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Heterosis for yield and its component characters in fodder sorghum (*Sorghum bicolor* L. Moench)

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Abstract
The present study was conducted to investigate the possibility of exploiting heterosis in breeding for improved fodder yield in sorghum. Three cytoplasmic male sterile lines and twelve testers were crossed in a line × tester mating design. A total of thirty six F_1 hybrids along with fifteen parents were evaluated for days to 50 % flowering, plant height, number of leaves, leaf length, leaf width, stem diameter, leaf: stem ratio, total soluble solid (TSS%), HCN content, green and dry fodder yield/plant. Among the thirty six hybrid combinations, 19 and 27 crosses had registered positive and significant heterobeltiosis and standard heterosis, respectively for green fodder yield. In case of dry fodder yield, 29 and 19 crosses depicted positive and significant heterobeltiosis and standard heterosis, respectively. The high standard heterotic hybrids for green fodder yield *viz,* AKMS 14A x CSV 21F, AKMS 14A x GFS 3, AKMS 14A x GFS 4, 2219A x HC 308 and AKMS 14A x GFS 5, also registered high positive and significant heterosis for yield attributing traits. The 2219A x SRF 289, AKMS 14A x GFS 5, 2219A x GFS 4, AKMS 14A x PANT CHARI 23 and 296A x SRF 305 depicted as promising heterotic hybrids for higher yield coupled with better quality like low HCN content and TSS%. While 296A x GFS 4, AKMS 14A x SRF 305, 2219A x HC 308, AKMS 14A x GFS 4, 2219A x SRF 289 and 296A x SRF 305 were for early flowering coupled with high green fodder yield and better or average performance for low HCN content.

Keywords: Sorghum, line × tester, fodder yield, heterosis

Introduction
Sorghum (Sorghum bicolor L. Moench) is an important dry land cereal crop cultivated over 47 million ha in 68 countries in the world. It is the fifth major cereal crop in the world after wheat, rice, maize and barley. It is one of the most important food and feed crops of India. The demand for fodder sorghum is fast increasing. To meet out the demand the increase in the production should come from same or even less area in the present situation of shrinking agricultural land. The fodder yield is the primary trait targeted for improvement of fodder sorghum productivity through exploitation of heterosis. In crops like sorghum with the availability of a large number of diversified cytosteriles, exploitation of heterosis for high yield potential is very easy.

Materials and Methods
The experimental materials comprised Three male sterile lines (AKMS 14A, 296A, and 2219A) were crossed with 12 testers (GFS 3,GFS 4, GFS 5, CSV 21F, GJ 39, HC 308, SRF 305, PANT CHARI 23, SSG 59-3, SRF 283, SRF 289 and SRF 335) in a L x T mating design during *Rabi* 2014. The parental line selection criteria were based on characters contributing to increased fodder yield and its component traits. Thirty six F_1 hybrids along with their 15 parents and one standard check *viz.*, CSH-13 were grown in a randomized block design with three replications during *kharif* 2015 at Main Sorghum Research Station, Navsari Agricultural University, Surat. Both parents and F_1 were raised each in one row with spacing of 30cm. The biometrical observations on fodder yield and other related components *viz.*, days to 50% flowering, plant height, number of leaves, leaf length, leaf width, stem diameter, leaf: stem ratio, TSS %, HCN content, green fodder yield and dry fodder yield were recorded on five randomly selected plants from each of the three replications at the time of harvesting. Heterobeltiosis and standard heterosis were estimated and tested by working out the standard errors as suggested by Fonseca and Patterson, 1968 [7], Meredith and Bridge, 1972 [13].

Results and discussion
Knowledge on the magnitude of heterosis for various characters is essential to locate better combinations to exploit them through heterosis breeding.

The measures of heterosis over better parent (heterobeltiosis) and standard check (standard heterosis) are better rational parameters for assessing its practical utility. Therefore, in present investigation heterosis is reported over better parent and standard check (CSH 13). Negative heterosis is considered as desirable for days to 50% flowering, Stem diameter and HCN content while for other characters positive heterosis was considered as desirable. Several workers reported substantial heterosis for various agronomic characters. The present study is an attempt to assess the possibilities of commercial exploitation of heterosis. The results in these directions are discussed in following ways. The value of percentage heterosis of hybrids for all the eleven traits over better and standard parent is given in the Table 1, 2 and 3.

Early flowering is a desirable feature of a genotype. Therefore, negative heterosis for days to 50% flowering was considered desirable. There is tremendous variation for blooming in fodder sorghum. It is due to interaction between genotypes, temperature and photoperiod. The early blooming in the hybrids may be due to their higher rate of growth. This is because the meristem of the hybrids became larger than those of parents in a shorter period and earliness could be result in hybrids (Qainby, 1973). The results of early blooming can be justified due to the fact that earliness is reported to be governed by dominant allele and F_1 is the generation in which maximum accumulation of dominant alleles take place (Liang, 1966) [11]. Heterobeltiosis for this trait ranged from -32.91 (296A x GFS 5) to 4.15 (2219A x CSV 21F) per cent and out of 36 hybrids, 22 hybrids depicted significantly negative heterobeltiosis. While in standard heterosis over CSH-13, ranged from -28.97 (296A x GJ 39) to 5.61 (2219A x CSV 21F) per cent and 20 hybrids recorded significantly negative standard heterosis. The results are in agreement with the findings of Parmar (1997) [15]; Prakash *et al.* (2010) [19] and Ramesh *et al.* (2006) [22] who have also reported heterosis for early flowering.

Cooner and Karper (1927) [4] were the first to report heterosis for plant height. Heterobeltiosis for plant height ranged from -33.33 (296A x GJ 39) to 50.48 (2219A x SRF 283) per cent and out of 36 hybrids, 13 hybrids depicted significantly positive heterobeltiosis. While in standard heterosis over CSH-13, ranged from 31.36 (AKMS 14A x SRF 283) to 61.48 (2219A x GFS 4) per cent and all the 36 hybrids exhibited significantly positive standard heterosis. Other workers *viz.*, Grewal *et al.* (2003) [8]; Khapre *et al.* (2007) [10] and Arun Bhatt (2008) [2] also observed tallness in hybrids as compared to their respective parents.

The range of heterosis over better parent for number of leaves per plant were recorded -19.41 (2219A x SRF 283) to 84.09 (AKMS 14A x CSV 21F) per cent and out of 36 hybrids, 12 hybrids depicted significantly positive heterobeltiosis. While in standard heterosis over CSH-13, ranged from 20.93 (2219A x GFS 5) to 88.37 (AKMS 14A x CSV 21F) per cent and 13 hybrids exhibited significantly positive standard heterosis. These findings are akin to the results of Shouny *et al*. (1990) [23] and Desai *et al.* (1999) [6]; who have reported heterosis for green as well as dry fodder yield.

Heterosis for leaf length, ranged from-22.80 (2219A x SRF 289) to 82.61 (296A x PANT CHARI 23) per cent and -7.29 (2219A x GJ 39) to 81.25 (AKMS 14A x HC 308) per cent over better parent and standard check respectively. Out of 36 hybrids, 15 hybrids and 18 hybrids recorded significantly positive heterobeltiosis and standard heterosis respectively. The positive heterotic effects observed under the present study for leaf length are in correspondence to those of Bhatt (2009) [3] and Prakash *et al.* (2010) [19].

Heterosis for leaf width, ranged from -39.73 (2219A x GJ 39) to 61.11 (296A x HC 308) per cent and -28.26 (2219A x PANT CHARI 23) to 41.85 (296A x HC 308) per cent over better parent and standard check respectively. Out of 36 hybrids, five hybrids and six hybrids recorded significantly positive heterobeltiosis and standard heterosis respectively. The positive heterotic effects observed under the present study for leaf width are in correspondence to those of Prakash *et al.* (2010) [19].

Negative heterotic value is desirable for stem diameter. The range of heterosis for stem diameter over better parent and standard check was from -38.41 (AKMS 14A x SRF 335) to 82.22 (2219A x SRF 305) per cent and -32.54 (AKMS 14A x SRF 335) to 48.41 (296A x PANT CHARI 23) per cent respectively. Out of 36 hybrids, five hybrids and one hybrid (AKMS 14A x SRF 335) recorded significantly negative heterobeltiosis and standard heterosis respectively. These findings are in accordance with Lodhi *et al.* (1978) [7]; Agarwal and Shrotria (2005) [1] and Prakash *et al.* (2010) [19].

Heterobeltiosis for leaf: stem ratio ranged from -56.25 (2219A x SRF 305) to 10.00 (2219A x HC 308) per cent and out of 36 hybrids, none of the hybrids depicted significantly positive heterobeltiosis. While in standard heterosis over CSH-13, ranged from -18.84 (2219A x SRF 305) to 105.80 (AKMS 14A x CSV 21F) per cent and 20 hybrids exhibited significantly positive standard heterosis. The positive heterotic effects observed in the present investigation are in accordance with the findings of Parmar (1997) [15] and Patel *et al.* (2006a) [17].

The magnitude of heterosis for total soluble solid (TSS %), ranged from -57.21 (296A x GJ 39) to 75.58 (2219A x GFS 5) per cent and -26.97 (296A x GJ 39) to 70.66 (2219A x SRF 289) per cent over better parent and standard check respectively. Among the 36 hybrids, five and fifteen hybrids recorded significantly positive heterobeltiosis and standard heterosis respectively. The positive heterosis observed under the present study is in agreement with those reported by Grewal *et al.* (2003) [8] and Tariq *et al.* (2014) [26-27].

HCN content is the anti nutritional factor for which negative heterotic value is desirable. The range of heterosis for HCN content over better parent and standard check was from -14.24 (AKMS 14A x HC 308) to 24.54 (2219A x GFS 3) per cent and -21.15 (AKMS 14A x HC 308) to -1.30 (2219A x GFS 3) per cent respectively. Out of 36 hybrids, two hybrids and 22 hybrids (AKMS 14A x SRF 335) recorded significantly negative heterobeltiosis and standard heterosis respectively. The negative heterosis observed under the present study is in agreement with those reported by Mungra *et al.* (2011) [14]; and Tariq *et al.* (2014) [26-27].

The magnitude of heterosis for green fodder yield, ranged from -30.02 (2219A x GJ 39) to 69.98 (2219A x HC 308) per cent and -15.67 (2219A x GJ 39) to 112.54 (AKMS 14A x CSV 21F) per cent over better parent and standard check respectively. Among the 36 hybrids, 19 and 27 hybrids were depicted significant heterobeltiosis and standard heterosis in desirable direction, respectively. The results are in agreement with the results reported by Shouny *et al*. (1990) [23] and Tariq *et al.* (2014) [26-27] for heterobeltiosis and Agarwal and Shrotria (2005) [1] and Arun Bhatt (2008) [2] for heterobeltiosis and standard heterosis.

Heterobeltiosis for dry fodder yield ranged from -9.09 (2219A x GJ 39) to 179.69 (296A x GFS 4) per cent and out of 36 hybrids, 29 hybrids depicted significant positive heterobeltiosis. While in standard heterosis over CSH-13, ranged from -40.30 (2219A x GJ 39) to 79.10 (2219A x GFS 5) per cent and 19 hybrids exhibited significantly positive standard heterosis. The results are in agreement with the report of Khapre *et al.* (2007) [10]; Arun Bhatt (2008) [2] and Jain and Patel (2014) [9].

A comparative study of most heterotic crosses for green fodder yield with heterobeltiosis and standard heterosis for various yield components (Table 4) revealed that the hybrid, AKMS 14A x CSV 21F expressing highest significant positive standard heterosis for green fodder yield, it has also manifested significant standard heterosis for related yield components *viz.*, plant height, number of leaves per plant, leaf length and leaf: stem ratio. Similar trend was also observed in remaining top four heterotic hybrids for green fodder yield *viz*. AKMS 14A x GFS 3, AKMS 14A x GFS 4, 2219A x HC 308 and AKMS 14A x GFS 5. Thus, heterosis for yield was reflected in the simultaneous heterosis of yield attributing traits. This can be exploited under development of fodder sorghum hybrids, after sufficient testing along with commercial hybrids/varieties.

Among the promising hybrids (Table 5) for green fodder yield, 2219A x SRF 289, AKMS 14A x GFS 5, 2219 A x GFS 4, AKMS 14A x PANT CHARI 23 and 296A x SRF 305 also found high heterotic in desirable direction for quality characters like low HCN content and TSS% while AKMS 14A x HC 308 for HCN content. The 296A x GFS 4, AKMS 14A x SRF 305, 2219A x HC 308, AKMS 14A x GFS 4, 2219A x SRF 289, 296A x SRF 305 were reported high significant standard heterosis for early flowering coupled with green fodder yield and better or average performance for low HCN content, these may be tested for development of short duration hybrids. The earlier workers have also observed reflection of high heterosis in green fodder yield per plant through heterosis for various yield attributing traits *viz.* plant height (Dangi and Paroda, 1979; Bhatt 2009 and Patel 2011) [5, 3, 11], number of leaves per plant (Patel *et al.*1997; Sumalini *et al.* 2005 and Premalatha *et al.* 2006) [24, 16], leaf length (Bhatt 2009) [3], leaf: stem ratio (Lodhi *et al.*1978; Patel *et al.*1997) [7, 16]. Thus, high heterotic response for green fodder yield coupled with high heterosis for its attributing traits reported by above workers confirm the present finding.

Table 1: Percentage of heterosis for Days to 50% flowering, Plant height, No of leaves per plant and Leaf length

Hybrids	Days to 50% flowering		Plant height		No of leaves per plant		Leaf length (cm)	
	BP	SC	BP	BP	SC	SC	BP	SC
AKMS 14A x GFS 3	-4.59	-2.80	-7.96	24.39 **	59.38 **	83.72 **	24.39 **	59.38 **
AKMS 14A x GFS 4	-16.51 **	-14.95 *	-5.16	38.68 **	53.13 **	76.74 **	38.68 **	53.13 **
AKMS 14Ax GFS 5	-13.25 *	-5.14	-20.66 **	15.00 *	43.75 **	69.77 **	15.00 *	43.75 **
AKMS 14A x CSV 21F	1.83	3.74	-20.90 **	33.33 **	75.00 **	88.37 **	33.33 **	75.00 **
AKMS 14A x GJ 39	-13.76 *	-12.15 *	-21.50 **	-12.26	-3.13	16.28	-12.26	-3.13
AKMS 14A x HC 308	-10.09	-8.41	7.22	45.00 **	81.25 **	13.95	45.00 **	81.25 **
AKMS 14A x SRF 305	-26.15 **	-24.77 **	-4.72	1.89	12.5	10.85	1.89	12.5
AKMS 14A x PANT CHARI 23	0.00	1.87	27.50 **	52.83 **	68.75 **	81.40 **	52.83 **	68.75 **
AKMS14A x SSG 59-3	-27.06 **	-25.70 **	14.99 **	-0.94	9.38	17.83	-0.94	9.38
AKMS 14A x SRF 283	-19.72 **	-18.22 **	10.83	-8.11	6.25	9.30	-8.11	6.25
AKMS 14A x SRF 289	-21.05 **	-15.89 *	2.08	-7.65	18.75 *	6.98	-7.65	18.75 *
AKMS 14A x SRF 335	-7.46	-1.40	28.75 **	-13.51 *	0.00	17.05	-13.51 *	0.00
296 A x GFS 3	-10.23	-9.81	-7.08	31.71 **	68.75 **	81.40 **	31.71 **	68.75 **
296 A x GFS 4	-0.49	-5.61	-8.92 *	43.48 **	37.50 **	6.20	43.48 **	37.50 **
296 Ax GFS 5	-32.91 **	-26.64 **	-15.70 **	30.00 **	62.50 **	79.07 **	30.00 **	62.50 **
296 A x CSV 21F	0.00	1.40	-29.10 **	9.52	43.75 **	69.77 **	9.52	43.75 **
296 A x GJ 39	-25.49 **	-28.97 **	-33.33 **	39.68 **	37.50 **	55.81 **	39.68 **	37.50 **
296 A x HC 308	-18.23 **	-22.43 **	2.06	22.50 **	53.13 **	41.86 **	22.50 **	53.13 **
296 A x SRF 305	-14.95 *	-14.95 *	-13.05 **	52.24 **	59.38 **	24.81 *	52.24 **	59.38 **
296 A x PANT CHARI 23	-13.79 *	-18.22 **	31.25 **	82.61 **	75.00 **	65.12 **	82.61 **	75.00 **
296 A x SSG 59-3	3.94	-1.40	21.30 **	-1.54	0.00	13.18	-1.54	0.00
296 A x SRF 283	-3.45	-8.41	45.48 **	5.41	21.88 **	10.08	5.41	21.88 **
296 A x SRF 289	-17.54 **	-12.15 *	18.94 **	-19.81 **	3.13	12.40	-19.81 **	3.13
296 A x SRF 335	-26.32 **	-21.50 **	31.61 **	4.05	20.31 **	17.05	4.05	20.31 **
2219 A x GFS 3	-1.40	-0.93	-6.19	34.15 **	71.88 **	60.47 **	34.15 **	71.88 **
2219 A x GFS 4	-6.64	-7.94	2.35	20.46 *	9.17	16.28	20.46 *	9.17
2219 A x GFS 5	-20.94 **	-13.55 *	-23.83 **	-21.08 **	-1.35	20.93 *	-21.08 **	-1.35
2219 A x CSV 21F	4.15	5.61	-27.61 **	-17.46 **	8.33	16.28	-17.46 **	8.33
2219 A x GJ 39	-9.48	-10.75	-26.93 **	-5.82	-7.29	11.63	-5.82	-7.29
2219 A x HC 308	-19.43 **	-20.56 **	4.12	-12.58 *	9.27	4.65	-12.58 *	9.27
2219 A x SRF 305	-15.42 *	-15.42 *	-8.49	3.48	8.33	-0.78	3.48	8.33
2219 A x PANT CHARI 23	-20.85 **	-21.96 **	27.71 **	15.52	4.69	3.88	15.52	4.69
2219 A x SSG 59-3	-18.01 **	-19.16 **	11.83 *	-7.18	-5.73	0.00	-7.18	-5.73
2219 A x SRF 283	-22.75 **	-23.83 **	50.48 **	-13.15 *	0.42	6.20	-13.15 *	0.42
2219 A x SRF 289	-28.95 **	-24.30 **	17.42 **	-22.80 **	-0.73	10.85	-22.80 **	-0.73
2219 A x SRF 335	-13.16 *	-7.48	24.30 **	-5.77	8.96	3.88	-5.77	8.96
S.E m ±	4.30	4.30	9.03	4.73	4.73	0.89	4.73	4.73
CD at 5%	8.57	8.57	18.02	9.44	9.44	1.78	9.44	9.44
Range	-32.91 to 4.15	-28.97 to 5.61	-33.3 to 50.48	-22.80 to 82.61	-7.29 to 81.25	20.9 to 88.37	-22.80 to 82.61	-7.29 to 81.25

*, ** indicates significance at 5% and 1% levels, respectively

Table 2: Percentage of heterosis for Leaf width, Stem diameter, L: Stem ratio and TSS%

Hybrids	Leaf width (cm)		Stem diameter (cm)		Leaf : Stem ratio		TSS %	
	BP	SC	BP	BP	SC	SC	BP	SC
AKMS 14A x GFS 3	-34.72 **	-28.26 **	-4.93	-14.68	-5.19	95.65 **	-14.68	-5.19
AKMS 14A x GFS 4	-32.39 **	-21.74 *	-24.24 **	14.96	22.71 *	44.93 **	14.96	22.71 *
AKMS 14Ax GFS 5	-14.71	-5.43	-1.52	-15.29 *	6.63	88.41 **	-15.29 *	6.63
AKMS 14A x CSV 21F	-18.75	-15.22	2.16	-1.80	19.65 *	105.80 **	-1.80	19.65 *
AKMS 14A x GJ 39	-8.22	9.24	-46.53 **	-30.94 **	17.87 *	11.59	-30.94 **	17.87 *
AKMS 14A x HC 308	-25.00 *	-21.74 *	-40.15 **	-42.44 **	1.33	14.49	-42.44 **	1.33
AKMS 14A x SRF 305	3.60	17.39	0.00	-7.05	4.03	91.30 **	-7.05	4.03
AKMS 14A x PANT CHARI 23	-28.13 **	-25.00 *	-45.45 **	13.28	20.92 *	4.35	13.28	20.92 *
AKMS14A x SSG 59-3	15.62	20.65 *	-24.24 **	-9.23	-3.11	44.93 **	-9.23	-3.11
AKMS 14A x SRF 283	-20.00 *	-16.52	-32.58 **	-19.91 **	7.55	28.99 *	-19.91 **	7.55
AKMS 14A x SRF 289	-9.38	-5.43	-12.12	-7.05	15.5	68.12 **	-7.05	15.5
AKMS 14A x SRF 335	6.25	10.87	-35.61 **	-13.31	12.62	23.19	-13.31	12.62
296 A x GFS 3	-34.72 **	-28.26 **	-42.96 **	-25.75 **	-17.23	17.39	-25.75 **	-17.23
296 A x GFS 4	-32.39 **	-21.74 *	-13.68	10.29	22.94 *	46.38 **	10.29	22.94 *
296 Ax GFS 5	-17.65	-8.70	-21.01 **	-20.01 **	0.69	36.23 **	-20.01 **	0.69
296 A x CSV 21F	-25.81 *	-25.00 *	-5.76	-7.14	13.14	89.86 **	-7.14	13.14
296 A x GJ 39	6.85	27.17 *	-50.00 **	-57.21 **	-26.97 **	4.35	-57.21 **	-26.97 **
296 A x HC 308	61.11 **	41.85 **	-32.48 **	-52.03 **	-15.56	14.49	-52.03 **	-15.56
296 A x SRF 305	17.99	33.70 **	-10.94	6.69	19.42 *	65.22 **	6.69	19.42 *
296 A x PANT CHARI 23	-7.41	-18.48	-15.38 *	11.63	24.44 **	43.48 **	11.63	24.44 **
296 A x SSG 59-3	44.44 **	27.17 *	9.84	-8.58	1.90	94.20 **	-8.58	1.90
296 A x SRF 283	27.78 *	12.50	-18.80 *	-17.34 **	11.01	37.68 **	-17.34 **	11.01
296 A x SRF 289	0.00	-11.96	-6.06	-19.57 **	-0.06	79.71 **	-19.57 **	-0.06
296 A x SRF 335	33.33 **	17.39	-41.88 **	-27.06 **	-5.24	-1.45	-27.06 **	-5.24
2219 A x GFS 3	-16.91	-8.70	-45.77 **	-4.56	6.05	11.59	-4.56	6.05
2219 A x GFS 4	-4.23	10.87	2.04	75.58 **	40.06 **	44.93 **	75.58 **	40.06 **
2219 A x GFS 5	16.18	28.80 **	-40.34 **	-32.05 **	-14.47	2.90	-32.05 **	-14.47
2219 A x CSV 21F	1.61	2.72	-42.45 **	9.93	33.95 **	15.94	9.93	33.95 **
2219 A x GJ 39	-39.73 **	-28.26 **	-43.75 **	-44.34 **	-5.01	17.39	-44.34 **	-5.01
2219 A x HC 308	7.69	-8.70	10.00	-30.39 **	22.54 *	59.42 **	-30.39 **	22.54 *
2219 A x SRF 305	-10.79	1.09	-56.25 **	21.88 **	36.43 **	-18.84	21.88 **	36.43 **
2219 A x PANT CHARI 23	2.33	-28.26 **	-45.19 **	52.54 **	49.11 **	-17.39	52.54 **	49.11 **
2219 A x SSG 59-3	8.53	-23.91 *	-46.72 **	23.95 *	18.73 *	-5.80	23.95 *	18.73 *
2219 A x SRF 283	19.12	-11.96	1.06	-8.24	23.23 **	37.68 **	-8.24	23.23 **
2219 A x SRF 289	0.71	-23.37 *	-42.42 **	37.34 **	70.66 **	10.14	37.34 **	70.66 **
2219 A x SRF 335	34.88 *	-5.43	-1.71	-29.72 **	-8.70	66.67 **	-29.72 **	-8.70
S.E m ±	0.63	0.63	0.03	0.50	0.50	0.03	0.50	0.50
CD at 5%	1.26	1.26	0.06	1.01	1.01	0.06	1.01	1.01
Range	-39.73 to 61.11	-28.26 to 41.85	-56.25 to 10.00	-57.21 to 75.58	-26.97 to 70.66	-18.84 to 105.80	-57.21 to 75.58	-26.97 to 70.66

*, ** indicates significance at 5% and 1% levels, respectively

Table 3: Percentage of heterosis for HCN content, green and dry fodder yield / plant in fodder sorghum

Hybrids	HCN content (ppm)		Green fodder yield /plant		Dry fodder yield/plant (g)	
	BP	SC	BP	SC	BP	SC
AKMS 14A x GFS 3	9.86	-6.57	69.59 **	109.69 **	131.63 **	69.40 **
AKMS 14A x GFS 4	4.12	-3.09	65.44 **	104.56 **	167.50 **	59.70 **
AKMS 14Ax GFS 5	-7.97	-12.93 *	49.04 **	100.00 **	126.44 **	47.01 **
AKMS 14A x CSV 21F	9.17	-7.16	44.85 **	112.54 **	86.51 **	75.37 **
AKMS 14A x GJ 39	6.10	-4.63	-5.99	16.24 *	82.50 **	8.96
AKMS 14A x HC 308	-14.24 *	-21.15 **	50.92 **	86.61 **	119.80 **	65.67 **
AKMS 14A x SRF 305	-2.99	-8.49	9.91	35.90 **	111.90 **	32.84 *
AKMS 14A x PANT CHARI 23	-4.85	-17.99 **	38.48 **	71.23 **	173.75 **	63.43 **
AKMS14A x SSG 59-3	-5.47	-16.74 **	-11.29	9.69	81.25 **	8.21
AKMS 14A x SRF 283	9.77	-4.90	1.38	25.36 **	102.50 **	20.9
AKMS 14A x SRF 289	-4.88	-14.93 **	-28.34 **	-11.40	26.25	-24.63
AKMS 14A x SRF 335	-6.08	-16.50 **	-19.35 **	-0.28	40.00	-16.42
296 A x GFS 3	-10.52	-15.78 **	9.18	32.19 **	131.63 **	69.40 **
296 A x GFS 4	-2.40	-8.14	27.27 **	11.68	179.69 **	33.58 **
296 Ax GFS 5	-10.98	-15.78 **	9.98	47.58 **	94.25 **	26.12 *
296 A x CSV 21F	-11.39	-16.60 **	-8.74	33.90 **	42.06 **	33.58 **
296 A x GJ 39	0.71	-5.22	-1.55	8.55	43.66	-23.88
296 A x HC 308	-3.96	-9.61	7.69	23.65 **	81.19 **	36.57 **
296 A x SRF 305	-7.76	-12.99 *	35.21 **	64.10 **	89.29 **	18.66
296 A x PANT CHARI 23	-9.22	-14.56 **	42.21 **	24.79 **	82.86 **	-4.48
296 A x SSG 59-3	-7.05	-12.52 *	25.65 **	10.26	78.13 **	-14.93
296 A x SRF 283	-10.86	-16.10 **	-13.70	-10.26	95.65 **	0.75

296 A x SRF 289	-12.68 *	-17.82 **	14.40	26.78 **	122.86 **	16.42
296 A x SRF 335	-0.28	-6.15	49.68 **	31.34 **	171.21 **	33.58 **
2219 A x GFS 3	24.54 **	-1.30	35.06 **	63.53 **	144.90 **	79.10 **
2219 A x GFS 4	-9.63	-15.89 **	47.52 **	77.78 **	147.73 **	62.69 **
2219 A x GFS 5	-7.49	-12.48 *	17.83 **	58.12 **	132.95 **	52.99 **
2219 A x CSV 21F	9.68	-16.07 **	1.17	48.43 **	76.98 **	66.42 **
2219 A x GJ 39	-6.78	-16.21 **	-30.02 **	-15.67	-9.09	-40.30 **
2219 A x HC 308	-1.78	-9.70	69.98 **	104.84 **	128.71 **	72.39 **
2219 A x SRF 305	-4.32	-9.74	35.21 **	64.10 **	29.55	-14.93
2219 A x PANT CHARI 23	1.56	-12.46 *	15.37 *	39.03 **	40.91 *	-7.46
2219 A x SSG 59-3	7.04	-5.72	-24.35 **	-8.83	-7.95	-39.55 **
2219 A x SRF 283	-3.03	-15.99 **	8.27	30.48 **	36.36	-10.45
2219 A x SRF 289	-2.97	-13.22 *	55.08 **	86.89 **	137.50 **	55.97 **
2219 A x SRF 335	-7.30	-17.58 **	29.08 **	55.56 **	71.59 **	12.69
S.E m±	6.76	6.76	9.38	9.38	5.63	5.63
CD at 5%	13.49	13.49	18.71	18.71	11.22	11.22
Range	-14.24 to 24.54	-21.15 to -1.30	-30.02 to 69.98	-15.67 to 112.54	-9.09 to 179.69	-40.30 to 79.10

*, ** indicates significance at 5% and 1% levels, respectively

Table 4: Best heterotic crosses and their performance for green fodder yield and its attributes in fodder sorghum

Best heterotic crosses/hybrids	Heterotic effects													
	Green fodder yield /plant(g)		Plant height(cm)		Number of leaves per plant		Leaf :Stem ratio		Leaf length (cm)		Leaf width (cm)		Stem diameter (cm)	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
AKMS 14 A x CSV 21F	44.85 ** (249)	112.54 **	-20.90** (212)	57.04 **	84.09** (16.2)	88.37**	2.16 (0.48)	105.80 **	33.33** (112)	75.00**	-18.75 (5.2)	-15.22	-18.84 (3.7)	-11.11
AKMS 14A x GFS 3	69.59 ** (245)	109.69 **	-7.96 (208)	54.07 **	68.09** (15.8)	83.72**	-4.93 (0.45)	95.65 **	24.39 ** (102)	59.38 **	-34.72** (4.4)	-28.26**	-21.74 (3.6)	-14.29
2219 A x HC 308	69.98 ** (240)	104.84 **	4.12 (202)	49.63 **	0.00 (9.0)	4.65	10.00 (0.37)	59.42**	-12.58* (70)	9.27	7.69 (5.6)	-8.70	50.00** (5.4)	28.57
AKMS 14Ax GFS 4	65.44 ** (239)	104.56 **	-5.16 (202)	49.63 **	68.89** (15.2)	76.74 **	-24.24** (0.33)	44.93 **	38.68** (98)	53.13 **	-32.39** (4.8)	-21.74**	-28.99** (3.3)	-22.22
AKMS 14A x GFS 5	49.04 ** (234)	100.00 **	-20.66 ** (192)	42.22 **	43.14 ** (14.6)	69.77 **	-1.52 (0.43)	88.41 **	15.00 * (92)	43.75 **	-14.71 (5.8)	-5.43	-34.78** (3.0)	-28.57

* Significant at 5% and ** Significant at 1% probability level. BP: better parent, SC: standard check. Bracket values has indicates parenthesis

Table 5: Promising Hybrids for green fodder yield per plant with Heterobeltiosis, Standard heterosis and their SCA effects and component characters showing significance in fodder sorghum

S. No.	Hybrids	GFY/P (g)	Heterosis		SCA effects	Significant Heterobeltiosis in other traits in desired direction	Significant Standard heterosis in other traits in desired direction
			BP	SH			
1	AKMS 14A x CSV 21F	249	44.85 **	112.54 **	33.30**	PH, NLP, LL & DFY	PH, NLP, LL, L:S, TSS% & DFY
2	AKMS 14A x GFS 3	245	69.59 **	109.69 **	34.85**	NLP, LL, L:S & DFY	PH, NLP, LL & DFY
3	2219 A x HC 308	240	69.98 **	104.84 **	9.96	DF, GFY & DFY	DF, PH, L:S, TSS% & DFY
4	AKMS 14A x GFS 4	239	65.44 **	104.56 **	-21.15**	DF, NLP, LL, SD & DFY	DF, PH, NLP, LL, L:S, TSS% & DFY
5	AKMS 14A x GFS 5	234	49.04 **	100.00 **	-13.70*	DF, NLP, LL, SD & DFY	PH, NLP, LL, L:S, HCN & DFY
6	AKMS 14A x HC 308	218	50.92**	86.61**	7.41	LL, HCN & DFY	PH, LL, HCN & DFY
7	2219 A x SRF 289	218	55.08**	86.89**	24.19**	DF, PH, TSS% & DFY	DF, PH, TSS%, HCN & DFY
8	2219 A x GFS 4	208	47.52**	77.78**	28.96**	LL, TSS% & DFY	PH, L:S, TSS%, HCN & DFY
9	AKMS 14A x PANT CHARI 23	200	38.48**	71.23**	-3.26	PH, NLP, LL & DFY	PH, NLP, LL, TSS%, HCN & DFY
10	296 A x SRF 305	192	35.21**	64.10**	-35.37**	DF, LL & DFY	DF, PH, NLP, LL, LW, L:S, TSS%, HCN

SH: standard heterosis, BP: better parent, SCA: specific combining ability, DF=days to flowering, PH=plant height, NLP=number of leaves per plant, LL=leaf length, LW=leaf width, SD= Stem diameter, L: S=leaf: stem ratio, TSS%=total soluble sugar, HCN=hydrocyanic acid, GFY=green fodder yield per plant, DFY=dry fodder yield per plant.

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