, leaf: stem ratio, dry fodder yield per plant and protein content. Thus, these hybrids showing significant *sca* effect can be directly used for hybrid breeding programme.

Key words : L × T analysis, gene action, combining ability, green fodder yield, grain yield

Sorghum [*Sorghum bicolor* (L.), Moench] is the fifth most important crop after wheat, rice, maize and barley in the world and popularly known as *jowar* is an annual crop, which belongs to the family *Poaceae*, having 2n=20 chromosomes. The area under this crop in the country is about 51.4 lakh hectares with an annual production of 45.7 lakh tonnes and productivity of 889 kg/ha. In Gujarat, area, production and productivity of sorghum is 1.0 lakh hectares, 1.5 lakh tonnes and 1408 kg/ha, respectively (Anonymous, 2017). Sorghum [*Sorghum bicolor* (L.) Moench] plays an important role as a major grain cum fodder crop is growing in many regions of the world due to its high productivity and ability to utilize efficiently water even under drought conditions. It is highly palatable and digestible than maize and pearl millet as for as the nutritional quality is concerned. It produces a tonnage of dry matter having digestible nutrients (50 %), crude protein (8%), fat (2.5%) and nitrogen free extracts (45 %) (Azam *et al.*, 2010).

The evaluation of breeding material for general combining ability and specific combing ability through Line × Tester mating design for yield contributing characters are prerequisites for any breeding programme aimed in the development of hybrids. Combining ability studies provide useful information regarding the selection of suitable parents for effective hybridization programmes and indicate the nature and magnitude of various types of gene action involved in the expression of quantitative characters (Bernardo, 2014).The Line × Tester mating design for combining ability suggested by Kempthorne (1957) is the appropriate method to identify superior parents and hybrids based on gca and sca, respectively. It is also helpful for estimating the nature and magnitude of gene action controlling the quantitative traits. The knowledge about nature of gene action governing the expression of various traits could help in predicting the effectiveness of selection. Information on combining ability and heterosis is a valuable tool in determining superior parents and hybrid combinations in hybrid breeding programmes.

MATERIALS AND METHODS

The experimental materials comprised of

three male sterile lines and nine genotypes as male parents along with two checks GJ 39 and CSH 30. The 27 hybrids were generated by L × T fashion during early summer, 2018 at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa using three females (2219A, 296A and 7A) as a line and nine males (DS 105, DS 173, DS 155, DS 137, DS 167, DS 176, DS 149, DS 156 and DS 161) as a tester. The resultant 27 hybrids along with 12 parents and two standard checks (GJ 39 and CSH 30) were evaluated in randomized block design with three replications at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa during *kharif,* 2018. Data were recorded on five competitive plants selected randomly for Plant height (cm), Number of leaf per plant (No), Stem girth (mm), Leaf length (cm), Leaf width (cm), Leaf : stem ratio, Grain yield per plant (g), Green fodder yield per plant (g), Dry fodder yield per plant (g) and Protein content (%), where as data for days to flowering was recorded based on plot basis. The replication-wise mean values for all the characters were subjected to statistical analysis. The analysis of variance was carried out as per the procedure suggested by Sukhatme and Amble (1989) as well as combining ability variance analysis by Kempthorne (1957). The data were analyzed statistically using the software WINDOSTAT version 8.1.

RESULTS AND DISCUSSION

The analysis of variance for combining ability and estimates of variance components showed in Table 1. It is estimated by partitioning the total genetic variance into general combining ability representing additive genetic variance and specific combining ability as a measure of non-additive genetic variance was carried out for twelve characters. The mean sum of squares due to lines were significant for days to flowering, number of leaf per plant, stem girth, leaf length and protein content. The mean sum of squares due to line × tester interaction were significant for all traits except for leaf length, revealed the significant contribution of hybrids for specific combining ability variance components. The sum of mean squares due to testers was larger in magnitude for plant height and green fodder yield per plant than the lines indicated greater contribution of testers to these traits while in the rest of the traits showed more contribution of female lines than male parents.

The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ being more than unity was found for days to flowering, stem girth and leaf width which suggested greater role of additive genetic variance in the inheritance of these traits (Table 1). These traits can be improved further as a source of favourable genes for earliness and yield contributing traits through selection of desired transgressive segregants from segregating generations. The magnitude of specific combining ability variance was higher than general combining ability variance for majority of the traits *viz.*, plant height, number of leaf per plant, leaf length, leaf : stem ratio, grain yield per plant, green fodder yield per plant, dry fodder yield per plant and protein content, which indicated importance of non additive gene effects in the inheritance of these traits, which suggesting exploitation of these traits for improvement of yield through heterosis breeding.

Nature and magnitude of combining ability effects helps in identifying the best parents for crossing and their utilization in the plant breeding programme. The result based on *gca* effect revealed that none of the parents was found good combiner for all the traits (Table 2). Based on the estimates of general combining ability effects, the parents were classified as good, average and poor combiners for twelve traits (Table 3). Among females, 296A was good general combiner for the traits like plant height, leaf length, leaf width, grain yield per plant, green fodder yield per plant and dry fodder yield per plant; 2219A was good general combiner for days to flowering, stem girth and protein content and 7A was good general combiner for leaf: stem ratio. The above results were in accordance with the findings of Udatha (2008), Padmashree *et al*. (2014) and Jain and Patel (2016) for grain yield per plant; Jain and Patel (2016) and Vekariya *et al.* (2017) for green fodder yield per plant; Singh and Sukhchain (2010), Jain and Patel (2014) and Patel *et al.* (2018). The *gca* of males indicated that DS 173, DS 155 and DS 137 were good general combiner for grain yield per plant, green fodder yield per plant and dry fodder yield per plant. There was also average general combiner for days to flowering, number of leaf per plant, stem girth and leaf length. DS 176 and DS 149 were good general combiner for leaf length and grain yield per plant, whereas average general combiner for number of leaf per plant, stem girth, leaf width and leaf: stem ratio. DS 105 was good general combiner for stem girth and leaf: stem ratio. DS 167 was good general combiner for protein and DS 156 was good general combiner for green fodder yield per plant. DS 161 was good general combiner for leaf: stem ratio,

TABLE 1
Analysis of variance for combining ability for different traits in sorghum

Sources of variation	d. f.	Days to flowering	Plant height (cm)	No. of leaf/ plant	Stem girth (mm)	Leaf length (cm)	Leaf width (cm)
Replications	2	182.99*	18.30**	2.07**	20.91**	3.97	0.00
Crosses	26	1541.81**	4.76**	1.05**	10.63**	4.71**	0.04**
Females (Lines)	2	5705.74*	1.64	4.42*	44.84*	29.47**	0.07
Males (Testers)	8	956.13	2.56	0.74	7.47	2.38	0.03
Females × Males	16	1314.15**	6.25**	0.78*	7.93*	2.79	0.04**
Error	52	201.34	1.81	0.37	3.77	1.58	0.00
Components of variance							
σ^2 Females		31.43**	203.06*	-0.03	1.46*	11.46	1.02**
σ^2 Males		2.47	81.45	0.02	0.24*	19.76	0.05
σ^2 gca		24.19**	172.66*	-0.01	1.16*	13.53	0.78**
σ^2 sca		5.01*	363.68**	1.30**	0.87	40.02**	0.29
σ^2 gca/σ^2sca		4.83	0.47	-0.01	1.33	0.34	2.69

Sources of variation	d. f.	Leaf : stem ratio	Grain yield/ plant (g)	Green fodder yield/plant (g)	Dry fodder yield/ plant (g)	Protein content (%)
Replications	2	0.00	2.35	97.66	426.93	0.02
Crosses	26	0.04**	1178.16**	15457.30**	3620.19**	4.65**
Females (Lines)	2	0.07	1176.66	8010.74	4882.32	13.63*
Males (Testers)	8	0.03	1100.11	16129.08	4773.53	4.59
Females × Males	16	0.04**	1217.37**	16052.23**	2885.75**	3.56**
Error	52	0.00	19.80	286.93	228.50	0.13
Components of variance						
σ^2 Females		0.03	42.92	285.41	173.03	0.59*
σ^2 Males		0.03	120.24	1758.26	507.02	0.49
σ^2 gca		0.03	62.25	653.62	256.53*	0.50*
σ^2 sca		0.01**	399.81**	5249.17**	891.79**	1.14**
σ^2 gca/σ^2sca		0.2	0.16	0.12	0.29	0.44

* and ** Significant at 5 and 1 per cent levels, respectively.

TABLE 2
Estimates of general combining ability (gca) effects of the parents for various traits in sorghum

Parents	Days to flowering	Plant height (cm)	No. of leaf/ plant	Stem girth (mm)	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Grain yield/ plant (g)	Green fodder yield/ plant (g)	Dry fodder yield/ plant (g)	Protein content (%)
Lines											
2219A	-5.73**	-7.44*	0.004	-1.29*	-0.77	-1.19**	-0.04**	-7.07**	-18.48**	-10.37**	0.64**
296A	5.57**	16.75**	0.244	-0.01	3.88 **	0.78**	-0.02**	6.00**	15.60**	15.20**	0.13
7A	0.16	-9.31**	-0.25	1.29**	-3.11 **	0.41	0.06**	1.07	2.88	-4.83	-0.77**
S. Em±	0.70	2.87	0.30	0.44	1.10	0.27	0.01	0.82	3.36	2.79	0.07
Testers											
DS 105	-2.25	-2.27	-0.04	-1.98*	-1.01	0.08	0.02*	-17.19**	-6.76	-11.25*	-0.39**
DS 173	-1.58	-7.55	0.83	0.90	0.88	-1.02*	-0.03**	6.17**	87.92**	50.20**	0.54**
DS 155	1.53	12.97*	-0.44	1.04	1.09	0.35	-0.03*	8.21**	19.17**	13.77**	0.183
DS 137	-0.25	-0.05	-0.50	-0.25	3.03	-0.47	-0.03*	9.73**	16.98**	10.53*	0.42**
DS 167	2.31	3.16	-0.04	0.52	-3.62	0.20	-0.04**	-13.98**	-30.96**	-5.45	0.64**
DS 176	3.31**	10.50*	0.85	0.12	4.02*	-0.10	-0.02	3.88**	-54.99**	-21.93**	-0.08
DS 149	-1.14	8.24	-0.62	-0.23	3.85*	0.82	0.02	8.50**	-26.87**	-18.92**	-1.55**
DS 156	-2.03	-4.80	-0.17	0.40	2.84	0.15	-0.04**	-12.29**	22.15**	3.44	-0.42**
DS 161	0.09	-20.21**	0.14	-0.53	-11.08**	-0.02	0.14**	6.96**	-26.65**	-20.40**	0.66**
S. Em±	1.22	4.98	0.51	0.77	1.91	0.46	0.01	1.41	5.82	4.83	0.13

* and ** Significant at 5 and 1 per cent levels, respectively.

TABLE 3
Classification of parent based on general combining ability (gca) effects of the parents for different traits in sorghum

Parents	Days to flowering	Plant height (cm)	No. of leaf/ plant	Stem girth (mm)	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Grain yield/ plant (g)	Green fodder yield/ plant (g)	Dry fodder yield/ plant (g)	Protein content (%)
Lines											
2219A	G	P	A	G	A	P	P	P	P	P	G
296A	P	G	A	A	G	G	P	G	G	G	A
7A	A	P	A	P	P	A	G	A	A	A	P
Testers											
DS 105	A	A	A	G	A	A	G	P	A	P	P
DS 173	A	A	A	A	A	P	P	G	G	G	G
DS 155	A	G	A	A	A	A	P	G	G	G	A
DS 137	A	A	A	A	A	A	P	G	G	G	G
DS 167	A	A	A	A	A	A	P	P	P	A	G
DS 176	P	G	A	A	G	A	A	G	P	P	A
DS 149	A	A	A	A	G	A	A	G	P	P	P
DS 156	A	A	A	A	A	A	P	P	G	A	P
DS 161	A	P	A	A	P	A	G	G	P	P	G

Where, G=Good general combiner; A = Average general combiner and P=Poor general combiner.

grain yield per plant and protein content.

The results based on specific combining ability effects of hybrids revealed that none of the hybrids was consistently superior for all the characters (Table 4). The range of *sca* effects are shown in Fig. 1. Considering the performance of the *sca* effect, 8 hybrids for grain yield per plant, 8 hybrids for green fodder yield per plant and 5 hybrids for dry fodder yield per plant exhibited significant and positive *sca* effects. Among 27 hybrids, one hybrids for days to flowering, five hybrids for plant height, two hybrids for number of leaf and leaf length, six hybrids for leaf : stem ratio and nine hybrids for protein content manifested significant and desirable *sca* effects. The most promising hybrids for grain yield per plant were 7A × DS 161, 7A × DS 149 and 296A × DS 137 on the basis of significant positive *sca* effect and for green fodder yield per plant were 296A × DS 161, 7A × DS 156 and 2219A × DS 155. These crosses also exhibited positive significant *sca* effect for other contributing traits *viz.*, plant height, leaf length, leaf:stem ratio, dry fodder yield per plant and protein content. Thus these hybrids showing significant *sca* effect can directly used for hybrid breeding programme.

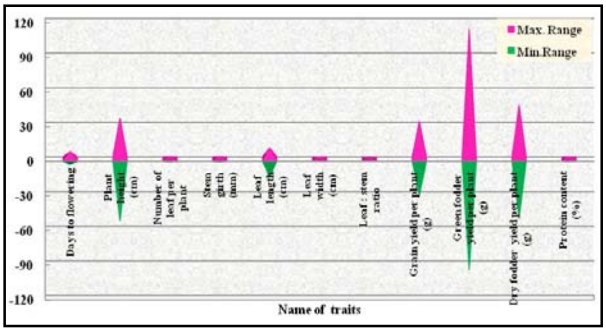

Fig. 1. Min. and Max. range of specific combining ability (sca) effects in sorghum.

CONCLUSION

The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ being more than unity was found for days to flowering, stem girth and leaf width which suggested greater role of additive genetic variance in the inheritance of these traits. Among females, 296A was good general combiner for the traits such as plant height, leaf length, leaf width, grain yield per plant, green fodder yield per plant and dry fodder yield per plant 2219A was good general combiner for days to flowering, stem girth and protein content and 7A was good general combiner for leaf: stem ratio. The *gca* of males indicated that DS 173, DS 155 and DS 137 were good general combiner for grain yield per plant, green fodder yield per plant and dry fodder yield per plant. These good general combiners for yield and its contributing traits can be utilized in intensive crossing programmes and subsequently selection of transgressive segregants for desired characters in segregating generations for development of superior lines. The most promising hybrids for grain yield per

TABLE 4
Estimates of specific combining ability (sca) effects of the hybrids for various traits in sorghum

S. No.	Crosses/Hybrids	Days to flowering	Plant height (cm)	No. of leaf/ plant	Stem girth (mm)	Leaf length (cm)	Leaf width (cm)
1.	2219A × DS105	3.17	-11.36	-0.63	0.39	2.73	0.08
2.	2219A × DS173	-0.16	-1.51	-0.83	-2.22	-2.30	-1.23
3.	2219A × DS155	-0.61	-9.10	-0.03	0.82	-0.30	-0.432
4.	2219A × DS137	-2.49	1.63	-2.10*	-1.04	-8.54*	-0.98
5.	2219A × DS167	-1.38	-8.921	-0.83	-0.53	5.50	0.42
6.	2219A × DS176	-4.72*	21.54*	1.82*	1.78	-2.05	0.64
7.	2219A × DS149	1.06	-0.63	-1.05	0.10	-2.68	-0.15
8.	2219A × DS156	3.28	-9.46	1.507	-0.37	-2.26	0.75
9.	2219A × DS161	1.840	17.80*	2.13*	1.07	9.90**	0.903
10.	296A × DS105	-2.46	-11.08	0.00	0.73	0.433	0.74
11.	296A × DS173	-1.12	-6.99	0.67	1.85	-3.33	0.57
12.	296A × DS155	1.77	-1.84	0.20	0.14	3.78	0.96
13.	296 A × DS137	2.54	-16.03	1.756	1.85	2.22	-0.36
14.	296A × DS167	3.32	3.57	-0.20	-1.38	-2.91	-0.44
15.	296A × DS176	-1.68	-7.47	-0.62	-0.94	-1.24	-0.96
16.	296A × DS149	0.10	0.82	-0.36	-2.20	-7.11*	-0.24
17.	296A × DS156	-3.01	3.18	-1.47	-0.55	2.35	-0.92
18.	296A × DS161	0.543	35.84**	0.022	0.52	5.81	0.65
19.	7A × DS105	-0.72	22.44*	0.63	-1.12	-3.16	-0.82
20.	7A × DS173	1.28	8.50	0.16	0.38	5.63	0.65
21.	7A × DS155	-1.16	10.94	-0.174	-0.95	-3.48	-0.524
22.	7A × DS137	-0.05	14.40	0.35	-0.81	6.32	1.34
23.	7A × DS167	-1.94	5.36	1.03	1.91	-2.58	0.011
24.	7A × DS176	6.40**	-14.07	-1.20	-0.84	3.29	0.32
25.	7A × DS149	-1.16	-0.19	1.40	2.11	9.80**	0.39
26.	7A × DS156	-0.27	6.28	-0.04	0.92	-0.10	0.18
27.	7A × DS161	-2.38	-53.64**	-2.15*	-1.59	-15.71**	-1.55
S. Em±		2.11	8.62	0.89	1.33	3.30	0.80
+ve significant		1	4	2	0	2	0
-ve significant		1	1	2	0	3	0
Range		-4.72 to 6.40	-53.64 to 35.84	-2.15 to 2.13	-2.22 to 2.11	-15.71 to 9.90	-1.55 to 1.34

Table 4 Contd…

S. No.	Crosses/Hybrids	Leaf : stem	Grain yield/	Green fodder	Dry fodder	Protein content
1.	2219A × DS105	-0.02	0.283	-39.64	-7.29	0.03
2.	2219A × DS173	0.03	-2.81	-21.47*	-16.04	-0.82**
3.	2219A × DS155	0.03	-17.76**	99.68**	38.73**	0.76**
4.	2219A × DS137	-0.005	3.27	-41.03**	-29.08*	-0.025
5.	2219A × DS167	0.09**	-0.379	13.57	-7.72	-0.09
6.	2219A × DS176	0.06**	7.85**	-43.70**	-14.28	-0.65**
7.	2219A × DS149	-0.05**	4.35	89.82**	47.11**	0.32
8.	2219A × DS156	0.03	7.19**	-11.72	-2.29	0.69**
9.	2219A × DS161	-0.17**	-1.98	-45.52**	-9.15	-0.23
10.	296A × DS105	0.04*	8.79**	73.28**	23.00**	0.79**
11.	296A × DS173	0.02	12.63**	22.63*	-0.05	1.02**
12.	296A × DS155	0.06**	14.61**	-45.42**	-1.67	0.231
13.	296 A × DS137	-0.01	27.67**	30.84**	14.15	-1.92**
14.	296A × DS167	0.03	4.69	-20.41*	11.02	1.17**
15.	296A × DS176	-0.03	-3.48	12.20	-0.95	0.77**
16.	296A × DS149	0.02	-29.55**	-96.24**	-51.64**	-0.83**
17.	296A × DS156	0.037*	-4.31	-89.71**	-31.17**	-0.48*
18.	296A × DS161	-0.17**	-31.04**	112.85**	37.31**	-0.74**
19.	7A × DS105	-0.02	-9.07**	-33.64**	-15.71	-0.81**
20.	7A × DS173	-0.05**	-9.82**	-1.16	16.09	-0.203
21.	7A × DS155	-0.09**	3.15	-54.26**	-37.06**	-0.99**
22.	7A × DS137	0.013	-30.94**	10.19	14.93	1.95**
23.	7A × DS167	-0.12**	-4.31	6.85	-3.30	-1.08**
24.	7A × DS176	-0.03	-4.37	31.50**	15.23	-0.13
25.	7A × DS149	0.033	25.20**	6.43	4.54	0.50*
26.	7A × DS156	-0.06**	-2.88	101.43**	33.46**	-0.21
27.	7A × DS161	0.34**	33.02**	-67.34**	-28.15**	0.96**
S. Em±		0.02	2.45	10.08	8.37	0.22
+ve significant		6	8	8	5	9
-ve significant		7	6	11	5	9
Range		-0.17 to 0.34	-31.94 to 33.02	-96.24 to 112.85	-51.64 to 47.11	-1.92 to 1.95

* and** Significant at 5 and 1 per cent levels, respectively.

plant were 7A × DS 161, 7A × DS 149 and 296A × DS 137 on the basis of significant positive *sca* effect and for green fodder yield per plant and other forage traits were 296A × DS 161, 7A × DS 156 and 2219A × DS 155.

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