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STUDY OF *PER SE* PERFORMANCE AND HETEROSIS FOR YIELD AND ITS ATTRIBUTING TRAITS IN FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

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SUMMARY

The present investigation in forage sorghum [*Sorghum bicolor* (L.) Moench] was carried out to study *per se* performance and magnitude of heterosis in 27 F_1 hybrids with nine female and three male were examined in Randomized Block Design (RBD) with three replications for fodder yield, its quality and other yield related traits during *Kharif* 2016-17. Analysis of variance revealed that significant differences was observed among the parents for all the characters except plant height. This indicated the presence of adequate amount of variability in parents (lines and testers) for most of the traits under study. An examination of mean performance of parents and hybrids indicated that the female DSF-140, male Malwan and the hybrids DSF-138 × CSV 21 F, DSF-123 × Malwan and DSF-140 × GFS 5 exhibited higher mean performance for green fodder yield per plant and some of the yield contributing traits. The cross combinations, DSF-130 × CSV 21 F, DSF-146 × GFS 5 and DSF-146 × CSV 21 F exhibited significant and positive heterobeltiosis for green fodder yield and its component traits. In case of standatd heterosis over best check CSH 13, the top ranking hybrids *viz*., DSF-138 × CSV 21 F, DSF-123 × Malwan and DSF-140 × GFS 5 were found promising for green fodder yield per plant and its component traits.

Key words : *Per se* performance, heterobeltiosis, standard heterosis, green fodder 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 genus *Sorghum* belongs to the native of Africa and Asia. It is an often cross pollinated crop having average 6 per cent natural cross pollination take place. Africa and India account for the largest share (>70%) of global sorghum growing area (Kumar *et al*., 2011).

The fodder sorghum is most nutritive for animal among all the fodder crops. Fodder requirement is increasing due to the fast development of dairy industry in the state. To meet this requirement, it is difficult to increase the area under fodder crops on account of even increasing pressure on land by commercial crops and cereals, over and above the industrial and housing occupation. Therefore, only alternative is by way of increasing the production per unit time and per unit area through providing improved technology in the form of improved varieties and agronomic practices as well as improving quality of fodder sorghum. In order to make fodder sorghum more remunerative crop, obviously there is an urgent need to initiate research for development of varieties and hybrids having faster growth, multicut habit with high regeneration capacity, early to medium maturity and higher biomass coupled with high protein content and minimum toxic constituents like HCN.

The breeding methods of forage sorghum are largely those, which are suitable for cross-pollinated crops. Its genetic improvement has been carried out through conventional breeding procedures. Use of cytoplasmic genetic male sterility and techniques of population improvement have provided a great scope for genetic upgrading of this crop.The aim of estimation of heterosis in the present study was to find out the superior combinations of parents giving the high degree of useful heterosis for yield and its contributing characters and for its future use in breeding programme.

MATERIALS AND METHODS

The present investigation was carried out at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat). The testing materials consisted of 27 F_1 hybrids and their nine line as female (DSF-123, DSF-130, DSF-138, DSF-140, DSF-141, DSF-146, DSF-150, DSF-152, DSF-154) and three tester as a male parents (Malwan, CSV 21 F and GFS 5). The F_1 hybrids along with twelve parents (9 line and 3 tester) and check CSH 13 were evaluated in a Randomized Block Design with three replications during *kharif* 2016. Data were recorded on five competitive plants selected randomly for Plant height (cm), Number of leaves per plant, Stem diameter (cm), Leaf length (cm), Leaf width (cm), Leaf : Stem Ratio, Brix (%), Green fodder yield per plant (g), Dry fodder yield per plant (g), Leaf area (cm^2) and Protein content (%).Whereas Days to flowering was recorded on plot basis. The mean data 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 estimation of relative heterosis, heterobeltiosis and economic heterosis as per the method given by Turner (1953), Fonseca and Peterson (1968) and Meredith and Bridge (1972), respectively. The data were analyzed statistically using the software WINDOSTAT version 8.1.

RESULTS AND DISCUSSION

The *per se* performance of parents and hybrids for quantitative and qualitative traits (Table 1) evinced that none of the parents (*i.e.* females and males) showed consistent good mean performance for all the traits. The female parent DSF-140 was top ranking for green fodder yield, plant height, number of leaves per plant, dry matter yield per plant and leaf area. DSF-123 was better for leaf length (102.85 cm) and leaf width (7.31 cm). The parent DSF-138 (65.67 days) took minimum days for flowering. The females DSF-130 and DSF-150 were better for stem diameter and leaf: stem ratio, respectively.

In case of male parents, Malwan was found superior for green fodder yield per plant, dry matter yield per plant, plant height and protein content. GFS 5 was found better for earliness, number of leaves per plant, leaf length, leaf width, leaf: stem ratio and leaf area. CSV 21 F showed better mean performance for stem diameter and brix% in desired direction.

In case of F_1 none of the hybrids was revealed superior performance for all the traits. The cross combination DSF-138 × CSV 21 F exhibited its superiority for different component *viz.* plant height, number of leaves per plant, leaf width, dry matter yield per plant and leaf area. DSF-123 × Malwan showed better mean performance for leaf length and protein content. Minimum stem diameter was recorded by DSF-140 × Malwan. The hybrid, DSF-138 × GFS 5 showed better mean performance for Brix %.

The analyses of variance for all the traits under study are presented in Table 2. The result revealed that significant differences among the parents for all the characters except plant height. This indicated the presence of adequate amount of variability in the parents (lines and testers) for all the traits except plant height. Mean sum of squares due to lines were significant for all the traits except plant height and stem diameter. Mean sum of squares due to testers were significant for all the traits except plant height. Further, mean sum of squares due to hybrids were significant for all the traits. Mean sum of squares due to parents *vs* hybrids were significant for plant height, leaf width, leaf : stem ratio, brix %, green fodder yield per plant and dry matter yield per plant which indicated the presence of enormous heterosis for these traits. Mean sum of squares due to lines *vs* testers were significant for all the characters except days to flowering, plant height, stem diameter, leaf length and leaf : stem ratio.

The magnitude of heterosis was measured as per cent increase or decrease of F_1 value over mid-parent (relative heterosis), over better parent (heterobeltiosis), and over standard check, CSH 13 (standard heterosis) for all 12 characters. The measures of heterosis over mid parent have relative less importance than better parent and standard check. Therefore, it is better to measure heterosis in terms of superiority of F_1 over better parent and standard check. Considerably high heterosis in certain crosses and low in other crosses suggested the nature of gene actions varied with the genetic architecture of the parent. The degree of heterosis varied from cross to cross for all the ten traits. Considerable heterosis in certain crosses and low in other crosses revealed that nature of gene action varied with the genetic architecture of parents. Negative heterosis is considered as desirable for days to flowering and stem diameter, while for other traits significant positive heterosis was considered as desirable. The results in this pursuit are discussed in following ways. A vary wide range of heterosis was found for all traits under study [Table 3].

TABLE 1
Per se performance of parents and their crosses in sorghum for yield and component traits in forage sorghum

S. No.	Parents / Crosses	Days to flowering	Plant height (cm)	No. of leaves/ plant	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Leaf : stem ratio	Brix (%)	Green fodder yield/ plant (g)	Dry matter yield/plant (g)	Leaf area (cm^2)	Protein content (%)
Lines													
1.	DSF-123	68.00	242.40	13.33	1.26	102.85	7.31	0.23	8.50	258.15	134.25	3477.64	8.14
2.	DSF-130	70.00	226.47	10.67	1.12	92.59	4.78	0.25	7.93	142.16	62.75	2307.99	7.68
3.	DSF-138	65.67	237.00	12.27	1.18	84.31	5.32	0.29	8.77	216.43	95.63	4239.11	6.79
4.	DSF-140	72.00	264.27	13.73	1.21	84.04	5.35	0.22	7.17	344.84	188.34	5393.28	7.11
5.	DSF-141	72.67	260.27	12.73	1.23	76.05	5.01	0.23	9.57	261.17	144.44	3971.73	7.36
6.	DSF-146	69.67	229.60	11.33	1.27	92.70	5.33	0.22	9.13	153.45	93.59	3252.31	6.25
7.	DSF-150	72.33	224.60	11.53	1.14	92.34	5.03	0.33	8.33	149.91	79.52	3513.11	7.44
8.	DSF-152	67.00	240.13	12.40	1.26	95.10	6.89	0.27	9.67	232.51	120.85	3893.05	8.63
9.	DSF-154	71.00	232.60	11.33	1.19	71.67	4.58	0.26	12.30	165.65	129.95	2060.61	7.22
	Mean	69.81	239.70	12.15	1.21	87.96	5.51	0.26	9.04	213.81	116.59	3567.65	7.40
Testers													
1.	Malwan	73.00	236.47	12.13	1.29	85.85	6.81	0.29	8.63	226.92	121.19	3394.94	9.12
2.	CSV 21 F	70.00	221.13	10.13	1.07	74.36	4.70	0.20	13.10	136.56	76.47	2722.30	8.25
3.	GFS 5 (Check)	66.67	232.73	12.27	1.17	96.14	8.11	0.30	9.50	197.46	100.30	6051.95	7.99
	Mean	69.89	230.11	11.51	1.18	85.45	6.54	0.26	10.41	186.98	99.32	4056.40	8.45
Crosses													
1.	DSF-123 × Malwan	74.00	287.60	13.20	1.23	106.60	8.83	0.27	14.20	349.79	168.77	4684.17	8.78
2.	DSF-123 × CSV 21 F	71.00	236.60	11.33	1.24	83.34	6.25	0.21	10.70	213.01	119.25	3400.58	7.61
3.	DSF-123 × GFS 5	69.33	249.80	13.80	1.21	92.89	6.83	0.30	11.67	222.71	132.61	3745.87	7.97
4.	DSF-130 × Malwan	72.00	263.53	12.87	1.21	101.35	8.21	0.34	11.70	265.57	115.13	4376.86	7.62
5.	DSF-130 × CSV 21 F	66.33	264.47	12.80	1.29	101.72	9.11	0.20	12.90	337.31	161.43	4672.95	7.60
6.	DSF-130 × GFS 5	67.67	185.73	7.00	1.23	62.20	4.41	0.40	11.67	84.06	58.13	1497.10	8.11
7.	DSF-138 × Malwan	74.00	228.93	11.20	1.33	80.06	5.88	0.27	12.33	199.63	123.59	2754.97	8.40
8.	DSF-138 × CSV 21 F	73.33	301.27	14.87	1.30	105.90	10.95	0.28	12.53	354.05	175.92	6035.26	7.71
9.	DSF-138 × GFS 5	66.33	240.47	12.13	1.21	84.74	6.59	0.25	16.00	220.04	123.01	3731.62	7.37
10	DSF-140 × Malwan	81.67	226.40	10.93	1.08	75.60	5.04	0.23	6.23	133.24	83.94	2617.96	8.18
11	DSF-140 × CSV 21 F	67.00	231.80	11.20	1.14	82.26	6.24	0.20	7.80	209.79	104.19	2947.95	7.07
12	DSF-140 × GFS 5	65.67	276.93	13.80	1.30	105.94	9.07	0.22	10.70	345.46	148.95	4483.10	6.65
13	DSF-141 × Malwan	74.67	253.67	12.40	1.23	96.06	7.80	0.23	7.43	249.05	131.67	4113.14	7.62
14	DSF-141 × CSV 21 F	70.00	230.60	11.20	1.19	80.48	6.23	0.26	7.50	207.78	117.19	2905.92	7.29
15	DSF-141 × GFS 5	74.00	250.07	12.07	1.22	105.94	7.09	0.17	7.50	223.77	116.54	3749.96	7.81
16	DSF-146 × Malwan	67.00	262.13	12.60	1.23	105.71	8.11	0.19	12.97	293.71	157.15	4362.99	7.30
17	DSF-146 × CSV 21 F	65.00	259.33	12.40	1.19	96.71	7.38	0.19	12.43	251.93	130.25	4085.91	6.20
18	DSF-146 × GFS 5	64.67	276.80	13.00	1.27	106.34	9.24	0.23	10.63	338.17	160.75	4430.43	7.56
19	DSF-150 × Malwan	72.67	254.60	11.60	1.23	94.28	7.21	0.24	8.80	245.16	132.92	3913.06	8.37
20	DSF-150 × CSV 21 F	69.00	250.13	11.67	1.23	96.50	7.23	0.21	6.57	225.50	125.62	3919.99	7.90
21	DSF-150 × GFS 5	66.33	237.53	11.47	1.22	83.74	6.30	0.19	10.67	218.55	131.22	3434.42	7.59
22	DSF-152 × Malwan	67.67	238.60	11.53	1.29	84.06	6.51	0.18	11.47	219.85	127.43	3515.22	8.30
23	DSF-152 × CSV 21 F	73.33	226.53	10.93	1.14	77.70	5.27	0.21	13.97	141.16	83.25	2637.01	7.43
24	DSF-152 × GFS 5	68.00	273.47	12.80	1.20	101.66	8.65	0.20	9.77	327.97	150.75	4213.89	7.90
25	DSF-154 × Malwan	71.33	220.60	10.73	1.14	70.43	4.69	0.22	10.60	121.29	63.53	2259.33	7.68
26	DSF-154 × CSV 21 F	74.00	211.53	10.60	1.19	66.84	4.63	0.24	14.30	104.82	61.98	2128.91	8.00
27	DSF-154 × GFS 5	72.33	228.20	11.07	1.20	77.70	5.29	0.25	8.33	145.08	70.19	2674.87	7.39
Mean		70.31	246.94	11.90	1.22	89.88	7.00	0.24	10.79	231.42	121.31	3603.46	7.68
Check													
1	CSH 13	71.00	224.07	12.93	1.34	75.83	11.11	0.21	8.00	298.58	149.53	6131.94	7.83
General mean		70.18	243.48	11.95	1.22	88.77	6.73	0.24	10.30	225.81	119.30	3692.59	7.68
S.Em. ±		1.16	10.14	0.42	0.04	4.49	0.13	0.01	0.30	11.56	3.74	138.16	0.16
C.D. 5%		3.26	28.54	1.18	0.11	12.64	0.37	0.03	0.83	32.53	10.53	389.00	0.46
C.V. %		2.86	7.21	6.09	5.77	8.76	3.35	7.59	4.97	8.86	5.43	6.48	3.66
Range		64.67 to 81.67	185.73 to 301.27	7.00 to 14.87	1.07 to 1.34	62.20 to 106.60	4.40 to 11.11	0.17 to 0.40	6.23 to 16.00	84.06 to 354.05	58.13 to 188.34	1497.10 to 6131.34	6.20 to 9.12

Heterosis for green fodder yield per plant indicated that out of 27 hybrids, 12 hybrids showed positive and significant relative heterosis. The significant and positive heterosis varied from -53.39 to 142.04 per cent. The heterobeltiosis and standard heterosis ranged from -61.36 to 137.27 per cent and -71.85 to 18.58 per cent respectively. Among 27 hybrids DSF-138 X CSV 21 F, DSF-123 X Malwan, DSF-140

X GFS 5, DSF-146 X GFS 5 and DSF-130 X CSV 21 F had higher mean with desire heterosis for greed fodder yield as well as for other yield attribute characters so it may be useful for commercial exploitation in forage sorghum. For days to flowering out of 27 hybrids, 7 hybrids depicted significant and negative relative heterosis which is desired for earliness. Range of heterosis from -6.92 to 12.64 per cent for mid parent, -6.70 to 13.43 per cent for heterobeltiosis and -8.92 to 15.02 per cent for standard heterosis. For stem diameter out of 27 hybrid 14 showed negative significant standard heterosis with range -19.65 to -1.00 per cent.

Ten hybrids depicted significant and positive relative heterosis for plant height. The heterosis over mid parent ranged from -19.11 to 31.52 per cent. The range of heterobeltiosis was from -20.19 to 27.12 per cent. Six hybrids exhibited significant positive heterosis over better parent. The standard heterosis varied from -17.11 to 34.45 per cent. Among 27 hybrids 11 hybrids expressed significant positive heterosis over standard check. While, for number of leaves per plant, its ranged in per cent from -38.95 to 32.74, -42.93 to 21.20 and -45.88 to 14.95 for mid parent, better parent and standard heterosis. Among leaf length and leaf: stem ratio showed very wide range of heterosis for mid parent, better parent as well as for standard heterosis [Table 3]. Fourteen and nine cross showed significant desire heterosis for standard heterosis. While, in case of leaf width and leaf area, none of the hybrid showed positive significant standard heterosis. In this investigation for quality characters like brix and protein content had range of standard heterosis was -22.08 to 100.00 per cent and -20.83 to 12.18 per cent respectively.

A perusal of Table 4 revealed that the hybrid, DSF-138 × CSV 21 F (18.58%) registered highest standard heterosis over CSH 13 for green fodder yield per plant followed by DSF-123 × Malwan (17.15 %), DSF-140 × GFS 5 (15.70 %), DSF-146 × GFS 5 (13.26 %) and DSF-130 × CSV 21 F (12.97 %). Majority of these hybrids also showed significant heterosis for the component traits like plant height, leaf length, brix % and dry matter yield per plant. The findings are in agreement with the results reported by Monteiro *et al*. (2008), Singh and Sukhchain (2010), Prakash *et al*. (2010) and Jain and Patel (2014).

TABLE 2

Analysis of variance showing mean sum of squares for different traits in forage sorghum

Parents	d. f.	Days to flowering	Plant height (cm)	No. of leaves/ plant	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)
Replications	2	6.80	143.69	1.53	0.001	6.70	0.12
Parents	11	18.88**	526.83	3.28**	0.01**	279.05**	4.21**
Lines	8	18.43**	598.81	3.09**	0.01	289.40**	2.67**
Testers	2	30.11**	191.80	4.28**	0.04**	355.92**	8.90**
Lines vs Testers	1	0.04	621.12	2.74*	0.01	42.51	7.12**
Parents vs Hybrids	1	5.63	2312.59**	0.21	0.01	161.69	37.80**
Hybrids	26	47.05**	1870.28**	6.28**	0.01*	542.42**	8.12**
Error	76	3.89	299.46	0.53	0.01	47.19	0.05

Parents	d. f.	Leaf : stem ratio	Brix %	Green fodder yield/plant (gm)	Dry matter yield/plant (gm)	Leaf area (cm^2)	Protein content (%)
Replications	2	0.001	0.31	15.77	83.05	222404.76	0.02
Parents	11	0.004**	8.82**	11667.54**	3639.74**	4025032.92**	1.95**
Lines	8	0.004**	6.34**	13842.83**	4377.44**	3008022.69**	1.49**
Testers	2	0.01**	16.83**	6370.82**	1501.85**	9299384.42**	1.05**
Lines vs Testers	1	0.00	12.68**	4859.71**	2013.90**	1612411.70**	7.47**
Parents vs Hybrids	1	0.01**	49.41**	14743.20**	2034.68**	185938.84	0.01
Hybrids	26	0.01**	19.95**	18234.88**	3300.97*	2870349.22**	0.87**
Error	76	0.001	0.26	409.57	41.20	54548.27	0.08

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

TABLE 3
Number of hybrids having significant heterotic effect in forage sorghum

Characters	Over mid parent				Over better parent				Over standard check (CSH 13)			
	+ve	-ve	Total	Range	+ve	-ve	Total	Range	+ve	-ve	Total	Range
Days to flowering	8	7	15	-6.92 to 12.64	8	2	10	-6.70 to 13.43	2	10	12	-8.92 to 15.02
Plant height	10	1	11	-19.11 to 31.52	6	4	10	-20.19 to 27.12	11	1	12	-17.11 to 34.45
Number of leaves per plant	5	2	7	-38.95 to 32.74	2	8	10	-42.93 to 21.20	1	14	15	-45.88 to 14.95
Stem diameter	4	2	6	-13.98 to 17.45	9	1	10	-11.26 to 21.12	0	14	14	-19.65 to -1.00
Leaf length	11	2	13	-34.08 to 33.48	2	7	9	-35.30 to 25.60	14	1	15	-17.97 to 40.59
Leaf width	15	7	22	-31.64 to 118.50	14	12	26	-45.69 to 105.76	0	26	26	-60.35 to -1.50
Leaf : Stem ratio	5	13	11	-39.04 to 44.24	2	16	18	-43.82 to 33.71	9	2	11	-21.28 to 85.94
Brix %	16	7	23	-38.72 to 75.18	14	8	22	-49.87 to 68.42	19	2	21	-22.08 to 100.00
Green fodder yield/plant	12	7	19	-53.39 to 142.04	9	11	20	-61.36 to 137.27	5	19	24	-71.85 to 18.58
Dry matter yield/plant	15	7	22	-49.40 to 131.90	11	12	23	-55.43 to 111.10	4	20	24	-61.12 to 17.65
Leaf area	9	14	23	-64.18 to 85.79	8	16	24	-75.26 to 71.65	0	26	18	-75.59 to -1.58
Protein content	2	11	13	-14.51 to 6.28	0	19	19	-24.89 to 1.46	4	5	9	-20.83 to 12.18

TABLE 4
Best five hybrids for heterosis (%) over better parent and standard check (CSH 13) for yield and component traits in forage sorghum

S. No.	Hybrids	Mean green fodder yield/plant (gm)	Heterosis (%) over		Significant standard heterosis for component traits in desired direction
			BP	Best SC	
1.	DSF-138 × CSV 21 F	354.05	63.59**	18.58**	PH, NLP, LL, LSR, Brix, DM.
2.	DSF-123 × Malwan	349.79	35.50**	17.15**	PH, LL, LSR, Brix, DMY, PC.
3.	DSF-140 × GFS 5	345.46	0.18	15.70**	DF, PH, LL, Brix.
4.	DSF-146 × GFS 5	338.17	71.26**	13.26*	DF, PH, LL, Brix, DMY
5.	DSF-130 × CSV 21 F	337.31	137.27**	12.97*	DF, PH, LL, Brix, DMY

DF=Days to flowering
PH=Plant height
NLP=Number of leaves per plant
LL=Leaf length
LSR=Leaf: stem ratio
Brix=Brix %
DMY=Dry matter yield per plant
PC=Protein content %

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