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Effect of Different Environmental Conditions on Sorghum Fodder Yield and Its Related Traits

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ABSTRACT

A study was made in Sorghum bicolor with line × tester (6 females × 4 males) to estimate the fodder yield and its component traits of different hybrids and parents under different environments. 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 59-3 and MFSH 4) were evaluated at two locations (Hisar and Karnal) with 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 the male parents HJ 541 (337.9 g) and G 46 (299.6 g) and in female parents 467A (407.1 g) and 56A (372.3 g) exhibited highest green fodder yield. Among male parents HJ 541 (90.0 g) and G 46 (87.5 g) and among female parents 56A (104.2 g) and 467A (105.4 g) showed highest dry fodder yield. Hybrid 465A × HJ 513 showed maximum green fodder yield (413.1 g) followed by 467A × G 46 (412.2 g), 9A × IS 2389 (370.8 g). This hybrid was also good for dry fodder yield (110.8 g), leaf length (76.5 cm) and leaf breadth (6.2 cm). Maximum dry fodder yield was recorded by the hybrid 467A × G 46 (114.6 g) followed by 465A × HJ 513 (110.8 g) and 9A × IS 2389 (109.6 g). This hybrid was also good for green fodder yield (412.2 g), leaf length (78.9 cm) and stem diameter (15.0 cm).

Key words: *Sorghum bicolor, Environment, Quantitative traits, Green fodder yield, Dry fodder yield*

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] originated in Africa, is one of the five top cereal crops in the world. It is an important staple food for more than 300 million people and feed for cattle in Asia and Africa. It is under cultivation in tropical, subtropical and even in the temperate regions of the world extending throughout the six continents as great millet. Due to its excellent growing habit, high yield potential and better nutritive value, it is greatly favored by all farmers. 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[1].

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At present, livestock population survives to a large extent on crop residues, which are nutritionally poor. Therefore, target of high production and productivity of forage sorghum can be achieved by developing the varieties/hybrids giving high yield per unit area, per unit time and better in quality[13]. Use of morphological characters for cultivar characterization represents an extension of classical taxonomic techniques used for species to cultivar. Availability of genetic variability for the component characters is a major asset for initiating a fruitful crop improvement programme. Sorghum has a significant role in livestock production, particularly in tropical zone where feed stuffs could not meet animal requirements due to many factors such as poor soil fertility and drought[14]. In view, present study was done to identify the high green fodder producing hybrids and parents under different environments.

MATERIALS AND METHOD

The experimental material for the present study comprised of 24 forage sorghum hybrids, 10 parents (six female and four male) and two standard checks (SSG 59-3 and MFSH 4). Hybrids were developed in a Line x Tester mating fashion on six females (lines) using four males (testers). The crosses were made in 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. 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 harvesting of the crop. Data on five randomly taken plants from each genotype in each replication were recorded on different quantitative characters *viz.* Plant height (cm), number of tillers per plant, leaf length (cm), leaf breadth (cm), stem diameter (cm), green fodder yield (g/plant) and dry fodder yield (g/plant) in all the four environments (Table 3 and 4) at first cut (55 days after sowing) and second cut (45 days after first cut). All the recommended cultural packages of practices were followed from sowing to till the crop harvesting.

RESULTS AND DISCUSSION

The mean sums of squares for all the different morphological and quality characters have been presented in Tables 2. On the basis of these tables, it is concluded that the mean sum of squares due to genotypes were highly significant for all the seven characters in all the four test environments (early and late sowing at two locations during *kharif* 2015-16) except number of tillers per plant in E_3 and E_4). This revealed that the genotypes selected for the present investigation were reasonably appropriate for further genetical analysis and estimation of stability as considerable amount of variability existed in the experimental material. Similar results have been reported by Fouman *et al.*[6], Pandey *et al.*[12] and Rani *et al*[15].

The environmental indices, for various traits under all the four test environments have been presented in Tables 1. High and positive environmental index showed that E_1 was the best environment for the expression of plant height, number of tillers per plant, leaf length, leaf breadth, green fodder yield and dry fodder yield while E_2 was the best environment for plant height, number of tillers per plant, leaf breadth, green fodder yield and dry fodder yield. On the other hand, E_3 was favorable for leaf length and stem diameter while E_4 was favorable for plant height, leaf length and stem diameter. Further mean performance of different hybrids in different environments for various characters is given below (Tables 3). Similar results have been reported by Biradar *et. al*[3] and Meshram *et. al*[10]. Progress in plant breeding depends on the extent of genetic variability present in a population. Therefore, the first step in any plant breeding programme is the study of genetic variability, which cannot easily be measured.

Plant height up to the base of flag leaf (cm)

Plant height has a great importance which determines structure and vigour of the plant. The maximum height was shown by the cross 14A × IS 2389 (190.7 cm) followed by 56A × G 46 (178.0 cm) and MFSH 4 [check (168.4 cm)] in E_1; while in E_2, the cross 14A × G 46 (165.3 cm) gained maximum plant height followed by 31A × G 46 (162.2 cm) and 465A × G 46 (155.8 cm). The check MFSH 4 (166.0 cm) exhibited maximum height followed by cross 56A × HJ 513 (163.2 cm) and 56A × HJ 541 (153.5 cm) in E_3; while in E_4, the cross 467A × HJ 513 (165.2 cm) attained maximum plant height, followed by 31A × HJ 513 (164.3 cm) and 31A × IS 2389 (161.5cm) (Table 3). On the basis of overall mean in all the four environments among male parents IS 2389 (154.8 cm) and G 46 (150.3 cm) and among female parents 467A (148.3 cm) and 465A (140.4 cm) showed maximum plant height (Table 4). The check MFSH 4 (159.2 cm) expressed highest plant height followed by 14A × IS 2389 (158.0 cm) and 31A × G 46 (151.0 cm) among crosses (Table 3 and 4). Similar results have been reported by Tilley *et. al.*[18], Grenier *et. al.*[7] and Cunha and Lima[4].

Table 1: Environmental indices for different characters in forage sorghum

Characters / Environment	E_1	E_2	E_3	E_4
Plant height	4.75	5.28	-0.85	1.38
Number of tillers per plant	0.16	0.01	-0.11	-0.06
Leaf length	0.51	-0.87	0.34	0.03
Leaf breadth	0.25	0 .02	-0.14	-0.12
Stem diameter	-0.35	-0.42	0.27	0.50
Green fodder yield	12.62	15.56	-10.42	-17.76
Dry fodder yield	3.61	3.75	-2.92	-4.44

E_1 = Early sowing at Hisar E_2 = Early sowing at Karnal
E_3 = Late sowing at Hisar E_4 = Late sowing at Karnal

Number of tillers per plant

All the tillers which had come out from the base were counted in all the parents as well as hybrids at first cut. The check SSG 59-3 (3.0) showed maximum number of tillers followed by check MFSH 4 (2.7) and crosses 14A × IS 2389 and 14A × HJ 541 (2.2) in E_1; while in E_2, the cross 14A × IS 2389 and check MFSH 4 (2.2) exhibited maximum number of tillers followed by cross 467A× IS 2389 and check SSG 59-3 (2.0). The highest number of tillers was shown by the check SSG 59-3 (2.7) followed by check MFSH 4 (2.3) and cross 56A × HJ 541(1.7) in E_3; while in E_4, the check MFSH 4 obtained maximum number of tillers (2.7) followed by check SSG 59-3 (2.5) and cross 31A × HJ 541 (2.0) (Table 3). As far as parents are concerned among testers, IS 2389 (1.7) and HJ 541 (1.5) and among lines 31A (1.6), 56A, 465A, and 467A (1.5) showed maximum number of tillers (Table 4). The check SSG 59-3 (2.6) recorded maximum number of tillers followed by check MFSH 4 (2.5) and crosses 14A × IS 2389, 31A × IS 2389 and 467A × IS 2389 (1.7) on the basis of overall mean in all the four environments (Table 3 and 4). It is pertinent to mentioned that most of the lines, testers and crosses recorded decreased number of tillers in all the test environments as they had lower number of tillers as compared with checks (SSG 59-3 and MFSH 4) having higher number of tillers. That's why coefficient of variance had higher value for this character. Similar results have been reported by Hoveland and Monson[8], Nagaraja *et. al*[11] and Joshi *et. al*[9].

Leaf length (cm)

The highest leaf length was shown by the cross 14A × IS 2389 (86.7 cm) followed by 465A × G 46 (84.3 cm) and 467A x G 46 (83.5 cm) in E_1; while in E_2, the cross 56A × G 46 (89.3 cm) exhibited highest length followed by crosses 467A X IS 2389 (85.2 cm) and 56A × IS 2389 (84.8 cm). The maximum length was shown by the cross 14A x G 46 (88.2 cm) followed by 31A × G 46 (85.7 cm) and 14A × HJ 541 (84.3 cm) in E_3; while in E_4, the cross 31A × HJ 513 (83.2 cm) attained maximum leaf length followed by 9A x G 46, 56A × IS 2389, 56A x G 46, 465A × IS 2389 and 465A × HJ 541 (82.0 cm) (Table 3). In case of male parents HJ 513 (78.5 cm) and IS 2389 (78.3 cm) and among female parents 9A and 14A (80.5 cm) showed maximum leaf length (Table 4). The cross 56A × G 46 (82.1 cm) exhibited maximum leaf length followed by crosses 465A × IS 2389 (81.3 cm) and 9A × G 46 (80.6 cm) on the basis of overall mean in all the four environments (Table 3 and 4). Similar results have been reported by Zulfiquar and Asim[19], Bhatt and Singh[2] and Dien *et. al*[5].

Table 2: Analysis of variance for different morphological characters in different environments in forage sorghum

SV	D.F.	Env.	PH	TT	LL	LB	SD	GFY	DFY
Replication	2	E_1	55.15	0.24	3.27	0.58	0.57	600.74	66.91
		E_2	53.97	0.30	59.35	0.11	0.46	390.63	124.51
		E_3	31.60	0.15	66.11	0.31	1.47	643.62	53.68
		E_4	72.93	0.19	34.24	0.09	0.31	1513.25	117.89
Treatment	33	E_1	850.27**	0.33*	144.28**	2.52**	16.89**	16105.79**	938.99**
		E_2	549.87**	0.23*	201.23**	1.82**	7.94**	17435.67**	882.45**
		E_3	441.23**	0.15	111.79**	1.21**	15.05**	8246.06**	323.80**
		E_4	401.46**	0.12	107.72**	1.60**	15.63**	8763.31**	489.02**
Error	66	E_1	37.79	0.18	11.37	0.30	1.07	262.86	31.81
		E_2	36.07	0.14	18.35	0.34	0.93	342.14	29.31
		E_3	29.40	0.12	12.80	0.30	1.14	304.17	33.47
		E_4	44.56	0.12	9.42	0.31	0.95	196.70	25.47

D.F. = Degree of freedom * Significant at 5% level **Significant at 1% level
E_1 = Early sowing at Hisar E_2 = Early sowing at Karnal
E_3 = Late sowing at Hisar E_4 = Late sowing at Karnal
PH = Plant height (cm) TT = Total number of tillers per plant
LL = Leaf length (cm)
LB = Leaf breadth (cm) SD = Stem diameter (cm)
Env. = Environments GFY = Green fodder yield per plant (g) DFY = Dry fodder yield per plant (g)

Leaf breadth (cm)

In general, broader leaves were recorded in the cross 465A × HJ 541 (8.1 cm) followed by 14A × IS 2389 (7.7 cm) and 467A × HJ 513 (7.5 cm) in E_1; while in E_2, the cross 14A × HJ 513 (7.3 cm) obtained maximum leaf breadth followed by 31A × G 46 (7.1 cm) and 9A × IS 2389 (7.0 cm). The cross 56A × HJ 541 (7.0 cm) recorded highest leaf breadth followed by 31A × HJ 513 (6.8 cm), 14A × G 46 and 56A × G 46 (6.6 cm) in E_3; while in E_4, the cross 467A × HJ 513 and 31A × HJ 541 (7.0 cm) gained maximum leaf breadth followed by the crosses 467A × IS 2389 and 465A × G 46 (6.6 cm) (Table 3). On the basis of overall mean in all the four environments, among male parents

HJ 513 (6.4 cm) and G 46 (5.8 cm) and female parents 467A (7.0 cm) and 14A (6.5 cm) showed maximum leaf breadth (Table 4). The crosses 31A × HJ 541 and 56A × HJ 541 (6.8 cm) recorded maximum leaf breadth followed by 14A × HJ 513 (6.7 cm), 56A × HJ 513 and 467A × HJ 513 (6.6 cm) (Table 3 and 4). Similar results have been reported by Tilley *et. al.*[18], Joshi *et. al.*[9], Dien *et. al.*[5] and Tariq *et. al*[17].

Table 3: Mean performance of different hybrids under different environments for different characters in forage sorghum

Hybrids	Plant height (cm)					Total number of tillers per plant					Leaf length (cm)				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
9A × HJ 513	138.8	147.8	145.2	130.3	140.5	1.2	1.2	1.3	1.0	1.2	63.3	69.3	81.5	74.2	72.1
9A × HJ 541	146.0	147.2	128.3	125.0	136.6	1.8	1.5	1.5	1.2	1.5	69.2	71.8	72.3	64.3	69.4
9A × IS 2389	156.5	134.0	143.2	125.2	139.7	1.5	1.5	1.3	1.2	1.4	76.7	63.7	81.7	71.0	73.3
9A × G 46	148.7	138.3	144.7	143.8	143.9	2.0	1.7	1.5	1.3	1.6	80.2	81.8	78.3	82.0	80.6
14A × HJ 513	145.7	127.5	125.3	144.2	135.7	1.0	1.3	1.5	1.2	1.3	82.7	73.3	76.3	73.7	76.5
14A × HJ 541	153.0	133.2	137.3	135.7	139.8	2.2	1.7	1.2	1.3	1.6	76.5	64.8	84.3	76.7	75.6
14A × IS 2389	190.7	139.0	151.7	150.7	158.0	2.2	2.2	1.3	1.2	1.7	86.7	68.7	69.7	71.5	74.1
14A × G 46	131.0	165.3	135.8	143.3	143.9	1.2	1.7	1.0	1.5	1.3	77.0	76.2	88.2	72.5	78.5
31A × HJ 513	151.8	138.2	137.2	164.3	147.9	1.7	1.8	1.7	1.2	1.6	71.7	69.7	81.3	83.2	76.5
31A × HJ 541	155.3	129.5	119.3	146.5	137.7	1.5	1.5	1.3	2.0	1.6	57.0	72.7	73.2	80.2	70.8
31A × IS 2389	155.3	137.0	119.3	161.5	143.3	2.0	1.7	1.3	1.7	1.7	67.5	54.8	78.0	81.5	70.5
31A × G 46	164.2	162.2	135.5	142.3	151.0	1.8	1.8	1.0	1.5	1.5	71.5	65.3	85.7	72.3	73.7
56A × HJ 513	155.2	125.2	163.2	140.7	146.0	1.5	1.2	1.5	1.8	1.5	73.2	78.0	74.2	81.7	76.8
56A × HJ 541	135.0	128.3	153.5	129.8	136.7	1.7	1.0	1.7	1.2	1.4	82.0	80.2	64.3	73.2	74.9
56A × IS 2389	136.8	130.8	146.7	152.8	141.8	1.3	1.5	1.2	1.3	1.3	82.0	84.8	71.0	82.0	80.0
56A × G 46	178.0	139.7	152.0	130.7	150.1	1.7	1.2	1.3	1.8	1.5	75.2	89.3	82.0	82.0	82.1
465A × HJ 513	118.3	136.0	137.8	144.5	134.2	1.3	1.0	1.3	1.2	1.2	77.2	81.8	73.7	73.2	76.5
465A × HJ 541	145.8	115.7	136.8	126.8	131.3	1.8	1.7	1.2	1.7	1.6	69.3	71.5	80.2	82.0	75.8
465A × IS 2389	127.2	133.3	140.2	145.8	136.6	1.7	1.3	1.2	1.8	1.5	81.5	79.2	82.3	82.0	81.3
465A × G 46	160.7	155.8	119.7	126.3	140.6	1.5	1.3	1.2	1.3	1.3	84.3	72.7	69.7	81.5	77.0
467A × HJ 513	117.2	143.2	137.8	165.2	140.8	1.0	1.5	1.0	1.2	1.2	82.0	77.7	76.8	72.3	77.2
467A × HJ 541	143.5	104.5	123.5	151.3	130.7	1.3	1.8	1.3	1.2	1.4	79.2	82.5	67.5	81.7	77.7
467A × IS 2389	122.8	142.5	145.8	156.0	141.8	2.0	2.0	1.3	1.3	1.7	68.2	85.2	68.5	69.2	72.8
467A × G 46	152.2	117.5	147.3	125.8	135.7	1.3	1.5	1.2	1.5	1.4	83.5	68.2	82.5	81.5	78.9
SSG 59-3 (Check)	151.3	138.9	141.0	140.0	142.8	3.0	2.0	2.7	2.5	2.6	75.7	74.0	69.7	69.2	72.1
MFSH 4 (Check)	168.4	153.7	166.0	148.5	159.2	2.7	2.2	2.3	2.7	2.5	76.5	78.4	75.2	76.7	76.7
General mean	**148.1**	**137.1**	**139.8**	**142.2**	**141.8**	**1.7**	**1.6**	**1.4**	**1.5**	**1.5**	**75.7**	**74.4**	**76.5**	**76.6**	**75.8**
Range	117.2-190.7	104.5-165.3	119.3-166.0	125.0-165.2	130.7-159.2	1.0-3.0	1.0-2.2	1.0-2.7	1.0-2.7	1.2-2.6	57.0-86.7	54.8-89.3	64.3-88.2	64.3-83.2	69.4-82.1
C.D. at 5 %	9.01	10.27	9.05	11.22		0.74	0.59	0.58	0.62		5.45	6.66	5.97	5.02	
S.E.(m)	3.16	3.61	3.18	3.94		0.26	0.21	0.20	0.22		1.91	2.34	2.10	1.76	
C.V. (%)	3.70	4.56	3.94	4.80		26.74	22.79	25.12	25.26		4.37	5.44	4.75	3.99	

Table 3 contd….

Hybrids	Leaf breadth (cm)					Stem diameter (cm)				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
9A × HJ 513	4.0	6.8	6.4	5.7	5.7	12.3	16.3	18.1	16.2	15.7
9A × HJ 541	6.3	6.8	6.3	4.9	6.1	14.9	18.5	12.2	14.3	15.0
9A × IS 2389	6.1	7.0	6.1	4.4	5.9	18.1	15.6	14.0	16.3	16.0
9A × G 46	5.2	5.9	5.9	6.4	5.9	12.3	16.6	13.7	19.8	15.6
14A × HJ 513	7.2	7.3	6.0	6.3	6.7	19.8	13.3	16.2	19.1	17.1
14A × HJ 541	6.3	6.1	5.2	6.1	5.9	19.1	14.8	14.3	14.5	15.7
14A × IS 2389	7.7	5.9	6.4	5.7	6.4	16.3	15.9	18.1	12.3	15.6
14A × G 46	6.6	5.9	6.6	4.9	6.0	13.5	13.8	13.3	14.0	13.6
31A × HJ 513	5.2	6.5	6.8	4.4	5.7	12.2	15.0	14.8	16.3	14.6
31A × HJ 541	7.1	6.6	6.3	7.0	6.8	14.0	13.5	13.7	12.9	13.5
31A × IS 2389	6.1	6.0	6.0	4.8	5.7	15.0	12.8	12.2	18.1	14.5
31A × G 46	5.9	7.1	5.2	5.0	5.8	12.1	15.2	14.0	13.7	13.7
56A × HJ 513	7.2	6.6	6.4	6.3	6.6	16.7	13.7	16.3	13.3	15.0
56A × HJ 541	7.4	6.8	7.0	6.1	6.8	12.3	13.3	16.3	14.8	14.2
56A × IS 2389	7.1	6.3	6.4	5.9	6.4	12.3	12.3	18.5	12.2	13.8
56A × G 46	6.3	5.5	6.6	6.0	6.1	13.5	13.1	18.1	14.0	14.7
465A × HJ 513	7.0	6.3	6.3	5.2	6.2	12.7	14.6	14.5	16.3	14.5
465A × HJ 541	8.1	5.3	5.7	6.4	6.4	15.7	14.8	12.3	19.8	15.7
465A × IS 2389	6.2	6.8	4.9	6.1	6.0	12.8	13.2	16.2	19.1	15.3
465A × G 46	7.2	6.7	4.4	6.6	6.2	16.4	17.3	14.3	13.4	15.3
467A × HJ 513	7.5	5.9	6.1	7.0	6.6	12.9	13.5	16.3	18.1	15.2
467A × HJ 541	7.3	4.9	5.9	6.3	6.1	18.6	15.8	18.5	16.2	17.3

467A × IS 2389	6.8	4.8	5.7	6.6	6.0	11.1	13.4	12.2	14.3	12.7
467A × G 46	5.6	5.5	4.9	6.0	5.5	17.9	13.5	14.0	14.5	15.0
SSG 59-3 (Check)	4.7	4.5	5.5	4.9	4.9	13.6	11.6	12.2	12.3	12.4
MFSH 4 (Check)	5.0	6.0	5.3	5.4	5.4	13.6	13.3	14.0	13.5	13.6
General mean	**6.4**	**6.1**	**5.9**	**5.8**	**6.1**	**14.6**	**14.4**	**14.9**	**15.4**	**14.8**
Range	4.0-8.1	4.5-7.3	4.4-7.0	4.4-7.0	4.9-6.8	11.1-19.8	11.6-18.5	12.2-18.5	12.2-19.8	12.4-17.3
C.D. at 5 %	0.78	0.91	0.99	0.93		1.77	1.59	1.79	1.55	
S.E.(m)	0.27	0.32	0.35	0.33		0.62	0.56	0.63	0.54	
C.V. (%)	7.35	9.04	10.10	9.78		7.36	6.71	7.28	6.12	

Table 3: contd….

Hybrids	Green fodder yield per plant (g)					Dry fodder yield per plant (g)				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
9A × HJ 513	293.3	293.3	321.7	336.7	311.3	85.0	85.0	93.3	96.7	90.0
9A × HJ 541	310.0	300.0	283.3	433.3	331.7	80.0	75.0	86.7	118.3	90.0
9A × IS 2389	395.0	525.0	286.7	276.7	370.8	123.3	136.7	90.0	88.3	109.6
9A × G 46	456.7	386.7	308.3	255.0	351.7	126.7	111.7	93.3	76.7	102.1
14A × HJ 513	343.3	340.0	310.0	223.3	304.2	101.7	100.0	85.0	73.3	90.0
14A × HJ 541	316.7	405.0	321.7	325.0	342.1	101.7	125.0	91.7	93.3	102.9
14A × IS 2389	336.7	321.7	283.3	241.7	295.8	106.7	101.7	85.0	73.3	91.7
14A × G 46	433.3	437.3	286.7	325.0	370.6	120.0	116.7	86.7	96.7	105.0
31A × HJ 513	401.7	456.7	308.3	276.7	360.8	110.0	125.0	98.3	88.3	105.4
31A × HJ 541	345.0	331.7	343.3	255.0	318.8	101.7	98.3	98.3	76.7	93.8
31A × IS 2389	331.7	311.7	223.3	343.3	302.5	106.7	101.7	75.0	110.0	98.3
31A × G 46	268.3	295.0	325.0	241.7	282.5	86.7	91.7	100.0	76.7	88.8
56A × HJ 513	408.3	343.3	310.0	325.0	346.7	120.0	101.7	88.3	93.3	100.8
56A × HJ 541	321.7	386.7	223.3	343.3	318.8	95.0	111.7	73.3	100.0	95.0
56A × IS 2389	283.3	313.3	375.0	276.7	312.1	81.7	86.7	111.7	85.0	91.3
56A × G 46	401.7	375.0	321.7	255.0	338.3	113.3	101.7	93.3	75.0	95.8
465A × HJ 513	515.0	476.7	437.3	223.3	413.1	135.0	125.0	110.0	73.3	110.8
465A × HJ 541	281.7	266.7	336.7	325.0	302.5	88.3	83.3	96.7	93.3	90.4
465A × IS 2389	286.7	285.0	276.7	321.7	292.5	83.3	83.3	85.0	96.7	87.1
465A × G 46	308.3	325.0	310.0	283.3	306.7	93.3	98.3	98.3	91.7	95.4
467A × HJ 513	343.3	310.0	293.3	336.7	320.8	106.7	96.7	90.0	105.0	99.6
467A × HJ 541	223.3	283.3	300.0	343.3	287.5	75.0	88.3	90.0	106.7	90.0
467A × IS 2389	325.0	325.0	336.7	321.7	327.1	106.7	105.0	100.0	93.3	101.3
467A × G 46	418.3	360.0	433.3	437.3	412.2	126.7	111.7	110.0	110.0	114.6
SSG 59-3 (Check)	275.0	295.0	311.7	266.7	287.2	81.6	91.7	98.4	83.3	88.8
MFSH 4 (Check)	305.0	300.0	295.0	285.0	296.3	96.7	95.0	95.0	91.7	94.7
General mean	**343.4**	**348.0**	**313.9**	**303.0**	**327.1**	**102.1**	**101.9**	**93.2**	**91.0**	**97.0**
Range	223.3-515.0	266.7-525.0	223.3-437.3	233.3-437.3	282.5-413.1	75.0-135.0	75.0-136.7	73.3-111.7	73.3-118.3	87.1-114.6
C.D. at 5 %	25.20	32.74	27.72	21.97		9.69	9.36	9.53	7.88	
S.E.(m)	8.85	11.49	9.73	7.71		3.40	3.29	3.35	2.77	
C.V. (%)	4.46	5.72	5.37	4.41		5.77	5.59	6.22	5.26	

Stem diameter (cm)

In forage sorghum thin stem is preferred by livestock. The cross 467A × IS 2389 (11.1 cm) showed minimum stem diameter followed by 31A × G 46 (12.1cm) and 31A × HJ 513 (12.2 cm) in E_1; while in E_2, the check SSG 59-3 (11.6 cm) obtained minimum stem diameter followed by 56A × IS 2389 (12.3 cm) and 31A × IS 2389 (12.8 cm). The minimum stem diameter was shown by the crosses 9A × HJ 541 31A × IS 2389, 467A × IS 2389 and check SSG 59-3 (12.2 cm) followed by 465A × HJ 541 (12.3 cm) and 14A × G 46 (13.3 cm) in E_3; while in E_4, the cross 56A × IS 2389 (12.2 cm) recorded minimum stem diameter followed by 14A × IS 2389 and check SSG 59-3 (12.3 cm) (Table 3). . As far as parents are concerned among testers, IS 2389 (12.8 cm) and HJ 541 (13.7 cm) and among lines, 9A (14.5 cm) and 56A (15.0 cm) showed minimum stem diameter (Table 4). The check SSG 59-3 (12.4 cm) attained minimum stem diameter followed by cross 467A × IS 2389 (12.7 cm) and 31A × HJ 541(13.5 cm) on the basis of overall mean in all the four environments (Table 3 and 4). Similar results have been reported by Nagaraja *et. al.*[11], Zulfiquar and Asim[19] and Tariq *et. al*[17].

Green fodder yield per plant (g)

The highest green fodder yield was recorded by the cross 465A × HJ 513 (515.0 g) followed by 9A × G 46 (456.7 g) and 14A × G 46 (433.3 g) in E_1; while in E_2, the cross 9A × IS 2389 (525.0 g) had maximum green fodder yield followed by 465A × HJ 513 (476.7 g) and 31A × HJ 513 (456.7 g). The highest green fodder yield was recorded by the cross 465A × HJ 513 (437.3 g) followed by 467A × G 46 (433.3 g) and 56A × IS 2389 (375.0 g) in E_3; while in E_4, the cross 467A × G 46 (437.3g) attained highest green fodder yield per plant followed by 9A × HJ 541(433.3 g), 56A × HJ 541 and 467A × HJ 541 (343.3g) (Table 3). Among the male parents HJ 541 (337.9 g) and G 46 (299.6 g) and in female parents 467A (407.1 g) and 56A (372.3 g) exhibited highest green fodder yield (Table 4). The crosses 465A × HJ 513 (413.1 g) exhibited maximum green fodder yield followed by 467A × G 46 (412.2 g) and 9A × IS 2389 (370.8 g) on the basis of overall mean in all the four environments (Table 3 and 4). Similar results have been reported by Nagaraja *et. al.*[11], Zulfiquar and Asim[19], Bhatt and Singh[2] and Singh *et. al*[16].

Table 4: Mean performance of different parents under different environments for various characters in forage sorghum

Parents	Plant height (cm)					Total number of tillers per plant					Leaf length (cm)				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
9A	119.5	139.3	139.0	141.5	134.8	1.3	1.3	1.3	1.3	1.3	84.8	83.2	81.5	72.3	80.5
14A	148.5	115.3	137.7	149.3	137.7	1.5	1.5	1.0	1.7	1.4	82.8	85.0	72.3	81.7	80.5
31A	126.5	114.3	118.7	148.7	127.0	1.2	1.7	2.0	1.5	1.6	70.5	76.8	68.7	64.3	70.1
56A	137.7	135.5	125.0	145.7	136.0	2.0	1.5	1.7	1.0	1.5	74.5	59.5	88.2	71.0	73.3
465A	128.7	122.0	157.8	153.0	140.4	1.7	1.7	1.3	1.3	1.5	71.5	75.8	75.7	82.0	76.3
467A	140.5	153.5	154.7	144.7	148.3	1.8	1.7	1.5	1.2	1.5	72.5	85.5	77.7	73.7	77.3
HJ 513	156.2	135.7	157.0	125.3	143.5	1.3	1.2	1.3	1.2	1.3	83.2	82.8	75.7	72.5	78.5
HJ 541	136.0	134.2	142.8	137.3	137.6	2.0	1.2	1.5	1.2	1.5	80.2	76.7	71.8	83.2	78.0
IS 2389	169.3	148.5	149.7	151.7	154.8	2.0	1.3	1.5	1.8	1.7	85.3	76.7	71.0	80.2	78.3
G 46	155.3	144.2	149.5	152.2	150.3	1.7	1.3	1.0	1.7	1.4	77.7	65.3	75.8	63.3	70.5
General mean	**141.8**	**134.3**	**143.2**	**144.9**	**141.0**	**1.7**	**1.4**	**1.4**	**1.4**	**1.5**	**78.3**	**76.7**	**75.8**	**74.4**	**76.3**
C.D. at 5 %	12.75	8.20	9.85	10.48		0.02	0.01	0.56	0.48		3.38	7.79	6.36	5.26	
S.E.(m)	4.26	2.74	3.29	3.50		0.24	0.22	0.19	0.16		1.13	2.60	2.12	1.76	
C.V. (%)	5.20	3.53	3.98	4.18		25.55	27.10	22.93	19.92		3.50	5.87	4.85	4.09	

Parents	Leaf breadth (cm)					Stem diameter (cm)					Green fodder yield per plant (g)				
	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean	E_1	E_2	E_3	E_4	Mean
9A	5.3	6.7	4.4	5.2	5.4	16.8	15.2	13.7	12.3	14.5	286.7	260.0	276.7	266.7	272.5
14A	6.8	6.4	6.4	6.4	6.5	14.7	17.1	16.2	13.7	15.4	390.0	400.0	255.0	285.0	332.5
31A	6.0	6.3	6.3	7.0	6.4	14.5	16.2	14.3	16.3	15.3	276.7	223.3	343.3	321.7	291.3
56A	5.5	4.8	6.1	6.6	5.7	12.3	14.3	19.8	13.4	15.0	366.7	375.0	310.0	437.3	372.3
465A	7.4	5.0	5.9	6.8	6.3	14.9	16.0	19.1	16.3	16.6	336.7	323.3	321.7	343.3	331.3
467A	7.1	7.1	7.0	6.6	7.0	16.2	12.1	18.1	18.5	16.2	513.3	538.3	283.3	293.3	407.1
HJ 513	4.9	7.5	6.1	7.0	6.4	13.7	13.2	13.3	16.2	14.1	241.7	248.3	336.7	300.0	281.7
HJ 541	6.0	5.0	5.5	6.3	5.7	14.3	11.4	14.8	14.3	13.7	325.0	306.7	433.3	286.7	337.9
IS 2389	5.2	5.7	5.5	6.1	5.6	11.6	13.7	12.5	13.4	12.8	253.3	276.7	223.3	308.3	265.4
G 46	6.4	4.9	6.1	5.9	5.8	12.3	14.8	13.7	18.1	14.7	231.7	255.0	375.0	336.7	299.6
General mean	**6.1**	**5.9**	**5.9**	**6.4**	**6.1**	**14.1**	**14.4**	**15.5**	**15.2**	**14.8**	**322.2**	**320.7**	**315.8**	**317.9**	**319.1**
C.D. at 5 %	1.27	1.21	0.82	0.93		1.52	1.57	1.76	1.84		21.22	24.54	32.04	24.29	
S.E.(m)	0.42	0.40	0.27	0.31		0.51	0.52	0.59	0.62		9.41	8.20	10.70	8.11	
C.V. (%)	12.11	11.77	7.97	8.38		6.20	6.30	6.54	6.99		5.77	4.43	5.87	4.42	

Table 4 contd…

Parents	Dry fodder yield per plant (g)					Parents	Dry fodder yield per plant (g)				
	E_1	E_2	E_3	E_4	Mean		E_1	E_2	E_3	E_4	Mean
9A	78.3	75.0	76.7	76.7	76.7	HJ 541	91.7	86.7	106.7	75.0	90.0
14A	105.0	108.3	75.0	81.7	92.5	IS 2389	78.3	81.7	73.3	90.0	80.8
31A	80.0	73.3	98.3	91.7	85.8	G 46	75.0	81.7	101.7	91.7	87.5
56A	105.0	106.7	88.3	116.7	104.2	**General mean**	**90.0**	**91.0**	**89.5**	**89.7**	**90.0**
465A	85.0	88.3	96.7	101.7	92.9	C.D. at 5 %	31.42	8.00	9.60	8.60	
467A	126.7	131.7	81.7	81.7	105.4	S.E.(m)	10.49	2.67	3.21	2.87	
HJ 513	75.0	76.7	96.7	90.0	84.6	C.V. (%)	5.64	5.08	6.20	5.55	

Dry fodder yield per plant (g)

The maximum dry fodder yield per plant was recorded by the cross 465A × HJ 513 (135.0 g) followed by 467A × G 46 and 9A × G 46 (126.7 g) in E_1; while in E_2, the cross 9A × IS 2389 (136.7 g) exhibited maximum dry fodder yield followed by 465A × HJ 513 and 31A × HJ 513 (125.0 g). The highest dry fodder yield was shown by the cross 56A × IS 2389 (111.7 g) followed by 467A × G 46 and 465A × HJ 513 (110.0 g) in E_3; while in E_4, the cross 9A × HJ 541 (118.3 g) had maximum dry fodder yield followed by 467A × G 46 and 31A × IS 2389 (110.0 g) (Table 3). On the basis of overall mean in all the four environments, among male parents HJ 541 (90.0 g) and G 46 (87.5 g) and among female parents 56A (104.2 g) and 467A (105.4 g) showed highest dry fodder yield (Table 4). The crosses 467A × G 46 (114.6 g) exhibited maximum dry fodder yield followed by 465A × HJ 513 (110.8 g) and 9A × IS 2389 (109.6 g) on overall mean basis (Table 3 and 4). Similar results have been reported by Tilley *et. al.*[18], Grenier *et. al.*[7], Zulfiquar and Asim[19], Bhatt and Singh[2], Singh *et. al.*[16] and Cunha and Lima[4].

Table 5: Promising crosses on the basis of mean performance for fodder yield and related traits in forage sorghum

S.N.	Hybrids	GFY	DFY	PH	TT	LL	LB	SD
1	465A × HJ 513	413.1	110.8	134.2	1.2	76.5	6.2	14.5
2	467A × G 46	412.2	114.6	135.7	1.4	78.9	5.5	15.0
3	9A × IS 2389	370.8	109.6	139.7	1.4	73.3	5.9	16.0
4	14A × G 46	370.6	105.0	143.9	1.3	78.5	6.0	13.6
5	31A × HJ 513	360.8	105.4	147.9	1.6	76.5	5.7	14.6
6	9A × G 46	351.7	102.1	143.9	1.6	80.6	5.9	15.6
7	56A × HJ 513	346.7	100.8	146.0	1.5	76.8	6.6	15.0
8	14A × HJ 541	342.1	102.9	139.8	1.6	75.6	5.9	15.7
9	56A × G 46	338.3	95.8	150.1	1.5	82.1	6.1	14.7
10	9A × HJ 541	331.7	90.0	136.6	1.5	69.4	6.1	15.0

D.F. = Degree of freedom
* Significant at 5% level **Significant at 1% level
E_1 = Early sowing at Hisar E_2 = Early sowing at Karnal
E_3 = Late sowing at Hisar E_4 = Late sowing at Karnal
PH = Plant height (cm) TT = Total number of tillers per plant LL = Leaf length (cm) LB = Leaf breadth (cm) SD = Stem diameter (cm) Env. = Environments GFY = Green fodder yield per plant (g) DFY = Dry fodder yield per plant (g)

On the basis of overall mean performance, top ten promising hybrids in all the four test environments were identified for green fodder, dry fodder yield and other traits which have been presented in Table 5.

Hybrid 465A × HJ 513 showed maximum green fodder yield (413.1 g) followed by 467A × G 46 (412.2 g), 9A × IS 2389 (370.8 g). This hybrid was also good for dry fodder yield (110.8 g), leaf length (76.5 cm) and leaf breadth (6.2 cm). Other hybrids that showed better green fodder yield were 14A × G 46 (370.6 g), 31A × HJ 513 (360.8 g) and 9A × G 46 (351.7 g).

Maximum dry fodder yield was recorded by the hybrid 467A × G 46 (114.6 g) followed by 465A × HJ 513 (110.8 g) and 9A × IS 2389 (109.6 g). This hybrid was also good for green fodder yield (412.2 g), leaf length (78.9 cm) and stem diameter (15.0 cm). Other hybrids that showed better dry fodder yield were 31A × HJ 513 (105.4 g), 14A × G 46 (105.0 g), 14A × HJ 541 (102.9 g) and 9A × G 46 (102.1 g).

Hybrids 56A × G 46 (82.1cm) recorded maximum leaf length and was also better for stem diameter (14.7 cm), crude protein (9.44 %) and protein yield (9.03 g).

Similar results have been reported by Tilley *et. al.*[18], Nagaraja *et. al.*[11], Grenier *et. al.*[7], Zulfiquar and Asim[19], Bhatt and Singh[2], Joshi *et. al.*[9], Dien *et. al.*[5], Singh *et. al*.[16] and Tariq *et. al*[17].

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