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Per Se Performance and Heterosis for Grain Yield and its Components in Dual Purpose Sorghum [*Sorghum Bicolor* (L.) Moench]

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Abstract

Line x Tester mating design was used to generate 30 hybrids from ten male sterile (A-lines) and three male fertile (R-lines) parents. Thirteen parents, thirty hybrids and three checks were evaluated in RBD with three replications. The analysis of variance revealed significant differences among the parents for all the traits except for days to 50% flowering. This showed the presence of sufficient amount of variability in parents (lines and testers) for most of the characters under study. Per se performance of parents and hybrids showed that the male SPV 245, female ICSA 29014 and hybrids ICSA 29003 x SPV 1822, ICSA 29012 x SPV 1822 and ICSA 29004 x SPV 1822 exhibited higher mean performance for grain yield (q ha^{-1}) and some of the yield contributing traits. The cross combinations, ICSA 29011 x SPV 1822, ICSA 29006 x SPV 1822 and ICSA 29016 x SPV 1822 exhibited significant and positive heterobeltiosis for green fodder yield, dry fodder yield and some of the yield contributing traits. In case of standard heterosis over best check CSH 23, the topmostlevel hybrids viz., ICSA 29003 x SPV 1822, ICSA 29012 x SPV 1822 and ICSA 29004 x SPV 1822 were found promising for grain yield (q ha^{-1}) and its component.

Key words : *Per se performance, heterobeltiosis, standard heterosis, grain yield, line x tester analysis.*

Introduction

Sorghum bicolor (L.) Moench (2n = 20), is one of the five major food grains of the globe because of its adaptation to a wide range of environmental conditions, fittingness for low input cultivation and various uses. The crop is broadly grown for staple food, animal feeding, green fodder, grazing forage and firewood in the Africa, America, semi-arid tropics (SAT) of Asia and Australia (1). It occupies 42.14 m ha area in the world with an annual grain production of 59.34 m tones and productivity of 1408 kg/ha (2). In India, it covers about 4.96 m ha with an annual grain production of 5.80 m tonnes and productivity of 967 kg/ha (3). Sorghum green fodder is one of the low-cost sources of animal feed for milch, meat and draft animals, sorghum playscrucial role being dual purpose (grain cum fodder) crop. In the present investigation, an effort has been made to assessmentper se performance and the heterosis in F_1 hybrids with respect to yield in sorghum using line x tester mating designs.

Materials and Methods

The present study was carried out at Research farm RCA, MPUAT, Udaipur, Rajasthan. The testing materials consisted of 30 F_1 hybrids and their ten lines as female (ICSA 29003, ICSA 29004, ICSA 29006, ICSA 29010, ICSA 29011, ICSA 29012, ICSA 29013, ICSA 29014, ICSA 29015 and ICSA 29016) and three testers as a male parent (SPV 245, SPV 1430 and SPV 1822). The F_1 hybrids along with thirteen parents (10 lines and 3 testers), two varietal checks CSV 23, CSV 27, and one hybrid check CSH 25 were evaluated in a Randomized Block Design using three replications during kharif 2015-16. Observations were note down on five competitive plants selected randomly for plant height (cm), green fodder yield (q ha^{-1}), dry fodder yield (q ha^{-1}), number of seeds per primaries, seed index, grain yield (q ha^{-1}), protein content in grain (%) and protein content in fodder (%). Whereas, Days to 50 % flowering and days to maturity were note down on plot basis. The mean data were subjected to statistical analysis. The analysis of variance was carried out as per the procedure suggested by (3) as well as estimation of relative heterosis, heterobeltiosis and economic heterosis as per the method given by (4, 5, 6) respectively.

Results and Discussion

The analysis of variance for all the traits under study revealed that significant differences among the parents for all the characters except for days to 50% flowering. This indicated the presence of adequate amount of variability in the parents (lines and testers) for all the traits except for days to 50% flowering. Mean sum of squares due to lines, testers and lines vs testers were significant for all the traits except for days to 50% flowering. Further, mean sum of squares due to hybrids and parent's vs hybrids were significant for all the traits which indicated the presence of enormous heterosis for these traits. Mean sum of squares

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Table-1 : Analysis of variance showing mean sum of squares for different traits in dual purpose sorghum.

Characters	Rep	Parents	Tester	Lines	L Vs T	P Vs C	Crosses	Error
	[2]	[12]	[2]	[9]	[1]	[1]	[29]	[90]
Days to 5% flowering	24.93*	3.97	1.44	4.89	0.72	642.40**	58.09**	6.05
Days to maturity	3.98	88.47**	18.11**	111.19**	24.70**	162.24**	38.68**	2.62
Plant height	367.75	1592.25**	2890.11**	837.29**	5791.12**	34104.20**	4964.34**	199.05
Green fodder yield	456.96	53678.03**	26850.33**	23243.63**	381243.08**	72638.53**	75741.33**	1117.98
Dry fodder yield	245.42	17175.53**	3073.78**	8013.19**	127840.09**	17213.42**	20862.36**	323.84
No. of seeds/primary	58.79	740.47**	684.33**	747.14**	792.62**	2494.68**	1503.32**	62.53
Seed index	0.04**	0.34**	0.60**	0.32**	0.01	2.61**	0.46**	0.01
Grain yield	106.44**	707.15**	187.44**	523.61**	3398.32**	3088.38**	1448.98**	19.75
Protein content in grain	0.37	9.75**	2.20**	6.92**	50.36**	6.82**	8.27**	0.31
Protein content in fodder	0.07	1.59**	0.22**	1.84**	2.04**	1.77**	4.65**	0.02

*, ** Significant at 5 and 1 percent level of significance.

due to were significant for all the characters except for days to 50% flowering and seed index.

The per se performance of parents and hybrids for phenological, fodder and quality traits (Table-2) revealed that none of the parents (i.e. females and males) showed consistent good mean performance for all the traits. The female parent line ICSA 29014 was top ranking for grain yield (52.67 q ha^{-1}) and days to 50% flowering (73.00 days). Line ICSA 29012 was better for green fodder yield (494.33 q ha-1) and dry fodder yield (241.67 q ha^{-1}). The females line ICSA 29006 was better for days to maturity (93.33 days) and seed index (3.39 gm). For number of seeds per primary the line ICSA 29011 (88.33 seeds) and for plant height line ICSA 29013 (185.33 cm) females were found better. In case of male parents, SPV 245 was top ranking for grain yield (56.33 q ha^{-1}), green fodder yield (621.67 q ha^{-1}), number of seeds per primary (83.00 seeds) and seed index (3.47 gm). R- line SPV 1430 was found better for days to flowering (73.67 days), days to maturity (99.33 days) and dry fodder yield (282.67 q ha^{-1}), whereas R-line SPV 1822 showed better mean performance for plant height (293.33 cm) in desired direction. The findings are in agreement with the results reported by (7, 8, 9).

In case of F_1 none of the hybrids was revealed superior performance for all the traits. The cross combination ICSA 29003 x SPV 1822 exhibited its superiority for grain yield (106.00 q ha^{-1}), ICSA 29011 x SPV 1822 for green fodder yield (788.33 q ha^{-1}), ICSA 29012 x SPV 1822for dry fodder yield (390.00 q ha^{-1}), ICSA 29006 x SPV 245 for seed index (3.92 gm), ICSA 29006 x SPV 1822 for plant height (293.33 cm), ICSA 29014 x SPV 245 for days to 50% flowering (62.33 days) and ICSA 29016 x SPV 1430 for days to maturity (92.33 days) exhibited their superiority in respective traits.

The magnitude of heterosis was measured as per cent increase or decrease of F_1 value over mid-parent (relative heterosis), over better parent (heterobeltiosis) and over standard check, CSV 23 (standard heterosis) for all 10 characters. The measures of heterosis over mid parent have relative less importance than better parent and standard check. Therefore, it is better to measure heterosis in terms of superiority of F_1 over better parent and standard check. Considerably high heterosis in certain crosses and low in other crosses suggested the nature of gene actions varied with the genetic architecture of the parent. The degree of heterosis varied from cross to cross for all the ten traits. Considerable heterosis in certain crosses and low in other crosses revealed that nature of gene action varied with the genetic architecture of parents. Negative heterosis is considered as desirable for days to flowering and days to maturity, while for other traits significant positive heterosis was considered as desirable. The results in this pursuit are discussed in following ways. A vary wide range of heterosis was found for all traits under study.

Heterosis for grain yield (q ha^{-1}) indicated that out of 30 hybrids, 10 hybrids showed positive and significant relative heterosis. The significant and positive heterosis varied from -18.37 to 139.34 per cent. The heterobeltiosis and standard heterosis ranged from 17.89 to 158.54 per cent and 15.27 to 56.65 per cent respectively. Among 30 hybrids ICSA 290003 x SPV 1822, ICSA 290012 x SPV 1822, ICSA 290004 x SPV 1822, ICSA 290006 x SPV 1822 and ICSA 290011 x SPV 1822 had higher mean with desire heterosis for grain yield (q ha^{-1}) as well as for other yield attribute characters so it may be useful for commercial exploitation in dual purpose sorghum. Whereas, for days to 50 % flowering out of 30 hybrids, 15 hybrids depicted significant and negative relative heterosis which is desired for earliness. Range of heterosis from -6.90 to 15.96 per cent for mid parent, -6.70 to -15.38 per cent for heterobeltiosis and -5.48 to

Table-2 : Mean values for days to 50% flowering, days to maturity, plant height, green fodder yield, dry fodder yield, no of seeds per primary, seed index, grain yield, protein content in grain and protein content in fodder.

S. No.	Genotype	DF	DOM	PH	GFY	DFY	S/P	SI	GY	PCG	PCF
		E3	E1	E2	E2	E2	E3	E4	E2	E3	E1
1.	SPV 245	74.67	104.00	154.33	621.67	240.00	83.00	3.47	56.33	11.99	7.58
2.	SPV 1430	73.67	99.33	191.33	471.33	282.67	55.33	2.65	45.33	13.38	7.10
3.	SPV 1822	75.00	103.00	216.00	447.00	220.00	58.67	2.73	41.00	13.56	7.13
4.	ICSA 29003	75.67	101.67	127.33	259.33	92.00	74.00	3.20	19.33	12.42	9.11
5.	ICSA 29004	73.33	97.33	172.33	261.00	89.33	74.00	2.71	19.33	11.65	8.65
6.	ICSA 29006	75.33	93.33	153.67	300.33	99.00	53.67	3.39	20.00	11.40	7.65
7.	ICSA 29010	73.67	102.67	138.33	227.67	93.00	36.67	2.64	19.00	9.31	8.25
8.	ICSA 29011	75.33	100.67	171.67	228.00	97.00	80.33	3.21	16.33	8.28	8.20
9.	ICSA 29012	75.00	103.33	159.00	494.33	241.67	56.00	3.01	46.33	8.74	7.62
10.	ICSA 29013	74.33	110.00	185.33	328.00	155.67	47.67	3.00	27.67	10.74	6.32
11.	ICSA 29014	73.00	110.67	160.00	272.33	110.33	44.33	2.98	52.67	9.11	7.42
12.	ICSA 29015	77.33	110.00	161.00	254.67	71.33	39.67	3.29	18.33	11.99	7.25
13.	ICSA 29016	74.67	110.33	154.33	161.00	67.33	43.33	2.35	15.00	9.17	7.68
14.	ICSA 29003 x SPV 245	72.33	101.00	143.67	202.67	81.33	59.00	3.37	35.67	13.21	8.34
15.	ICSA 29004 x SPV 245	67.00	97.33	246.67	205.67	78.00	99.33	3.03	18.00	11.32	7.53
16.	ICSA 29006 x SPV 245	74.00	104.00	168.33	192.00	79.67	48.67	3.92	51.67	12.18	7.53
17.	ICSA 29010 x SPV 245	65.00	103.33	148.33	236.33	114.33	48.00	3.34	23.00	9.30	5.92
18.	ICSA 29011 x SPV 245	68.67	96.67	210.00	433.33	198.67	64.67	3.73	41.67	9.68	8.11
19.	ICSA 29012 x SPV 245	69.67	99.67	205.67	238.67	89.67	80.67	3.33	21.67	7.99	6.84
20.	ICSA 29013 x SPV 245	65.67	99.67	178.67	397.33	128.33	73.00	3.07	27.33	9.37	8.40
21.	ICSA 29014 x SPV 245	62.33	96.33	171.33	283.33	107.33	37.00	2.81	27.67	8.41	8.57
22.	ICSA 29015 x SPV 245	69.00	105.33	172.67	233.33	94.67	46.00	2.94	22.00	10.11	6.13
23.	ICSA 29016 x SPV 245	74.00	105.33	195.00	283.67	126.67	67.67	2.69	37.67	12.07	9.27
24.	ICSA 29003 x SPV 1430	74.67	106.00	162.00	355.33	96.67	31.67	3.03	29.00	14.84	8.05
25.	ICSA 29004 x SPV 1430	71.00	104.33	196.00	247.00	110.67	83.67	2.75	21.67	9.54	6.32
26.	ICSA 29006 x SPV 1430	73.00	99.67	172.33	408.33	163.67	49.67	3.86	41.00	9.26	8.26
27.	ICSA 29010 x SPV 1430	70.67	103.67	153.00	291.67	105.00	111.67	3.01	26.00	10.06	7.52
28.	ICSA 29011 x SPV 1430	66.00	104.67	190.33	400.00	128.67	87.00	2.81	31.33	10.88	5.82
29.	ICSA 29012 x SPV 1430	62.67	103.33	189.67	416.67	134.67	89.67	3.22	25.33	13.24	7.71
30.	ICSA 29013 x SPV 1430	71.67	98.67	161.67	410.33	130.67	92.33	3.19	30.67	9.62	6.13
31.	ICSA 29014 x SPV 1430	62.67	103.67	171.33	589.00	217.67	60.33	3.43	40.00	8.35	8.23
32.	ICSA 29015 x SPV 1430	74.33	103.67	170.67	325.67	171.67	60.33	3.29	21.67	9.74	8.82
33.	ICSA 29016 x SPV 1430	67.67	92.33	195.00	357.00	286.00	43.67	3.45	61.33	12.44	7.39
34.	ICSA 29003 x SPV 1822	75.67	96.67	226.67	403.33	171.00	54.33	3.54	106.00	9.79	6.18
35.	ICSA 29004 x SPV 1822	74.00	98.33	253.67	390.00	329.67	96.00	3.67	78.00	11.72	9.87
36.	ICSA 29006 x SPV 1822	76.67	102.67	293.33	750.00	311.67	31.33	3.74	73.00	12.29	5.35
37.	ICSA 29010 x SPV 1822	65.67	96.00	185.67	466.00	150.33	113.67	3.46	30.67	9.04	9.72
38.	ICSA 29011 x SPV 1822	75.67	99.00	284.00	788.33	284.67	80.00	3.80	69.67	8.45	6.85
39.	ICSA 29012 x SPV 1822	68.67	99.00	255.00	387.33	390.00	65.33	2.51	81.33	9.77	5.88
40.	ICSA 29013 x SPV 1822	66.33	99.67	270.00	562.67	215.33	68.33	3.57	48.33	9.77	8.66
41.	ICSA 29014 x SPV 1822	63.33	103.67	237.33	283.00	186.33	65.33	3.67	45.67	9.77	5.89
42.	ICSA 29015 x SPV 1822	73.67	106.33	195.00	283.33	109.67	52.67	3.52	17.00	9.94	6.63
43.	ICSA 29016 x SPV 1822	73.33	103.67	208.33	713.33	252.67	49.33	2.71	51.00	9.88	7.12
44.	CSV 23	77.00	100.33	224.00	583.00	278.33	81.00	3.64	67.67	9.15	6.15
45.	CSV 27	77.33	101.33	240.67	600.00	181.00	58.00	2.99	44.33	8.83	6.20
46.	CSH 25	76.67	101.33	190.00	521.33	222.33	75.33	3.43	57.67	11.09	7.29
	GM	71.67	101.80	191.54	381.86	164.92	64.59	3.20	39.16	10.50	7.45
	PM	74.69	103.56	164.97	332.82	143.03	57.44	2.97	30.51	10.90	7.69
	F_1 M	69.83	101.12	200.38	384.49	168.18	67.01	3.28	41.17	10.40	7.43
	Check M	77.00	101.00	218.22	568.11	227.22	71.44	3.36	56.56	9.69	6.55
	Se	1.42	0.94	8.15	19.30	10.39	4.57	0.04	2.57	0.32	0.09
	CD 5%	6.94	5.76	22.89	54.24	29.19	12.83	0.12	7.21	0.90	0.25
	CV	3.43	1.59	7.37	8.76	10.91	12.24	2.22	11.35	5.31	2.09

Table-3 : Number of hybrids having significant heterotic effect in dual purpose sorghum.

Charac-ters	Heterosis				Heterobeltiosis				Economic Heterosis			
	+ ve	- ve	Total	Range	+ ve	- ve	Total	Range	+ ve	- ve	Total	Range
DF	0	15	15	-6.90 to 15.96	0	15	15	-6.70 to -15.38	0	14	14	-5.48 to -14.61
DM	6	14	20	-2.78 to 6.10	0	9	9	-3.55 to -7.37	0	9	9	-3.27 to -7.28
PH	8	1	9	-14.16 to 58.70	6	0	6	17.14 to 43.13	2	0	2	2.49 to 21.88
GFY	4	12	16	-13.70 to 100.71	5	0	5	24.96 to 76.36	3	0	3	14.75 to 26.81
DFY	8	17	25	-24.24 to 113.15	5	0	5	14.85 to 61.38	2	0	2	16.63 to 37.97
S/P	12	9	21	-16.07 to 142.75	6	0	6	19.68 to 101.81	4	0	4	15.66 to 36.95
SI	20	6	26	-4.32 to 38.00	16	0	16	6.35 to 34.39	3	0	3	4.30 to 7.69
GY	11	10	21	-18.37 to 139.34	8	0	8	17.8 to 158.5	3	0	3	15.27 to 56.65
PCG	5	20	25	-11.34 to 19.71	1	0	1	10.49 to 19.71	2	0	2	9.49 to 11.40

Table-4 : Best five hybrids for heterosis (%) better parent and best standard check for grain yield (q ha^{-1}) and other component traits in dual purpose sorghum.

S. No.	Crosses	Mean grain yield (q ha^{-1})	Heterosis (%) over BP (SPV 245)	Best SC (CSV 23) Significant standard heterosis for desired direction	
1.	ICSA 290003 x SPV 1822	106.00	158.54**	56.65**	
2.	ICSA 290012 x SPV 1822	81.33	75.54**	20.20**	Days to 50 % flowering, dry fodder yield (q ha^{-1})
3.	ICSA 290004 x SPV 1822	78.00	90.40**	15.27**	Dry fodder yield (q ha^{-1}), protein content in grain
4.	ICSA 290006 x SPV 1822	73.00	78.05**	7.88	Days to 50 % flowering,protein content in grain
5.	ICSA 290011 x SPV 1822	69.67	69.92**	2.96	Plant height,green fodder yield (q ha^{-1})

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

-14.61 per cent for standard heterosis.out of 30 hybrids, 15 hybrids for heterobeltiosis and out of 30 hybrids, 14 hybrids for standard heterosis depicted significant and negative relative heterosis which is desired for earliness. While, for seed index out of 30 hybrids 20 hybrid showed significant positive heterosis with range -4.32 to 38.00 per cent, out of 30 hybrids16 hybrids showed significant positive heterobeltiosis with range 6.35 to 34.39 per cent and out of 30 hybrids 3 hybrid showed significant positive economic heterosis with range 4.30 to 7.69per cent for seed index.

Eight hybrids depicted significant and positive relative heterosis for plant height. The heterosis over mid parent ranged from -14.16 to 58.70 per cent. The range of heterobeltiosis was from 17.14 to 43.13 per cent. Six hybrids exhibited significant positive heterosis over better parent. The standard heterosis varied from 2.49 to 21.88 per cent. Two hybrids expressed significant positive heterosis over standard check. Whereas, four hybrids depicted significant and positive relative heterosis for green fodder yield. The heterosis over mid parent ranged from -13.70 to 100.71 per cent. The range of heterobeltiosis was from 24.96 to 76.36 per cent. Five hybrids exhibited significant positive heterosis over better parent. The standard heterosis varied from 14.75 to 26.81 per cent. Three hybrids expressed significant positive heterosis over standard check.While, for dry fodder, its ranged in per cent from -24.24 to 113.15, 14.85 to 61.38 and 16.63 to 37.97 for mid parent, better parent and standard heterosis. Eight hybrids depicted significant and positive relative heterosis, 5 hybrids depicted significant and positive heterobeltiosis and 2 hybrids depicted significant and positive standard heterosis.

Five hybrids depicted significant and positive relative heterosis for protein content in grain. The heterosis over mid parent ranged from -11.34 to 19.71 per cent. The range of heterobeltiosis was from 10.49 to 19.71 per cent. The standard heterosis varied from 9.49 to 11.40 per cent. 1 hybrids depicted significant and positive heterobeltiosis and 2 hybrids depicted significant and positive standard heterosis. Ten hybrids depicted significant and positive relative heterosis for protein content in fodder. The heterosis over mid parent ranged from -3.89 to 28.79 per cent. The range of heterobeltiosis was from 7.97 to21.61 per cent. The standard heterosis varied from 6.66 to 8.34 per cent. 9 hybrids depicted significant and positive heterobeltiosis and 2 hybrids depicted significant and positive standard heterosis.

A perusal of (Table-4) revealed that the hybrid, ICSA 290003 x SPV 1822 (56.65%) registered highest standard heterosis over CSV 23 for grain yield followed by ICSA 29012 x SPV 1822 (20.20%), ICSA 290004 x SPV 1822 (15.27%), ICSA 290006 x SPV 1822 (7.88%) and ICSA 29011 x SPV 1822 (2.96%). Preponderance of these hybrids also showed significant heterosis for the component traits like plant height, green fodder yield, dry fodder yield, days to 50 % flowering and protein content in grain. The findings are in agreement with the results

reported by. In conclusion two dual purpose crosses ICSA 29004 × SPV 1822 and ICSA 29012 × SPV 1822 were identified for multi-location testing as these were having economic heterosis more than 15 per cent for grain yield and dry fodder yield. Apart from above, grain purpose cross ICSA 29003 × SPV 1822is also identified for multi-location testing as it had very high economic heterosis for grain yield (56.65%) along with good nicking in flowering and taller male parent.

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