Genetic Improvement Through Standard Heterosis for Fodder Yield in Single cut of Forage Sorghum [*Sorghum bicolor* (L.) Moench]

A.K. Dehinwal*, S. K. Pahuja and M. Shafiqurrahaman

CCS Haryana Agricultural University, Hisar - 125 004, India.

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A study was made in *Sorghum bicolor* with line x taster (6 females x 4 males) to estimate the magnitude of heterosis among different cross combinations for yield and its component traits. For this purpose, 24 specific cross combinations were developed by using 10 diverse parents during *kharif* season in 2014-15. These hybrids along with 10 parents and two standard checks (SSG 59-3and MFSH 4) were evaluated at two locations with two dates of sowing (Early and late sowing) during kharif season in 2015-16. The analysis of variance indicated the presence of variability among hybrids and their parents. Among male parents, HJ 541 and G 46 and among female parents, 467A and 56A showed maximum green and dry fodder yield. Maximum heterosis for green fodder yield as comparison with all the four environments over both the checks (SSG 59-3 and MFSH 4) was showed by 9A × IS 2389 (81.1 % and 75.3 % respectively). Alongwith green fodder yield this hybrid is also better for dry fodder yield (46.4 % and 41.4 % respectively) and leaf breadth (60.6 % and 41.9 % respectively). Hybrid 465A × HJ 513 demonstrate better heterosis for green fodder yield (80.7 %) as well as for dry fodder yield (57.7 %). Hybrid 467A × G 46 show better heterosis for green fodder yield (64.7 %) as well as for dry fodder yield (29.6 %). This is also better for plant height, leaf length, leaf breadth and stem diameter.

Keywords: *Sorghum bicolor*, heterosis, quantitative traits, green and dry fodder yield.

Sorghum [Sorghum bicolor (L.) Moench] was originated in Africa is one of the five top cereal crops in the world. It's extremely drought tolerant ability makes it an excellent choice for arid and dry areas. It is one of the major multi-purpose crops grown for forage and grain production purpose. The yield of sorghum varies from state to state with varying rainfall, soil types and also with varying seasons. It's quick growing habit, high yield, regeneration potential, better palatability, digestibility and drought tolerance makes it good choice of fodder for farming community on which the livestock industry depends.

It is preferred over maize in kharif season because of its high tolerance to various stresses and its superiority to pearl millet in having lower oxalate and fibre content. It can grow in the areas where all other major cereal crops could not grow successfully. Sorghum [*Sorghum bicolor* (L.) Moench] is popular as a dual purpose crop and is next to rice and wheat in its acreage and importance in India.

In India, the area under cultivated sorghum is 5.82 million hectare with production of 5.39 million ton and productivity 926 kg/ha. In Haryana, 72 thousand hectares area was under sorghum with production of 40 thousand tons and productivity 500 kg/ha (Anonymous, 2014-2015).Therefore, the present study was undertaken to find out the extent of useful heterosis over the

* To whom all correspondence should be addressed.
E-mail: ashokdehinwalccshau@gmail.com

checks (SSG 59-3 and MFSH 4) for fodder yield and its component traits. This necessitates the study of combining ability effects of crosses for the selection of superior parents and hybrids.

MATERIAL AND METHODS

The material to be use in this study was developed by crossing six diverse female lines, *viz:* 9A. 14A, 31A, 56A, 465A and 467A with four agronomically superior male parents to be used as testers i.e. HJ 513, HJ 541, IS 2389 and G 46. The crosses were made at research area of forage section, Department of Genetics and Plant Breeding, CCS HAU, Hisar during the *Kharif* season of 2014-15. Hybrids and parents were evaluated at two locations *i.e*. research area of forage section, department of genetics and plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar and Regional Research Station Uchani, Karnal with two date of sowing (Early and late sowing) during the *Kharif* season of 2015-16. Data on five randomly selected plants from each genotype in each replication were recorded on different quantitative characters viz. Days to 50% flowering, Plant height (cm), Number of tillers per plant, Leaf length (cm), Leaf breadth (cm), Stem diameter (cm), Green fodder yield (g per plant) and Dry fodder yield (g per plant), in all the four environments. All the thirty six genotypes were grown in a randomized block design in three replications of a two-row plot of 4.0 m length. All the recommended cultural package of practices was followed from sowing to till harvesting the crop. The L x T analysis of heterosis was performed as suggested by Kempthorne (1957). Heterosis was calculated in terms of per cent increase (+) or decrease (-) of the F_1 hybrids against its standard check value as suggested by Fehr (1987).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) indicated that the mean squares of genotypes for all the characters investigated were significantly different, indicating the presence of variability among hybrids and their parents except number of tillers in E_4. Mean performance and range of hybrids and parents are presented in Table 2 and Table 3 respectively.

Table 1. Analysis of variance for different characters in different environments in single cut in forage sorghum

Source of variation	D.F	Environ-ments	Plant Height (cm)	No. of Tillers per plant	Leaf Length (cm)	Leaf Breadth (cm)	Stem Diameter (cm)	Green Fodder Yield (g per plant)	Dry Fodder Yield (g per plant)
Replication	2	E1	60.663	0.480	6.657	0.937	0.843	289.951	31.127
		E2	26.304	0.010	32.069	0.012	0.593	73.775	27.451
		E3	119.147	1.088	95.951	0.170	0.820	217.892	42.157
		E4	151.010	0.029	49.618	0.030	0.187	265.441	17.892
Treatment	33	E1	1002.092**	1.928*	181.442**	3.262**	21.464**	4857.583**	303.773**
		E2	668.187**	1.889*	215.412**	1.849**	10.479**	4838.859**	236.126**
		E3	450.244**	2.207**	134.616**	1.713**	22.049**	2711.081**	121.220**
		E4	430.353**	1.667	142.883**	1.772**	24.175**	2738.243**	146.145**
Error	66	E1	65.153	0.309	15.950	0.392	1.295	106.113	10.168
		E2	63.435	0.293	20.523	0.460	1.688	104.078	10.279
		E3	62.612	0.088	16.001	0.429	1.447	105.266	10.591
		E4	67.626	0.252	11.739	0.470	1.380	85.391	10.316

D.F. = Degree of Freedom * Significant at 5% level**significant at 1% level, E 1 = Early sowing at Hisar, E2 = Early sowing at Karnal, E 3 = Late sowing at Karnal, E4 = Late sowing at Hisar, E4 = Late sowing at Karnal

Table 2. Mean performance and range of hybrids for different characters under different environments in single cut in forage sorghum

S.	Characters	E_1		E_2		E_3		E_4	
No.		Mean	Range	Mean	Range	Mean	Range	Mean	Range
1	Plant Height (cm)	157.1	127.3-199.3	145.9	116.3-185.3	148.7	124.3-172.7	147.4	128.7-173.0
2	No. of Tillers per plant	1.8	1.0-3.0	1.6	1.0-2.3	1.3	1.0-3.0	1.5	1.0-3.0
3	Leaf Length (cm)	78.7	58.3-90.0	76.4	56.3-92.3	79.4	66.7-93.0	79.6	66.7-92.3
4	Leaf Breadth (cm)	6.8	4.2-8.5	6.4	4.6-7.6	6.2	4.6-7.3	6.1	4.6-7.3
5	Stem Diameter (cm)	15.5	11.3-21.8	15.1	11.7-20.1	15.8	12.6-20.1	16.3	12.6-21.8
6	Green Fodder Yield (g per plant)	180.7	118.3-265.0	183.7	141.7-271.7	164.2	115.0-240.0	159.4	118.3-240.0
7	Dry Fodder Yield (g per plant)	53.3	38.3-68.3	53.6	38.3-68.3	48.4	36.7-61.7	47.0	36.7-61.7

Table 3. Mean performance and range of parents for different characters under different environments in single cut in forage sorghum

S.	Characters	E_1		E_2		E_3		E_4	
No.		Mean	Range	Mean	Range	Mean	Range	Mean	Range
1	Plant Height (cm)	154.6	133.7-191.7	144.8	121.3-166.3	150.3	131.7-166.0	154.3	141.7-168.3
2	No. of Tillers per plant	1.8	1.3-2.3	1.3	1.0-2.0	1.2	1.0-2.0	1.3	1.0-2.3
3	Leaf Length (cm)	81.8	71.7-93.0	79.5	61.0-88.7	78.6	70.0-91.7	78.1	66.7-92.3
4	Leaf Breadth (cm)	6.3	5.2-7.7	6.4	5.2-7.9	6.1	4.6-7.3	6.7	5.2-7.3
5	Stem Diameter (cm)	14.8	11.8-17.4	14.9	11.6-17.5	16.3	13.0-21.8	15.8	12.6-20.1
6	Green Fodder Yield (g per plant)	170.3	120.0-273.3	170.3	115.0-281.7	165.7	115.0-240.0	166.5	141.7-233.3
7	Dry Fodder Yield (g per plant)	47.3	38.3-68.3	47.5	36.7-68.3	46.3	36.7-58.3	46.5	38.3-58.3

Table 4. Extent of economic heterosis for different characters in different environments in single cut in forage sorghum

Hybrids	Env.	Checks	PH	TT	LL	LB	SD	GFY	DFY
9A X HJ-513	E1	Ch. 1	-12.1	-55.6	-9.4	-13.1	-8.4	4.5	3.5
		Ch. 2	-25.3	-55.6	-9.0	-19.2	-5.6	-2.1	-13.3
	E2	Ch. 1	7.4	-20.0	-6.2	59.1	53.6	3.3	2.0
		Ch. 2	-8.4	-42.9	-12.8	40.6	27.7	0.8	-3.4
	E3	Ch. 1	2.3	-55.6	16.4	14.5	51.2	2.0	-6.5
		Ch. 2	-14.7	-42.9	7.6	18.7	30.6	8.6	0.5
	E4	Ch. 1	-5.4	-66.7	8.9	14.2	25.8	21.2	7.4
		Ch. 2	-13.1	-66.7	-0.4	10.1	15.8	12.0	-3.3
9A X HJ-541	E1	Ch. 1	-6.4	-22.2	-8.5	29.7	19.5	11.4	-3.8
		Ch. 2	-20.4	-22.2	-8.2	20.5	23.1	4.3	-16.7
	E2	Ch. 1	3.2	-20.0	-0.9	48.9	71.8	1.1	-17.9
		Ch. 2	-12.0	-42.9	-7.9	31.6	42.8	-2.2	-20.7
	E3	Ch. 1	-7.9	-66.7	2.7	9.3	6.6	-11.1	-12.9
		Ch. 2	-23.2	-57.1	-5.1	13.3	-13.7	-5.4	-6.9
	E4	Ch. 1	-9.6	-66.7	-6.5	-4.3	11.9	69.4	37.0
		Ch. 2	-17.0	-66.7	-14.5	-7.7	3.0	56.5	23.3
9A X IS-2389	E1	Ch. 1	10.5	-44.4	0.9	27.6	34.7	45.5	53.8
		Ch. 2	-6.1	-44.4	0.4	18.6	38.8	36.2	33.3
	E2	Ch. 1	-2.5	-4.1	-14.2	60.6	38.9	81.1	46.4
		Ch. 2	-16.9	-28.6	-20.2	41.9	15.5	75.3	41.4
	E3	Ch. 1	5.3	-66.7	16.0	10.5	15.8	-10.1	-9.7
		Ch. 2	-12.2	-57.1	7.2	14.5	5.4	-4.3	-3.4
	E4	Ch. 1	-9.3	-66.7	1.4	-15.4	38.1	0.5	0.8
		Ch. 2	-16.7	-66.7	-7.3	-18.5	27.1	-7.6	-10.0
9A X G-46	E1	Ch. 1	-1.4	-22.2	9.4	13.8	-5.5	55.7	46.2
		Ch. 2	-16.2	-22.2	9.9	5.8	-2.6	45.7	26.7
	E2	Ch. 1	-1.4	0.5	10.2	32.1	50.2	30.0	21.4
		Ch. 2	-15.9	-28.6	2.5	16.8	24.9	25.8	17.2
	E3	Ch. 1	5.3	-66.7	11.0	11.6	6.0	-5.1	-9.7
		Ch. 2	-12.2	-57.1	2.5	15.7	-8.5	1.1	-3.4
	E4	Ch. 1	3.7	-44.4	21.0	21.6	67.4	-5.9	-14.8
		Ch. 2	-4.7	-44.4	10.7	17.3	54.1	-13.0	-23.3
14A X HJ -513	E1	Ch. 1	-8.6	-66.7	8.5	62.1	53.4	23.9	23.1
		Ch. 2	-22.3	-66.7	9.0	50.6	58.0	16.0	6.7
	E2	Ch. 1	-7.6	4.0	-0.4	65.7	17.3	18.9	14.3
		Ch. 2	-21.2	-28.6	-7.4	46.5	-2.4	15.1	10.3
	E3	Ch. 1	-1.6	-66.7	5.5	8.1	29.5	-1.0	-16.1
		Ch. 2	-18.0	-57.1	-2.5	12.0	11.8	5.4	-10.3
	E4	Ch. 1	3.0	-66.7	7.5	16.0	53.6	-16.5	-18.5
		Ch. 2	-5.4	-66.7	-1.7	11.9	41.3	-22.8	-26.7
14A X HJ -541	E1	Ch. 1	-2.9	-33.3	-0.9	65.5	40.7	10.2	23.1
		Ch. 2	-17.5	-33.3	-0.4	53.8	45.0	3.2	6.7
	E2	Ch. 1	-3.0	20.0	-9.8	44.5	46.2	45.6	42.9
		Ch. 2	-17.3	-14.3	-16.1	27.7	21.5	40.9	37.9
	E3	Ch. 1	16.9	-55.6	17.4	-8.7	15.1	2.0	-6.5

		Ch. 2	-2.5	-42.9	8.4	-5.4	-0.6	8.6	2.0
	E4	Ch. 1	-2.6	-55.6	9.3	17.3	31.9	22.4	7.4
		Ch. 2	-10.5	-55.6	6.0	13.1	21.4	13.0	-3.3
14A X IS-2389	E1	Ch. 1	20.1	-33.3	15.4	64.8	21.3	17.0	23.1
		Ch. 2	2.1	-33.3	15.9	53.2	25.0	9.6	6.7
	E2	Ch. 1	3.9	40.0	-4.9	30.7	39.2	13.3	14.3
		Ch. 2	-11.4	6.2	-11.6	15.5	15.7	9.7	10.3
	E3	Ch. 1	9.0	-55.6	-3.2	14.5	51.2	-11.1	-16.1
		Ch. 2	-9.1	-42.9	-10.5	18.7	30.6	-5.4	-10.3
	E4	Ch. 1	7.7	-55.6	3.7	14.2	-3.6	-11.8	-18.5
		Ch. 2	-1.1	-55.6	-5.1	10.1	-11.3	-18.5	-26.7
14A X G-46	E1	Ch. 1	-13.6	-55.6	0.9	44.8	2.5	63.6	53.8
		Ch. 2	-26.5	-55.6	1.3	34.6	5.6	53.2	33.3
	E2	Ch. 1	15.6	20.0	4.9	37.2	24.2	55.6	35.7
		Ch. 2	-1.4	-14.3	-2.5	21.3	3.2	50.5	31.0
	E3	Ch. 1	-2.8	-66.7	27.4	22.1	8.6	-10.1	-12.9
		Ch. 2	-18.9	-57.1	17.7	26.5	-6.3	-4.3	-6.9
	E4	Ch. 1	2.3	-44.4	6.1	-4.3	12.6	21.2	14.8
		Ch. 2	-6.0	-44.4	-3.0	-7.7	3.6	12	3.3
31A X HJ -513	E1	Ch. 1	-4.1	-33.3	-4.7	8.3	-11.0	44.3	34.6
		Ch. 2	-18.5	-33.3	-4.3	0.6	-8.3	35.1	16.7
	E2	Ch. 1	4.1	20.0	-4.9	45.3	40.1	55.6	35.7
		Ch. 2	-11.2	-14.3	-11.6	28.4	16.5	50.5	31.0
	E3	Ch. 1	7.2	-55.6	16.4	23.3	35.2	-5.1	2.5
		Ch. 2	-10.6	-42.9	7.6	27.7	16.7	1.1	6.9
	E4	Ch. 1	17.1	-66.7	29.4	-15.4	38.1	5.0	6.2
		Ch. 2	7.5	-66.7	18.4	-18.5	27.1	-7.6	-10.0
31A X HJ-541	E1	Ch. 1	-10.7	-44.4	-25.2	49.7	3.1	23.9	23.1
		Ch. 2	-24.1	-44.4	-24.9	39.1	6.3	16.8	6.7
	E2	Ch. 1	-0.2	0.3	0.4	47.4	20.5	15.6	7.1
		Ch. 2	-14.9	-28.6	-6.6	30.3	0.2	11.8	3.4
	E3	Ch. 1	-6.9	-55.6	2.7	9.3	6.8	10.1	2.1
		Ch. 2	-22.4	-42.9	-5.1	13.3	-8.5	17.2	6.9
	E4	Ch. 1	7.2	-22.2	13.1	35.8	0.5	-5.9	-14.8
		Ch. 2	-1.5	-22.2	3.4	31.6	-7.5	-13.6	-23.3
31A X IS-2389	E1	Ch. 1	5.5	-33.3	-7.7	31.0	9.6	17.1	26.9
		Ch. 2	-10.3	-33.3	-7.3	21.8	13	9.6	10.3
	E2	Ch. 1	-1.6	20.0	-24.9	49.6	15.6	10.0	14.3
		Ch. 2	-16.1	-14.3	-30.2	32.3	-3.9	6.5	10.3
	E3	Ch. 1	-13.7	-66.7	13.7	8.1	6.8	-28.3	-25.8
		Ch. 2	-28.0	-57.1	5.1	12.2	-13.7	-23.7	-20.7
	E4	Ch. 1	18.2	-22.2	19.2	-1.2	47.0	28.2	25.9
		Ch. 2	8.6	-22.2	9.2	-4.8	35.3	18.5	13.3
31A X G-46	E1	Ch. 1	-6.6	-33.3	-5.1	32.4	-10.4	-6.8	6.1
		Ch. 2	-20.6	-33.3	-4.7	23.1	-7.7	-12.8	-13.3
	E2	Ch. 1	27.8	40.0	-9.3	64.2	34.5	3.3	3.6
		Ch. 2	9.0	3.6	-15.7	45.2	11.8	5.1	6.6
	E3	Ch. 1	-4.2	-66.7	22.4	-8.7	15.8	5.1	3.2
		Ch. 2	-20.1	-57.1	13.1	-5.4	6.8	11.8	10.3
	E4	Ch. 1	3.3	-66.7	5.1	1.9	3.3	-11.8	-14.8

		Ch. 2	-5.2	-66.7	-3.8	-1.8	-5.2	-18.5	-23.3
56A X HJ-513	E1	Ch. 1	4.1	-66.7	-5.1	57.2	25.4	65.9	57.7
		Ch. 2	-11.5	-66.7	-4.7	46.2	29.2	55.3	36.7
	E2	Ch. 1	-11.0	-40.2	5.3	53.3	19.9	21.1	14.3
		Ch. 2	-24.1	-57.1	-2.1	35.5	-0.4	17.2	10.3
	E3	Ch. 1	19.2	-66.7	6.4	14.5	42.1	-1.1	-9.7
		Ch. 2	-0.6	-57.1	-1.7	18.7	22.7	5.4	-3.4
	E4	Ch. 1	0.2	-55.6	18.7	16.1	5.5	21.2	7.4
		Ch. 2	-7.9	-55.6	8.5	11.9	-2.9	12.1	-3.3
56A X HJ-541	E1	Ch. 1	-6.8	-55.6	10.7	57.2	-7.2	14.8	15.4
		Ch. 2	-20.8	-55.6	11.2	46.2	-4.4	7.4	5.5
	E2	Ch. 1	-3.0	-40.2	8.9	54.7	19.2	33.3	25.1
		Ch. 2	-17.3	-57.1	1.2	36.8	-0.9	29.1	20.7
	E3	Ch. 1	11.3	-66.7	-8.7	27.9	42.1	-30.3	-29.2
		Ch. 2	-7.1	-57.1	-15.6	32.5	22.7	-25.8	-24.1
	E4	Ch. 1	-2.1	-55.6	3.7	17.3	31.4	28.2	14.8
		Ch. 2	-10.1	-55.6	-5.1	13.1	20.9	18.5	3.3
56A X IS-2389	E1	Ch. 1	-8.6	-44.4	11.1	51.1	-8.4	5.5	-3.8
		Ch. 2	-22.3	-44.4	11.6	40.4	-5.6	-6.4	-16.7
	E2	Ch. 1	3.2	-20.2	16.2	38.7	10.3	14.4	3.6
		Ch. 2	-12.0	-42.9	7.9	22.6	-8.3	10.8	5.5
	E3	Ch. 1	8.1	-55.6	-0.9	14.5	58.9	18.2	16.1
		Ch. 2	-9.8	-42.9	-8.4	18.7	37.2	25.8	24.1
	E4	Ch. 1	9.3	-55.6	21.2	18.5	-2.8	3.6	-3.7
		Ch. 2	0.4	-55.6	10.7	14.3	-10.6	-7.6	-13.3
56A X G-46	E1	Ch. 1	22.8	-33.3	2.1	31.2	-0.4	44.3	38.5
		Ch. 2	4.4	-33.3	2.6	21.8	2.6	35.1	20.3
	E2	Ch. 1	-0.2	-40.3	23.1	25.5	14.2	32.2	14.3
		Ch. 2	-14.9	-57.1	14.5	11.2	-5.1	28	10.3
	E3	Ch. 1	8.8	-55.6	18.3	22.1	51.2	3.1	-6.5
		Ch. 2	-9.3	-42.9	9.3	26.5	30.6	9.7	5.5
	E4	Ch. 1	-4.0	-44.4	21.5	14.8	12.6	-5.9	-14.8
		Ch. 2	-11.8	-44.4	11.1	10.7	3.6	-13.1	-23.3
465A X HJ -513	E1	Ch. 1	-17.5	-55.6	10.3	48.3	-8.3	80.7	57.7
		Ch. 2	-29.8	-55.6	10.7	37.8	-5.5	69.1	36.7
	E2	Ch. 1	-3.0	-40.2	14.7	43.1	27.4	77.8	46.4
		Ch. 2	-17.3	-57.1	6.6	26.5	5.9	72.1	41.4
	E3	Ch. 1	5.8	-55.6	5.2	9.3	35.7	41.4	12.9
		Ch. 2	-11.8	-42.9	-3.2	13.3	17.1	50.5	20.7
	E4	Ch. 1	2.3	-55.6	3.7	-3.1	38.1	-16.5	-18.5
		Ch. 2	-6.0	-55.6	-5.1	-6.5	27.1	-22.8	-26.7
465A X HJ -541	E1	Ch. 1	-4.9	-55.6	-8.1	75.2	17.1	-1.1	3.8
		Ch. 2	-19.2	-55.6	-7.7	62.8	20.7	-7.4	-10.3
	E2	Ch. 1	-19.1	-40.1	-0.9	27.2	32.2	-5.6	-3.6
		Ch. 2	-31.0	-57.1	-7.9	12.3	9.8	-8.6	-6.9
	E3	Ch. 1	5.1	-55.6	13.7	7.6	-0.8	5.1	-6.5
		Ch. 2	-12.4	-42.9	5.1	11.4	-14.4	11.8	6.3
	E4	Ch. 1	-6.1	-33.3	21.2	21.6	67.4	22.4	11.1
		Ch. 2	-13.7	-33.3	10.7	17.3	54.1	13.1	9.3
465A X IS-2389	E1	Ch. 1	-17.5	-33.3	9.0	30.3	-3.7	1.1	-3.8

		Ch. 2	-29.8	-33.3	9.4	21.2	-0.8	-5.3	-16.7
	E2	Ch. 1	-6.0	-20.0	8.0	54.7	16.3	2.2	-3.6
		Ch. 2	-19.8	-42.9	0.4	36.8	-3.3	-1.1	-6.9
	E3	Ch. 1	2.3	-66.7	15.5	-9.9	29.5	-14.1	-16.1
		Ch. 2	-14.7	-57.1	6.8	-6.6	11.8	-8.6	-10.3
	E4	Ch. 1	5.4	-44.4	21.5	17.3	53.6	18.8	11.1
		Ch. 2	-3.2	-44.4	11.1	13.1	41.3	9.8	0.3
465A X G-46	E1	Ch. 1	4.1	-55.6	9.8	63.4	21.2	6.8	7.7
		Ch. 2	-11.5	-55.6	10.3	51.9	24.8	0.5	-6.7
	E2	Ch. 1	13.8	-40.0	-2.2	51.1	50.2	15.6	10.7
		Ch. 2	-2.9	-57.1	-9.1	33.5	24.9	11.8	6.9
	E3	Ch. 1	-9.0	-66.7	3.2	-20.3	15.1	-1.0	0.3
		Ch. 2	-24.1	-57.1	-4.6	-17.5	-0.6	5.4	6.9
	E4	Ch. 1	-3.5	-55.6	19.2	29.6	-0.4	3.5	3.7
		Ch. 2	-11.4	-55.6	9.0	25.1	-8.3	-4.3	-6.7
467A X HJ -513	E1	Ch. 1	-21.6	-66.7	10.7	69.1	-7.9	22.7	30.8
		Ch. 2	-33.3	-66.7	11.2	57.1	-5.1	14.9	13.3
	E2	Ch. 1	7.8	20.0	6.7	38.2	18.4	13.3	14.3
		Ch. 2	-8.0	-14.3	-0.8	21.9	-1.6	9.7	10.3
	E3	Ch. 1	-0.2	-66.7	10.5	10.5	42.1	-6.1	-6.5
		Ch. 2	-16.8	-57.1	2.1	14.5	22.7	0.4	0.3
	E4	Ch. 1	21.3	-66.7	5.1	35.8	47.2	22.4	18.5
		Ch. 2	11.4	-66.7	-3.8	31.2	35.3	13	6.7
467A X HJ-541	E1	Ch. 1	-2.5	-55.6	3.4	62.8	37.3	-19.3	-11.5
		Ch. 2	-17.1	-55.6	3.9	51.3	41.5	-24.5	-23.3
	E2	Ch. 1	-19.8	0.1	12.0	18.2	31.9	0.2	0.1
		Ch. 2	-31.6	-28.6	4.1	4.5	9.7	-3.2	-3.4
	E3	Ch. 1	-11.8	-55.6	-5.5	11.6	58.9	-8.1	-12.9
		Ch. 2	-26.4	-42.9	-12.7	15.7	37.2	-2.2	-6.9
	E4	Ch. 1	10.5	-55.6	18.7	16.1	25.8	28.2	25.9
		Ch. 2	1.5	-55.6	8.5	11.9	15.8	18.5	13.3
467A X IS-2389	E1	Ch. 1	-18.5	-11.1	-13.7	49.7	-20.4	18.2	30.8
		Ch. 2	-30.7	-11.1	-13.3	39.1	-18.1	10.6	13.3
	E2	Ch. 1	-0.2	0.2	14.2	2.9	17.2	14.4	17.9
		Ch. 2	-14.9	-28.6	6.2	-9.1	-2.7	10.8	13.8
	E3	Ch. 1	10.0	-55.6	-2.3	7.6	0.1	4.7	-6.5
		Ch. 2	-8.3	-42.9	-9.7	11.4	-13.7	10.8	0.2
	E4	Ch. 1	18.2	-55.6	0.2	29.6	11.9	20.3	7.4
		Ch. 2	8.6	-55.6	-8.5	25.1	3.2	10.9	-3.3
467A X G-46	E1	Ch. 1	-3.9	-44.4	9.8	26.9	35.2	52.3	57.7
		Ch. 2	-18.3	-44.4	10.3	17.9	39.3	42.6	36.7
	E2	Ch. 1	-10.3	20.0	-5.8	25.5	16.6	27.8	25.4
		Ch. 2	-23.5	-14.3	-12.4	11.0	-3.2	23.7	20.7
	E3	Ch. 1	6.0	-66.7	16.9	-9.9	15.8	45.5	19.4
		Ch. 2	-11.6	-57.1	8.0	-6.6	0.1	54.8	27.6
	E4	Ch. 1	-9.8	-55.6	19.2	14.8	31.9	64.7	29.6
		Ch. 2	-17.2	-55.6	9.0	10.7	21.4	52.2	16.7
	Minimum		-33.30	-66.70	-30.20	-20.30	-14.40	-30.30	-29.00
	Maximum		27.80	40.00	29.40	75.20	71.80	81.10	57.70

The range for green fodder yield varied from 118.3 g (467A X HJ 541) to 265.0 g (465A X HJ 513) with mean of 180.7 g in E_1; from 141.7 g (465A X HJ 541) to 271.7 g (9A X IS 2389) with mean 183.7 g in E_2; from 115.0 g (56A X HJ 541) to 240.0 g (467A X G 46) with mean of 164.2 g in E_3 and from 118.3 g (14A X HJ 513) to 240.0 g (9A X HJ 541) with mean of 159.4 g in E_4. On the basis of pooled analysis over all the environments among male parents, HJ 541 (181.7 g) and G 46 (155.4 g) and among female parents, 196.7 g (467A) and 214.2 g (56A) showed maximum green fodder yield per plant and the crosses 222.1 g (467A X G 46) obtained maximum green fodder yield per plant, followed by 220.8 g (465A X HJ 513) and 198.3 g (14A X G 46).

The range for dry fodder yield varied from 38.3 g (467A X HJ 541) to 68.3 g (467A X G 46) with mean of 53.3 g in E_1; from 38.3 g (9A X HJ 541) to 68.3 g (465A X HJ 513) with mean 53.6 g in E_2; from 36.7 g (56A X HJ 541) to 61.7 g (467A X G 46) with mean of 48.4 g in E_3 and from 36.7 g (14A X HJ 513) to 61.7 g (9A X HJ 541) with mean of 47.0 g in E_4 on the basis of pooled analysis of first cut and second cut . On the basis of pooled analysis over all the four test environments among male parents, HJ 541 (48.3 g) and G 46 (45.8 g) and among female parents, 55.4 g (467A) and 54.2 g (56A) showed maximum dry fodder yield per plant and the crosses 61.7 g (467A X G 46) obtained maximum dry fodder yield, followed by 57.9 g (465A X HJ 513) and 56.7 g (14A X G 46). Similar results have been reported by Fouman *et. al* (2003), Iyanar, and Khan *al* (2004), Gore *et. al* (2004), Agarwal and Shrotria *et. al* (2005), Satpute *et. al* (2005).

Heterosis estimates over both the checks in all four test environments for different characters of 24 hybrid combinations is presented in Table 4. Economic heterosis range for plant height was varied from -33.3 % to 27.8 %. Maximum heterosis over the first check (SSG 59-3) for plant height as comparison with all the four environments was showed by 31A × G 46 (27.8 %) followed by 56A × G 46 (22.8 %), 467A × HJ 513 (21.3 %) and 14A × IS 2389 (20.1 %) and over the second check (MFSH 4) for plant height was showed by 31A × G 46 (9.0 %) and 467A × IS 2389 (8.6 %).

Economic heterosis range for number of tillers was varied from -66.7 % to 40.0 %. Maximum heterosis over the first check (SSG 59-3) for number of tillers as comparison with all the four environments was sown by 31A × G 46 (40.0 %) and 14A × IS 2389 (40.0) and over the second check (MFSH 4) for plant this character was showed by 14A × IS 2389 (6.2 %).

Economic heterosis range for leaf length was varied from -30.2 % to 29.4 %. Maximum heterosis over the first check (SSG 59-3) for leaf length as comparison with all the four environments was sown by 31A × HJ 513 (29.4 %) followed by 14A × G 46 (27.4 %), 56A × G 46 (23.1 %) and 31A × G 46 (22.4 %) and over the second check (MFSH 4) for leaf length was showed by 31A × HJ 513 (18.4 %) followed by 14A × G 46 (17.7 %) and 14A × IS 2389 (15.9 %).

Economic heterosis range for leaf breadth was varied from -20.3 % to 75.2 %. Maximum

Table 5. Promising crosses for green and dry fodder yield and related traits on the basis of economic heterosis in single cut of forage sorghum

S.N.	Hybrids	Env.	Ch.	GFY	DFY	PH	TT	LL	LB	SD
1	9A × IS 2389	E2	Ch. 1	81.1	46.4	-2.5	-4.1	-14.2	60.6	38.9
2	465A × HJ 513	E1	Ch. 1	80.7	57.7	17.5	-55.6	10.3	48.3	-8.3
3	465A × HJ 513	E2	Ch. 1	77.8	46.4	-3.0	-40.2	14.7	43.1	27.4
4	9A × IS 2389	E2	Ch. 2	75.3	41.4	-16.9	-28.6	-20.2	41.9	15.5
5	465A × HJ 513	E2	Ch. 2	72.1	41.4	-17.3	-57.1	6.6	26.5	5.9
6	9A × HJ 541	E4	Ch. 1	69.4	37.0	-9.6	-66.7	-6.5	-4.3	11.9
7	465A × HJ 513	E1	Ch. 2	69.1	36.7	29.8	-55.6	10.7	37.8	-5.5
8	56A × HJ 513	E1	Ch. 1	65.9	57.7	4.1	-66.7	-5.1	57.2	25.4
9	467A × G 46	E4	Ch. 1	64.7	29.6	-9.8	-55.6	19.2	14.8	31.9
10	14A × G 46	E1	Ch. 1	63.6	53.8	-13.6	-55.6	0.9	44.8	2.5

PH = Plant Height; TT =No. of Tillers per plant; LL = Leaf Length (cm)
LB = Leaf Breadth (cm); SD = Stem Diameter (cm); GFY = Green Fodder Yield (g per plant)
Ch. = Checks; Env. = Environments; DFY = Dry Fodder Yield (g per plant)

heterosis over the first check (SSG 59-3) for leaf breadth as comparison with all the four environments was showed by 465A × HJ 541 (75.2 %) followed by 467A × HJ 513 (69.1 %), 14A × HJ 513 (65.7 %), 14A × HJ 541 (65.5 %) and 14A × IS 2389 (64.8 %) and over the second check (MFSH 4) for leaf breadth was showed by 467A × HJ 513 (57.1 %) followed by 14A × HJ 541 (53.8 %), and 14A × IS 2389 (53.2%).

Economic heterosis range for stem diameter was varied from -20.4 % to 71.8 %. Maximum heterosis over the first check (SSG 59-3) for stem diameter as comparison with all the four environments was showed by 9A × HJ 541 (71.8 %) followed by 465A × HJ 541 (67.4 %), 9A × G 46 (67.4 %) and 467A × HJ 541 (58.9 %) and over the second check (MFSH 4) for stem diameter was showed by 914A × HJ 513 (58.0%) followed by 465A × HJ 541 (54.1 %) and 9A × G 46 (54.1).

Economic heterosis range for green fodder yield was varied from -30.3% to 81.1 %. Maximum heterosis over the first check (SSG 59-3) for green fodder yield as comparison with all the four environments was showed by 9A × IS 2389 (81.1 %) followed by 465A × HJ 513 (80.7 %) and 9A × HJ 541 (69.4 %) and over the second check (MFSH 4) for green fodder yield was showed by 9A × IS 2389 (75.3 %) followed by 465A × HJ 513 (72.1 %), and 9A × HJ 541 (56.5%).

Economic heterosis range for dry fodder yield was varied from -29.2% to 57.7 %. Maximum heterosis over the first check (SSG 59-3) for dry fodder yield as comparison with all the four environments was showed by 467A × G 46 (57.7 %), 465A × HJ 513 (57.7 %), 56A × HJ 513 (57.7 %) followed by and 14A × G 46 (51.02 %) and over the second check (MFSH 4) for dry fodder yield was showed by 9A × IS 2389 (53.8 %) and 9A × IS 2389 (53.8%).

Maximum heterosis over the first check (SSG 59-3) for green fodder yield as comparison with all the four environments was showed over both the checks (SSG 59-3 and MFSH 4) by 9A × IS 2389 (81.1 % and 75.3 % respectively). Alongwith green fodder yield hybrid 9A × IS 2389 is also better for dry fodder yield (46.4 %) and leaf breadth (60.6 %).

Hybrid 465A × HJ 513 demonstrate better heterosis for green fodder yield (80.7 %) as well as for dry fodder yield (57.7 %). This is also better for plant height (17.5 %), leaf length (10.3 %) and leaf breadth (48.3 %). Hybrid 56A × HJ 513 show better heterosis for green fodder yield (65.9 %) as well as for dry fodder yield (57.7 %). This is also better for leaf breadth (57.2 %) and stem diameter (25.4 %).

Hybrid 467A × G 46 show better heterosis for green fodder yield (64.7 %) as well as for dry fodder yield (29.6 %). This is also better for leaf length (19.2 %), leaf breadth (14.8 %) and stem diameter (31.9 %).Thus these crosses can be used for development of hybrids. The study also reveals good scope for commercial exploitation of heterosis.

Similar results have been reported by Abo *et. al* (2005), Premalatha *et. al* (2006), Kamdi *et. al* (2011), Bibi *et. al* (2012), Pandey *et. al* (2013) and Prabhakar *et. al* (2013).

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