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RESEARCH ARTICLE :

Heterosis studies in sweet sorghum [*Sorghum bicolor* (L.) Moench] hybrids for green fodder yield and its attributing traits

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SUMMARY : An experiment was conducted to study the magnitude of heterosis in forty eight F_1 hybrids of sweet sorghum [*Sorghum bicolor* (L.) Moench] for single-cut green fodder yield and its components. The hybrids and their parents (4 lines and 12 testers) were evaluated in Randomized Block Design with three replications. Observations were recorded on seventeen characters *viz.*, early vigour, days to 50 per cent flowering, plant height, number of leaves per plant, leaf length, leaf breadth, number of nodes per plant, internodal length, stem girth, leaf to stem ratio, sugar brix, green fodder yield, dry matter content, dry fodder yield, ADF, NDF and crude protein. Heterotic studies revealed the presence of significant heterosis over best check in many cross combinations. The hybrid 185A x RSSV466 exhibited significant heterosis in desirable direction for green fodder yield, its component characters and quality traits. Therefore, this cross could be utilized for commercial cultivation after sufficient testing in All India trials.

KEY WORDS :
Sweet sorghum, Heterosis, Fodder yield

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BACKGROUND AND OBJECTIVES

Agricultural crops and livestock play a vital role in the national economy since they fulfill the basic needs of life. Agriculture accounts for 54.6% of total employment in India and contributes 15.2% of total GDP. Livestock occupies a crucial position in Indian agriculture and directly contributes 27% of agricultural GDP. India, with 2.29% of the world land area, is maintaining about 10.71% of world's livestock population. The number of milch animals have increased from 62 million in 2000 to 83.15 million in 2012 resulting in 4.04% year-on-year growth rate of milk (Livestock census, 2012). Thus, to sustain this growth rate and for further expansion to meet the demands of ever growing human population, livestock needs sustainable supply of feed material.

The area under fodder cultivation is estimated to be about 4% of the gross cropped area which remained static for the last four decades. The available fodder production is less than the actual requirement. At present, the country faces a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% concentrate feeds (Datta, 2013). Moreover, livestock population survives to a large extent on crop residues, which are nutritionally poor.

There is an urgent need to reduce the demand and supply gap by enhancing the production and productivity of fodder crops. Forage yield in quantity alone cannot measure the feeding value of the crops. So, there is also a necessity for improving the nutritive value of forages in order to obtain a better animal performance.

In India, sorghum [*Sorghum bicolor* (L.) Moench] is one of the most important forage crops grown widely in north western states and to a limited scale in central and southern states. Sorghum ranks first among the cereal fodder crops because of its growing ability in poor soil, faster growing habit, high yield potential, suitability to cultivate throughout the year, palatability, nutritious fodder quality, higher digestibility and various forms of its utilization. It gives uniform green fodder throughout the year and produces tonnage of dry matter having digestible nutrients (50%), crude protein (8%), fat (2.5%) and nitrogen free extracts (45%) (Azam *et al.*, 2010). The cultivated area under different forage crops is 4.4 per cent of the total area under cultivation, of which about 2.3 m ha is under forage sorghum (Anonymous, 2011).

Sweet sorghum, being a well-known crop can supply food, feed, fodder, fiber and fuel. However, it has not been studied much as a fodder crop. Sweet sorghum has high biomass production, high brix percentage, short duration, low water requirement and wider adaptability (Reddy *et al*., 2005). Sweet sorghum hybrids have been reported to produce higher sugar yield (21%) and higher grain yield (15%) than non-sweet sorghum hybrids in the rainy season indicating that there is no trade-off between grain and sugar. The palatability and quality of forage will increase by increasing the sugar content of sorghum stalk. Therefore, the important goals of sweet sorghum forage breeding programs are to increase sweetness, leafiness and juiciness in sorghum (Poehlman and Sleper, 2006) which can be achieved by developing fodder varieties/hybrids in sweet sorghum with high fodder yield per unit area and time combined with superior quality. Therefore, the present study was undertaken to assess the possibility of commercial exploitation of heterosis for fodder yield and quality through estimating of heterosis over better parent and standard check.

RESOURCES AND METHODS

The present investigation involving four lines, twelve testers and forty eight crosses. Four lines, namely 185A, ICS38A, 24A, PMS71A were crossed on to each of the twelve testers PMS130, KR135, SSV74, SSVV84, NSSV14, RSSV138-1, RSSV404, RSSV466, IS18542, 6NRL, BNM16, UK81 in line x tester fashion to produce forty eight F_1 hybrids during *Rabi* season of 2015 at Indian Institute of Millets Research, Hyderabad. The forty eight F_1 hybrids along with their corresponding sixteen parents were sown in Randomized Block Design with three replications at AICRP on Forage Crops, ARI, Rajendranagar during *Kharif*, 2016. Each entry was raised in two rows of 4 m length with a spacing of 30 cm between the rows and 10 cm between the plants with in the row. The soil was sandy loam in texture with pH of 8.13, low in available Nitrogen and medium in available phosphorous and available K_2O. All the recommended agronomical practices under AICRP on sorghum were followed and plant protection measures were applied as and when required to ensure good crop. The observations were recorded on five randomly selected plants per each entry in each replication for days to 50 per cent flowering, plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), leaf to stem ratio, green fodder yield (t/ha), dry matter content (%), dry fodder yield (t/ ha) and CP (%). Mean of five plants for each entry for each character was calculated and the data was analyzed statistically using the software WINDOSTAT version 8.1.

OBSERVATIONS AND ANALYSIS

The magnitude of heterosis exhibited by forty eight crosses was measured as per cent increase or decrease over the check (standard heterosis) using CSV 30F as the best check for all the seventeen characters and presented in the Table 1. Standard heterosis is the most effective parameter amongst the three parameters of heterosis. Earliness in fodder crops is desirable trait that enables the genotype to fit into the food and fodder cropping systems. Therefore, negative heterosis is desirable for days to 50 per cent flowering.

In the present investigation, the degree of standard heterosis and heterobeltiosis varied among the crosses in the desirable direction for majority of the traits. The results obtained on magnitude of heterosis are presented below.

Table 1: Estimation of heterobeltiosis and standard heterosis effects for yield, yield components and quality traits

Genotype	Days to 50% flowering		Plant height (cm)		No. of leaves /plant		Leaf length (cm)	
	HB	SH	HB	HB	SH	SH	HB	SH
185A x PMS130	-19.50**	-11.54**	-2.54*	-4.91	-18.33**	-29.04**	-3.70	-27.0**
185A x KR135	-13.21**	-6.01	-9.30**	-6.43	-19.64**	-36.54**	-14.66**	-35.31**
185A x SSV74	-16.96**	-5.14	-11.65**	0.39	-13.78*	-38.18**	-15.35**	-35.83**
185A x SSV84	-18.09**	-5.14	-21.84**	-22.84**	-23.23**	-38.41**	-18.02**	-35.56**
185A x NSSV14	-21.71**	-9.33*	-15.52**	-43.96**	-45.80**	-28.4**	-4.36	-27.50**
185A x RSSV138-1	2.82	15.42**	15.69**	17.59**	6.03	-4.36**	21.70**	11.53**
185A x RSSV404	-11.86**	-11.86**	-20.73**	-9.55	-11.05	-21.18**	-5.00	-15.56**
185A x RSSV466	-14.57**	-14.23**	6.99**	-8.61	-12.35*	-9.40**	-1.27	-13.89**
185A x IS18542	-22.49**	-11.46**	1.80	-20.07**	-17.93**	-22.42**	-13.64**	-20.83**
185A x6NRL	-22.18**	-9.88*	5.78**	2.53	-6.23	-8.33**	-0.33	-24.44**
185A x BNM16	-20.77**	-11.07**	-3.88**	-11.13	-18.57**	-2.61**	-0.15	-24.31**
185A x UK81	-20.28**	-9.88*	-3.01*	-9.76	-15.39**	-23.83**	-4.29	-25.56**
ICS38A x PMS130	-9.71**	-0.79	8.15**	19.56*	-10.10	-21.26**	12.05**	-31.53**
ICS38A x KR135	-6.93*	0.79	16.66**	26.32**	-7.23	-27.94**	9.09*	-26.67**
ICS38A x SSV74	-10.97**	1.70	34.38**	8.73	-13.02*	-8.49**	17.82**	-12.94**
ICS38A x SSV84	-3.41	11.86**	-5.48**	-1.14	-1.64	-25.51**	5.65	-16.94**
ICS38A x NSSV14	-2.39	13.04**	3.73**	5.57	2.12	-12.16**	-1.24	-27.03**
ICS38A x RSSV138-1	-4.26	7.47	0.20	9.05	-1.68	-17.16**	1.00	-7.44**
ICS38A x RSSV404	3.56	3.56	-11.42**	-5.67	-7.23	-11.93**	-14.91**	-24.36**
ICS38A x RSSV466	2.76	3.16	-4.34**	-8.96	-12.68*	-18.99**	-11.85**	-23.11**
ICS38A x IS18542	1.38	15.81**	12.43**	8.25	11.15	-14.32**	14.52**	4.97
ICS38A x x6NRL	-9.22**	5.14	9.04**	11.05	1.56	-5.51**	4.08	-24.83**
ICS38A x BNM16	-5.99	5.53	2.67*	3.54	-5.13	-17.34**	2.66	-25.00**
ICS38A x UK81	-6.64*	5.53	14.12**	1.57	-4.77	-10.38**	-8.61**	-28.92**
27A x PMS130	-16.91**	-8.70*	7.47**	27.88**	-3.84	-21.75**	9.09*	-33.33**
27A x KR135	-12.04**	-4.74	42.33**	32.72**	-4.72	-12.08**	23.97**	-16.67**
27A x SSV74	-4.84	8.70*	43.17**	27.97**	2.36	-2.50**	11.92**	-17.31**
27A x SSV84	-6.14	8.70*	20.79**	-5.68	-6.16	-4.81**	4.24	-18.06
27A x NSSV14	-7.51*	7.11	11.75**	0.63	-2.66	-5.37**	3.12	-23.81**
27A x RSSV138-1	0.35	12.65**	28.48**	10.49	-0.38	6.22**	14.58**	5.00
27A x RSSV404	5.15	-13.04**	3.89**	-5.83	-7.39	3.29**	8.75**	-3.33
27A x RSSV466	-14.34**	-7.91*	9.32**	-10.93	-14.57*	-7.43**	-8.92**	20.56**
27A x IS18542	0.69	15.02**	24.21**	-7.41	-4.93	5.34**	-0.61	-8.89**
27A x 6NRL	-23.55**	-11.46**	-0.54	-6.37	-14.37*	-13.80**	1.92	-26.39**
27A x BNM16	-17.61**	-7.51*	9.25**	9.91	0.70	-12.04**	1.14	-26.11**
27A x UK81	-7.69*	4.35	10.53**	-2.22	-8.32	-13.19**	-2.68	-24.31**
PMS71A x PMS130	-0.36	9.49*	-10.57**	-5.26	-14.04*	-34.88**	-15.16**	-35.67**
PMS71A x KR135	1.82	10.28**	26.56**	7.50	-2.46	-21.82**	1.58	-22.97**
PMS71A x SSV74	-0.35	13.83**	34.41**	4.73	-4.97	-8.47**	3.00	-21.89**
PMS71A x SSV84	-1.37	14.23**	-1.04	-12.98*	-13.42*	-22.01**	-15.19**	-33.33**
PMS71A x NSSV14	-7.17*	7.51*	9.74**	-3.62	-6.77	-7.07**	-9.89**	-31.67**
PMS71A x RSSV138-1	-2.82	9.09*	18.07**	12.63*	2.20	-2.39*	-1.18	-9.44**
PMS71A x RSSV404	1.14	5.53	-5.21**	2.35	0.65	-5.75**	-7.28*	-17.58**
PMS71A x RSSV466	-5.68	-1.58	-0.14	-7.80	-11.57*	-15.44**	-17.32**	-27.89**
PMS71A x IS18542	-1.38	12.65**	17.57**	-9.74	-7.32	-10.40**	-0.85	-9.11**
PMS71A x x6NRL	-10.92**	3.16	0.95	3.79	-5.08	-12.52**	-5.42	-28.28**
PMS71A x BNM16	-3.17	8.70*	3.23**	4.20	-4.53	-16.89**	-1.90	-25.61**
PMS71A x UK81	1.05	14.23**	10.94	-4.74	-10.68	-12.87**	-8.89**	-29.14**

Table 1 : Contd……….

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Genotype	Leaf breadth (cm)		Leaf to stem ratio		Green fodder yield (t/ha)		Dry matter content (%)	
	HB	HB	SH	HB	SH	HB	HB	SH
185A x PMS130	-5.02**	-33.39**	-50.05**	-40.45**	-47.85**	-14.40**	-0.63	-27.17**
185A x KR135	-18.47**	-24.85**	-43.64**	-37.38**	-40.38**	-4.58	-10.71**	-31.85**
185A x SSV74	-12.47**	-19.21**	-39.41**	-13.39*	-38.68**	-11.54**	-6.60**	-31.55**
185A x SSV84	-26.53**	-23.37**	-42.54**	-20.24**	-31.29**	-23.15**	-13.02**	-34.33**
185A x NSSV14	1.83	-0.01	-25.02**	-35.13**	-40.53**	-12.46**	-7.45**	-26.19**
185A x RSSV138-1	0.51	-23.37**	-42.54**	20.62**	-6.53	-6.83*	-1.91*	-8.67**
185A x RSSV404	-0.94	-13.40**	-17.74**	-40.65**	-38.7**2	12.05**	-13.94**	-15.50**
185A x RSSV466	3.74*	32.56**	12.53**	-23.29**	-38.67**	4.03	2.73*	-14.85**
185A x IS18542	-3.49*	-29.31**	-46.99**	-24.70**	-50.32**	13.28**	4.92**	-19.63**
185A x6NRL	2.81	-10.00	-32.51**	-45.68**	-33.32**	2.69	-1.63	-11.36**
185A x BNM16	-2.60	-7.36	-30.53**	-19.00**	-37.43**	-10.73**	-9.20**	-28.64**
185A x UK81	-5.06**	10.02	-17.50**	-41.06**	-48.73**	-3.35	-2.35*	-22.36**
ICS38A x PMS130	7.78**	150.40**	-25.00**	-20.35**	-30.24**	18.94**	-0.56	-29.89**
ICS38A x KR135	22.83**	4.85	-66.00**	-24.42**	-28.04**	19.66**	-2.81*	-25.82**
ICS38A x SSV74	4.61**	15.20	-53.63**	-2.52	-26.73**	2.62	34.76**	-10.47**
ICS38A x SSV84	-10.12**	-13.33	-67.53**	-7.50	-11.42*	-12.40**	27.95**	-3.40**
ICS38A x NSSV14	1.51	33.52*	-60.01**	-25.96**	-32.12**	-20.60**	-0.54	-20.67**
ICS38A x RSSV138-1	3.01	27.19**	-47.53**	-5.12	-26.48**	8.25**	2.07*	-4.96**
ICS38A x RSSV404	-1.79	-31.59**	-35.02**	-21.60**	-19.04**	13.11**	-10.76**	-12.37**
ICS38A x RSSV466	-1.42	-32.34**	-42.56**	-11.02	-28.86**	9.57**	-2.48*	-19.17**
ICS38A x IS18542	1.00	50.18**	-55.02**	12.45	-15.48**	7.90**	17.47**	-10.02**
ICS38A x x6NRL	12.29**	-41.06**	-58.77**	-17.74**	0.97	0.54	-9.93**	-18.84**
ICS38A x BNM16	8.46**	22.21**	-37.55**	12.33*	-13.23**	22.92**	-0.27	-21.62**
ICS38A x UK81	12.74**	6.54	-58.80**	-13.24*	-24.53**	6.31*	11.40**	-11.42**
27A x PMS130	28.86**	108.95**	-42.54**	-33.01**	-41.33**	-2.09	9.64**	-22.70**
27A x KR135	23.85**	119.81**	-28.73**	-36.05**	-39.11**	-2.20	11.96**	-14.55**
27A x SSV74	-1.14	11.26	-55.51**	31.95**	3.03	-11.45**	42.32**	-5.45**
27A x SSV84	-11.03**	9.97	-58.80**	-15.58**	-19.16**	-27.01**	18.62**	-10.44**
27A x NSSV14	-10.40**	76.26**	-50.02**	-4.54	-12.48**	-25.74**	17.82**	-6.03**
27A x RSSV138-1	-0.67	51.51**	-37.49**	32.10**	3.15	-21.65**	-0.53	-7.38**
27A x RSSV404	-3.34*	-40.83**	-43.80**	-7.99	-4.98	-19.86**	-8.92**	-10.56**
27A x RSSV466	6.65**	-14.64**	-27.54**	-34.13**	-47.34**	-0.77	7.24**	-11.12**
27A x IS18542	-14.53**	71.27**	-48.79**	13.55*	-11.33*	-27.73**	20.79**	-7.47**
27A x 6NRL	12.98**	-21.45**	-45.06**	-37.20**	-22.92**	-4.38	-12.03**	-20.74**
27A x BNM16	13.87**	61.47**	-17.49**	-18.04**	-36.00**	-11.83**	7.17**	-15.77**
27A x UK81	1.70	25.88*	-51.31**	-16.67**	-27.52**	-17.26**	-1.04	-21.32**
PMS71A x PMS130	-19.51**	-6.06	-61.27**	14.65**	1.47	-25.66**	-3.13*	-31.70**
PMS71A x KR135	-2.25	-1.24	-59.28**	-13.02*	-17.18**	-33.28**	3.61**	-20.92**
PMS71A x SSV74	-3.28*	2.99	-57.54**	26.61**	12.06*	-47.54**	17.50**	-18.56**
PMS71A x SSV84	-17.69**	15.23	-52.49**	-8.55	-12.43*	-34.38**	2.31	-22.76**
PMS71A x NSSV14	-8.26**	12.15	-53.76**	11.83*	2.52	-44.84**	8.33**	-13.60**
PMS71A x RSSV138-1	-9.01**	121.04**	-8.80*	-2.44	-13.65**	-46.40**	1.68	-5.33**
PMS71A x RSSV404	-8.44**	-10.55*	-15.04**	-1.38	1.84	-34.66**	0.94	-0.89
PMS71A x RSSV466	1.69	-13.16*	-26.28**	7.90	-4.50	-47.63**	-2.11	-18.87**
PMS71A x IS18542	-8.88**	9.12	-55.01**	17.09**	3.63	-23.16**	13.95**	-12.71**
PMS71A x x6NRL	-9.05**	-51.83**	-66.31**	-22.88**	-5.34	-47.58**	-15.02**	-23.43**
PMS71A x BNM16	-7.69**	22.31**	-37.50**	9.10	-3.43	-40.30**	-0.04	-21.44**
PMS71A x UK81	-9.52**	24.18*	-48.81**	11.79*	-1.06	-45.64**	4.51**	-16.91**

Table 1 : Contd…..

Table 1: Contd………..

Genotype	Dry fodder yield (t/ha)		Crude protein (%)	
	HB	SH	HB	SH
185A x PMS130	-19.70**	-20.69**	-46.67**	-74.06**
185A x KR135	24.99**	23.44**	-26.09**	-66.74**
185A x SSV74	9.47**	13.54**	-17.37	-62.82**
185A x SSV84	25.03**	23.48**	-12.21	-60.50**
185A x NSSV14	14.97**	13.54**	-0.48	-55.22**
185A x RSSV138-1	-40.00**	-40.74**	19.39*	-46.28**
185A x RSSV404	5.03	3.72	-48.68**	-49.55**
185A x RSSV466	14.97**	13.54**	1.92	-30.83**
185A x IS18542	-40.00**	-40.74**	-46.71**	-73.61**
185A x6NRL	-4.84	-6.02*	-47.48**	-54.99**
185A x BNM16	14.97**	13.54**	-3.33	-56.50**
185A x UK81	-4.17	8.80**	-5.95	-57.68**
ICS38A x PMS130	-7.23**	23.59**	116.37**	-47.65**
ICS38A x KR135	-4.058**	-20.84**	-20.71	-75.54**
ICS38A x SSV74	-29.51**	-6.09*	19.12	-66.21**
ICS38A x SSV84	-25.78**	-1.13	-19.91	-71.22**
ICS38A x NSSV14	-18.41**	8.69**	4.39	-72.83**
ICS38A x RSSV138-1	-29.54**	-6.13*	21.11	-61.41**
ICS38A x RSSV404	-14.77**	13.54**	-46.44**	-47.35**
ICS38A x RSSV466	-7.23**	23.59**	-39.77**	-59.13**
ICS38A x IS18542	-25.87**	-1.24	67.48**	-62.41**
ICS38A x x6NRL	-22.14**	3.72	-51.37**	-58.32**
ICS38A x BNM16	-25.76**	-1.09	37.15**	-45.92**
ICS38A x UK81	-29.68**	-6.32*	-6.55	-68.94**
27A x PMS130	5.3	23.48**	38.86*	-66.40**
27A x KR135	-11.52**	3.72	40.72**	-56.59**
27A x SSV74	-36.84**	-25.96**	61.76**	-54.11**
27A x SSV84	-7.12**	8.88**	-6.90	-66.55**
27A x NSSV14	-36.87**	-26.00**	68.27**	-56.20**
27A x RSSV138-1	-28.37**	-16.03**	102.41**	-35.50**
27A x RSSV404	-16.72**	-2.37	-45.66**	-46.68**
27A x RSSV466	-32.61**	-20.99**	-43.43**	-61.61**
27A x IS18542	-28.56**	-16.25**	111.47**	-54.61**
27A x 6NRL	5.39*	23.55**	-50.54**	-57.61**
27A x BNM16	-7.16**	8.84**	34.25**	-47.07**
27A x UK81	-24.26**	-11.21**	5.74	-64.85**
PMS71A x PMS130	-27.21**	-20.81**	7.82	-60.62**
PMS71A x KR135	0.03	8.84**	-7.38	-66.17**
PMS71A x SSV74	-45.54**	-40.74**	30.63**	-52.29**
PMS71A x SSV84	-22.89**	-16.10**	13.83	-58.43**
PMS71A x NSSV14	-13.90**	-6.32*	29.51*	-52.70**
PMS71A x RSSV138-1	-9.09**	-1.09	115.63**	-21.25**
PMS71A x RSSV404	9.44**	19.07**	-11.96**	-13.45**
PMS71A x RSSV466	-24.00**	-17.31**	4.0	-29.42**
PMS71A x IS18542	-31.98**	-26.00**	27.65*	-53.38**
PMS71A x x6NRL	-22.82**	-16.03**	-62.43**	-67.80**
PMS71A x BNM16	-19.61**	-12.53**	53.30**	-39.55**
PMS71A x UK81	-26.04**	-16.03**	39.08**	-49.21**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

The range of heterosis for days to 50 per cent flowering varied from -23.55 (27A x 6NRL) to 5.15 per cent (PMS71A x SSV74) over better parent. The standard heterosis ranged from -14.23 (185A x RSSV466) to 15.81 per cent (ICS38A x PMS130). Fourteen crosses exhibited significant negative heterosis over the standard check. 185A x RSSV466 (-14.23%), 27A x RSSV404 (-13.04%), 185A x RSSV404 (-11.86%) and 185A x PMS130 (-11.54%) exhibited significant and higher negative standard heterosis over the check. Ravindrababu *et al.* (2002); Patel and Patel (2011) and Akbari *et al.* (2012) also observed considerable amount of negative heterosis for days to 50 per cent flowering

The range of heterosis for plant height varied from -21.84 to 43.17 per cent (27A x SSV74) over better parent. Twenty six crosses exhibited significant and positive magnitude of heterobeltiosis. Ravindrababu *et al*. (2002) Singh *et al.* (2008) and Tariq *et al*. (2014) also reported same range of heterosis for plant height over better parent.

The standard heterosis ranged from -38.41 to 6.22 per cent (27A x RSSV138-1). Out of 48 hybrids only three crosses 27A x RSSV138-1 (6.22), 27A x IS18542 (5.34) and 27A x RSSV404 (3.29) exhibited significant and positive standard heterosis over the check CSV30F which is confirmed as best check for plant height. In earlier studies, Singh *et al*. (2008) and Akbari *et al.* (2012) also reported considerable heterosis for plant height.

The range of heterosis varied from -18.02 to 23.97 per cent over better parent for number of leaves per plant. 185A x RSSV138-1 (21.70), ICS38A x SSV74 (17.82), 27A x RSSV138-1 (14.58) and ICS38A x IS18542 (14.52) exhibited higher magnitude of heterosis. This results are in similarity with those obtained earlier by Pandey and Shrotria (2012).

Performance of hybrids over check for number of leaves per plant varied from -35.83 to 20.56 per cent (27A x RSSV466). 27A x RSSV466 (20.56%) followed by three crosses 185A x RSSV138-1 (11.53%), 27A x RSSV138-1 (5%) and ICS38A x IS18542 (4.97%) exhibited positive standard heterosis over the check CSV30F. Akbari *et al.* (2012) also reported positive standard heterosis for number of leaves per plant.

The range of heterobeltiosis varied from -43.96 to 32.72 per cent (27A x KR135) for leaf length. 27A x KR135 (32.72) exhibited highest magnitude of heterosis followed by 27A x SSV74 (27.97), 27A x PMS130 (27.88) and ICS38A x KR135 (26.32). Agarwal and Shrotria (2005) also reported heterobeltiosis for leaf length in their studies.

Standard heterosis for leaf length varied from -45.80 to 11.15 per cent (ICS38A x IS18542). Eight crosses showed positive standard heterosis over the check CSV30F. Similar results were reported by Patel and Patel (2011) and Jain and Patel (2013).

Table 2: The range of heterobeltiosis and standard heterosis and number of crosses showing significant heterosis for various traits in sweet sorghum

Characters	Range of heterosis		Noumber of hybrids having significant heterotic effect			
	HB	SH	HB		SH	
			+ve	-ve	+ve	-ve
Days to 50% flowering	-23.55 to 5.15 (27A x 6NRL)	-14.23 to 15.81 (185A x RSSV466)	-	25	16	14
Plant height (cm)	-21.84 to 43.17 (27A x SSV74)	-38.41 to 6.22 (27A x RSSV138-1)	27	12	2	44
No of leaves /plant	-18.02 to 23.97 (27A x KR135)	-35.83 to 11.53 (185A x RSSV138-1)	10	14	3	43
Leaf length (cm)	-43.96 to 32.72 (27A x KR135)	-45.80 to 11.15 (ICS38A x IS18542)	7	4	8	16
Leaf breadth (cm)	-26.53 to 28.86 (27A x PMS130)	-12.18 to 23.69 (185A x RSSV466)	12	20	31	2
Sugar brix (%)	-69.23 to 95.47 (ICS38A x 6NRL)	-62.69 to 42.73 (PMS71A x SSV74)	10	25	12	22
Leaf to stem ratio	-47.63 to 22.92 (ICS38A x BNM16)	-36.32 to 0.82 (ICS38A x KR135)	10	28	1	45
Green fodder yield (t/ha)	-51.83 to 150.40 (ICS38A x PMS130)	-67.53 to 12.53 (185A x RSSV466	16	16	1	47
Dry matter content (%)	-45.68 to 32.10 (27A x RSSV138-1)	-50.32 to 12.06 (PMS71A x SSV74)	10	25	7	34
Dry fodder yield (t/ha)	-62.43 to 116.37 (ICS38A x PMS130)	-75.54 to -13.45 (PMS71A x RSSV404)	17	12	-	48
Acid detergent fibre	-27.50 to 31.50 (PMS71A x BNM16)	-18.08 to 35.60 (ICS38A x SSV84)	15	24	25	6
Neutral detergent fibre	-49.09 to 13.04 (185A x NSSV14)	-49.78 to 7.90 (185A x NSSV14)	11	22	2	41
Crude protein (%)	-45.54 to 24.99 (185A x KR135)	-40.74 to 23.59 (185A x KR135)	7	35	16	23

The range of heterosis for leaf breadth varied from -26.53 to 28.86 per cent (27A x PMS130) over better parent. 27A x PMS130 (28.86) exhibited highest magnitude of heterosis followed by 27A x KR135 (23.85) and ICS38A x KR135 (22.83). Pandey and Shrotria (2012) also reported better parent heterosis for leaf breadth.

Performance of hybrids over check varied from -12.18 to 23.69 per cent with the cross 185A x RSSV466 exhibiting highest value followed by 185A x 6NRL (23.64), 185A x NSSV14 (22.47) and 27A x PMS130 (22.01). Out of 48 crosses 31 crosses exhibited significant and positive heterosis over check. All the crosses with 185A except 185A x KR135 and 185A x SSV84 showed significant and positive heterosis over the check. Similar results for leaf breadth were reported by Jain and Patel (2013).

The range of heterosis varied from -47.63 to 22.92 per cent over better parent for leaf to stem ratio. ICS38A x BNM16 (22.92) exhibited highest magnitude of heterosis followed by ICS38A x KR135 (19.66), ICS38A x PMS130 (18.94) and 185A x RSSV404 (12.05).

All the crosses showed significant negative heterosis over check except the cross ICS38A x KR135. Negative heterosis for leaf to stem ratio was also reported earlier by Patel and Patel (2011).

Improvement in forage yield is one of the important objective. So, the superiority of hybrids over the best cultivar is essential for increasing its commercial value. The range of heterosis for green fodder yield varied from -51.83 to 150.40 per cent over the better parent. ICS38A x PMS130 (150.40) exhibited highest magnitude of heterosis followed by PMS71A x RSSV138-1 (121.04), 27A x KR135 (119.81), 27A x PMS130 (108.95) and 27A x NSSV14 (76.26). High heterobeltiosis for green fodder yield is in agreement with the reports of Sukhchain and Dara (2008) and Jain and Patel (2013).

Only 185A x RSSV466 (12.53%) cross exhibited positive and significant heterosis over check. Several workers reported the presence of considerable degree of heterosis for green fodder yield per plant in sorghum. Rajguru *et al*. (2005); Singh *et al*. (2008); Bhatt (2009); Patel (2011) and Akbari *et al*. (2012).

The range of heterosis for dry fodder yield varied from -62.43 to 116.37 per cent over better parent. ICS38A x PMS130 (116.37) exhibited highest magnitude of heterosis followed by PMS71A x RSSV138-1 (115.63), 27A x IS18542 (111.47) and 27A x RSSV138-1 (102.41). Pandey and Shrotria (2012) also reported heterobeltiosis for dry fodder yield.

All the crosses showed negative heterosis for dry fodder yield over the best check.

The range of heterosis for dry matter content varied from -45.68 to 32.10 per cent over better parent. 27A x RSSV138-1 (32.10) exhibited highest magnitude of heterosis followed by 27A x SSV74 (31.95), PMS71A x SSV74 (26.61) and 185A x RSSV138-1 (20.62).

Performance of hybrids over check for dry matter content varied from -50.32 to 12.06 per cent with the highest value seen in the cross PMS71A x SSV74. Seven crosses exhibited positive heterosis over check but only PMS71A x SSV74 cross exhibited significant positive heterosis. Most of the crosses showed negative heterosis. This results are in similarity with those reported by Patel and Patel (2011).

The range of heterosis for crude protein varied from -45.54 to 24.99 per cent over better parent. 185A x KR135 (24.99) exhibited highest magnitude of heterosis followed by 185A x NSSV14 (14.97), 185A x RSSV466 (14.97) and 185A x BNM16 (14.97). Significant and positive better parent heterosis for crude protein was reported earlier by Tariq *et al*. (2014).

Performance of hybrids over check for crude protein varied from -40.74 to 23.59 per cent. The crosses ICS38A X PMS130, ICS38A x RSSV466, 27A X 6NRL and 185A x KR135 exhibited highest positive heterosis over the best check which is desirable. Out of 42 crosses 16 crosses exhibited significant heterosis in desirable direction. Patel and Patel (2011) and Akbari and Parmar (2014) also reported significant heterosis for crude protein in their studies.

Heterotic studies revealed the presence of significant heterosis over best check in many cross combinations. The crosses 185A x RSSV466 (days to 50 per cent flowering), 27A x RSSV138-1 (plant height), 185A x RSSV138-1 (number of leaves per plant), ICS38A x IS18542 (leaf length), 185A x RSSV466 (leaf breadth), ICS38A x KR135 (leaf to stem ratio), 185A x RSSV466 (green fodder yield), PMS71A x RSSV404 (dry matter content), 185A x RSSV466 (dry fodder yield), ICS38A x PMS130, ICS38A x RSSV466 (crude protein) exhibited highly significant heterosis in the desirable direction for yield, its component characters and quality.

In the present study, hybrid 185A x RSSV466 exhibited highest significant positive heterosis of 12.53 per cent over the best check with highest green fodder yield of 62.47 t ha^{-1}. In addition, the hybrid also exhibited significant heterosis in desirable direction for days to 50 per cent flowering, leaf breadth and crude protein. The hybrid 185A x RSSV466 also recorded 10.7 per cent increased green fodder yield over the best check variety CSV30F. Therefore, this cross could be utilized for commercial cultivation after sufficient testing in All India trials.

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