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Heterosis studies for yield and its attributing traits in sorghum (*Sorghum bicolor* (L.) Moench).

Krishna Murthy S.L[1]., Ambedkar S.S[1]., Dushyanta kumar B.M[2]., Satish R.G[3]., Shashidhara N[3]. and Sunil Kumar S.V[3].
1 College of Agriculture, MAU, Parbhani-431402. MS, India.
2 Zonal Agricultural Research Station, Mudigere, UAS Bangalore, Karnataka, India.
3 College of Agriculture, UAS, Bangalore, GKVK, Karnataka, India.

Abstract: *Sorghum is one of the main staple food crop that sustains world's poorest people. India contributes 12% of the world's sorghum production but low productivity is the major concern. Although sustainable heterosis has been reported commercial exploitation to its full potential has not been possible. Heterosis helps to exploit the vigor with present genetic variability that helps to achieve a quantum jump in the yield. The present investigation was undertaken at Sorghum Research Station, Parbhani, Maharashtra with the aim to study heterosis for grain yield and its component traits. Five male sterile lines, eight male fertile lines and 14 crosses were evaluated with 3 replications. The female parent PMS 7B and PMS 37B and male parents KR 192 and RS 29 exhibited high mean value for grain yield/plant and other yield components. The crosses PMS 23A x C 43, and PMS 7A x RS 29 exhibited high mean, high average heterosis and high heterobeltiosis for grain yield and its component traits. So the crosses PMS 23A x C 43 and PMS 7A x RS 29 identified as good crosses can be evaluated for multilocation testing for commercial exploitation.*

Key words: Heterosis, Sorghum.

INTRODUCTION

Sorghum is one of the main staple food crops of the world's poorest people. It is the 4th important cereal crop in the world after rice, wheat and maize. Sorghum covers 39.6 million hectare area, producing 57.79 million tones with a productivity of 1.46 t/ha. India contributes 12% of world's sorghum production. Sorghum is the 3rd important cereal crop after rice and wheat in India. Sorghum covers 9.4 million hectare area in India producing 5.53 million tones with a productivity of 0.77 t/ha. Although sustainable heterosis has been reported, commercial exploitation to its full potential has not been possible. Hence study of heterosis helps to exploit the vigour with present genetic variability that helps to achieve aquantum jump in yield.

MATERIALS AND METHOD

The present study comprised of 5 female lines viz, PMS 7A, PMS 8A, PMS 9A, PMS 28A and PMS 37A and 8 males viz, RS 29, C 43, IB 12, KR 191, KR 192, KR 196, KR 199 and KR 200. The experiment was carried out at Sorghum Research Station, MAU, Parbhani during kharif 2004-05. Fourteen crosses and their parents were sown in a randomized block design with three replications adopting 45 x 15 cm spacing. Five competitive plants were selected randomly from each plot for recording observations on days to 50% flowering, plant height, number of leaves/plant, flag leaf area, third leaf area from top, ear head length, ear head breadth, grain yield/plant, fodder yield/plant, 1000 seed weight, weight of ear head, total chlorophyll content, relative water content, free soluble sugar content and protein content of seed. The data were subjected to analysis of variance for various characters, mean performance of parents and their crosses and heterosis.

RESULTS AND DISCUSSION

The analysis of variance revealed that the variation among the genotypes was highly significant for all the characters, overall heterosis of crosses tested by using parents. Mean performance of male parents, female parents and their crosses is represented in Table 1. Crosses with their mid parent and better parent heterosis are represented in Table 2. The manifestation of seed yield heterosis over mid parent and better parent in the present investigation ranged from –43.19 % (PMS 7A X KR 200) to 55.20% (PMS 28A X C 43) and –43.98% (PMS 7A X KR 200) to 28.11% (PMS 28A X C 43), respectively. For fodder yield, heterosis over mid parent and better parent ranged from -25.33% (PMS 7 A x KR 196) to 71.82% (PMS 28 A x RS 29) and -42.91 %(PMS 7 A x KR 196) to 45.43 % (PMS 28 A x RS 29), respectively. For relative water content, average heterosis ranged from -9.12 % (PMS 7 A x KR 199) to 9.28 % (PMS 28 A x IB 12) and

heterobeltiosis ranged from -9.40 %(PM 5 9 A x KR 196) to 7.91 % (PMS 28 A x IB 12). For protein content, average heterosis ranged from -0.79 % (PMS 8 A x KR 192) to 7.73 % (PMS 28 A x RS 29) and better parent heterosis ranged from -1.46% (PMS 28 A x KR 43) to 7.21 %(PMS 28 A x RS 29).

The range of mid parent heterosis and heterobeltiosis, and number of hybrids showing significant heterosis are represented in Table 3. Heterosis for grain yield is due to simultaneous heterosis in more than one components of yield. In the present study average heterosis and better parent heterosis for yield and its attributing traits are positive and significant. Ear head length is an important yield component trait. Significant positive average heterosis and heterobeltiosis were observed in eight and seven crosses, respectively. Earlier workers like Kaul *et al.* (2003), Hemalatha *et al.* (2003), also reported similar results. Ear head breadth is also important yield attributing character and eight and six hybrids showed significant positive average heterosis and better parent heterosis for this character and these results are in conformity with Kaul *et al.* (2003) and Hemalatha *et al.* (2003). For weight of ear head ten hybrids each exhibited significant positive average and better parent heterosis respectively. These findings are in accordance with earlier workers like Umakanth *et al.* (2003)and Kulkarni and Patil (2004). Six hybrids exhibited significant positive average heterosis for 1000 seed weight. This finding is in accordance with that of the earlier workers Umakanth *et al*. (2003) and none of the hybrids exhibited significant positive heterobeltiosis for 1000 seed weight. Similar results have been reported by Swarnalata and Rana (1988) and Thawari *et al.* (2000).

Heterosis for end product, *i.e*., fodder yield is being manifested as the cumulative effect of heterosis for the component traits. In the present investigation, the elaborative study of 14 crosses revealed this fact as most of crosses showed significant mid parent and better parent heterosis for fodder yield and its component traits *i.e*., number of leaves/plant, area of flag leaf and area of 3rd leaf from top. One and zero hybrids for number of leaves/plant, seven and four hybrids for area of flag leaf, nine and four hybrids for area of 3rd leaf from top and six and four hybrids for fodder yield exhibited positive significant on mid parent and better parent heterosis. Similar findings are also reported by Jey Prakash and Das (1994) and Desai *et al.* (1985).

Earliness is a desirable character that helps to develop early varieties. Significant negative mid parental heterosis and heterobeltiosis for days to 50% flowering was observed in 13 and 11 hybrids respectively. Plant height is desirable to develop semi dwarf high yielding varieties that will be lodging resistant and fertilizer responsive. Three and four hybrids exhibited significant negative mid parent and better parent heterosis for plant height. These findings are in conformity with Kaul *et al.* (2003).

Physiological characters like total chlorophyll content and relative water content are contributing traits of yield character. Eight and Seven crosses exhibited positive and highly significant average and better parent heterosis for total chlorophyll. Seven and Three hybrids exhibited positive and highly significant average and better parent heterosis for relative water content respectively. These findings are in accordance with Grewal *et al.* (2003) and Deshpande *et al*. (2003).

Protein and Free sugar content are quality characters. Four and one hybrids exhibited positive and significant average heterosis and better parent heterosis for free sugar content respectively and eight and seven hybrids for protein content respectively. Benerji. (1988) and Deshpande *et al.* (2003) reported similar results.

The promising hybrids for characters like seed yield, fodder yield, physiological and quality characters are presented in Table 4. Overall, two hybrids PM 28A X C-43 and PMS 7A X RS 29 were identified superior for most of the seed yield, fodder yield, physiological and quality characters, which could be utilized commercially for the exploitation of heterosis of these characters.

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Table 1. Mean performance of hybrids, male lines and female lines for the different characters.

Genotypes	Days to 50% flow.	Plant height (cm)	No. of leaves/ plant	Area of flag leaf (cm^2)	Area of 3^{rd} leaf (cm^2)	Ear head length (cm)	Ear-head breadth (cm)	Grain yield (gm)	Fodder yield (gm)	1000 seed weight (gm)	Weight of ear-head (gm)	Chlorophyll content	Relative water content	Free sugar content	Protein content
PMS 9 A x KR 196	69.00	162.33	9.80	401.17	780.64	36.00	7.90	76.60	305.00	27.52	131.60	3.10	79.87	1.30	8.20
PMS 7 A x KR 199	68.00	138.13	10.53	348.08	670.66	29.66	7.20	82.00	298.30	26.69	105.30	3.05	78.49	1.20	8.18
PMS 28 A x C 43	71.33	171.93	11.33	210.06	522.17	37.80	8.00	92.50	243.30	28.70	206.60	3.43	82.55	2.34	8.06
PMS 28 A x KR 191	75.00	158.80	12.20	281.88	674.76	35.93	7.80	68.20	336.60	24.84	262.00	3.08	82.22	1.31	8.45
PMS 7 A x KR 191	74.00	139.80	11.73	313.52	574.13	30.40	6.90	80.40	278.60	27.76	136.00	2.75	85.96	1.50	8.59
PMS 7 A x KR 196	70.33	134.80	9.33	395.91	673.33	27.93	6.00	64.50	211.00	26.77	86.66	2.35	80.23	1.43	8.65
PMS 28 A x RS 29	75.33	214.20	11.13	352.76	669.78	24.40	7.40	77.20	347.60	25.68	158.60	3.61	83.32	1.37	8.77
PMS 7 A x RS 29	74.00	161.87	10.06	400.80	674.96	29.33	8.00	89.50	368.00	27.77	185.30	3.54	82.43	1.43	8.65
PMS 37 A x RS 29	79.00	162.07	9.40	381.57	674.84	26.86	7.30	82.70	240.30	27.93	156.30	3.55	80.65	1.25	8.22
PMS 7 A x KR 200	72.00	152.67	10.33	304.68	688.18	27.86	6.20	48.40	261.60	28.22	97.30	3.61	83.92	1.54	8.28
PMS 8 A x KR 200	66.33	163.60	10.53	319.07	676.01	34.00	7.00	74.10	242.00	26.80	129.60	3.88	76.22	1.62	8.24
PMS 28 A x IB 12	73.33	157.07	10.46	277.36	639.94	35.93	6.90	86.20	258.00	26.70	155.00	3.49	86.16	1.36	8.18
PMS 28 A x KR 200	70.00	157.27	10.60	311.80	709.98	36.73	7.80	86.20	344.30	28.38	129.60	3.75	83.35	1.47	8.11
PMS 8 A x KR 192	66.00	154.87	9.30	329.07	728.79	33.46	7.10	74.30	237.60	29.17	156.30	3.80	78.63	1.30	8.10
PMS 7 B	78.00	144.20	11.00	315.79	623.15	30.13	7.40	84.00	369.60	28.15	122.30	3.45	82.52	1.07	8.16
PMS 8 B	72.33	145.53	10.46	205.26	523.15	31.26	6.70	65.60	287.00	28.88	80.60	3.41	77.80	1.23	8.21
PMS 9 B	75.66	140.00	9.60	262.41	546.97	27.06	6.00	53.30	199.00	24.24	77.60	3.25	88.16	1.06	8.02

PMS 28 B	79.33	145.47	11.33	161.72	433.24	27.93	6.00	47.00	239.00	20.95	94.30	3.16	79.84	1.24	8.18
PMS 37 B	75.00	144.43	9.60	315.30	617.51	23.33	6.70	79.10	139.00	23.32	99.60	3.27	79.99	1.27	8.16
C 43	74.00	137.07	10.93	430.10	721.28	30.13	7.10	72.20	216.10	27.86	112.00	2.71	86.74	1.97	8.05
RS 29	77.33	167.87	10.73	189.29	455.26	22.80	7.20	79.80	195.60	27.96	134.60	3.09	79.85	1.78	8.10
IB 12	79.33	128.07	10.73	431.78	670.64	28.73	6.10	79.60	248.60	26.76	101.00	3.70	77.84	1.43	8.06
KR 191	79.66	158.07	10.93	337.50	583.95	28.33	7.00	71.60	251.10	28.73	104.60	2.88	83.18	1.63	8.08
KR 192	75.00	177.80	9.86	327.60	647.53	27.43	7.00	84.40	189.30	27.38	110.00	3.11	86.07	1.52	8.12
KR 196	69.66	163.20	10.40	351.92	610.32	30.00	7.10	75.40	294.00	28.00	99.00	2.94	83.98	2.07	8.09
KR 199	74.00	162.00	10.30	319.67	616.83	29.20	7.70	87.30	265.60	28.00	107.30	3.08	84.22	1.81	8.10
KR 200	75.00	153.67	9.86	352.02	638.75	24.33	6.90	86.40	260.30	29.22	103.30	2.91	83.21	1.71	8.14
SE	0.91	2.60	0.35	20.85	26.60	0.50	0.12	2.25	5.84	0.44	6.02	0.032	0.33	0.017	0.037
CD	2.53	7.21	0.98	57.70	73.60	1.31	0.34	6.23	16.18	1.22	16.66	0.09	0.93	0.048	0.10

Table 2. Heterosis over mid parent (MP) and over better parent (BP) for different characters.

Crosses	50% flowering		Plant height		Number of leaves		Area of flag leaf		Area of 3rd leaf	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
PM 5 9 A x KR 196	-5.03**	-0.94	7.07	15.95	-2.00	-5.76	30.60**	13.99	34.90**	27.90**
PMS 7 A x KR 199	-10.52**	-8.10**	-9.77**	-4.20	-1.12	-4.27	9.52	8.88*	8.17	7.62
PMS 28 A x KR 43	-6.95**	-3.60*	21.70	25.43	1.79	0.0	-29.01	-51.16	-9.54	-27.60
PMS 28 A x KR 191	-5.65**	-5.45**	4.63	9.16	9.61*	7.67**	12.92	-16.48	32.67**	15.55*
PMS 7 A x KR 191	-6.12**	-5.12*	-7.49**	-3.05	6.97	3.00	-4.10	-7.10	-4.87	-7.86
PMS 7 A x KR 196	-4.74**	0.96	-12.29**	-6.51	-12.80	-15.18	18.58*	12.5	9.17	8.05
PMS 28 A x RS 29	-3.82	-2.58**	36.72	47.24	-0.90	-1.76	100.99**	86.35**	50.76**	47.12**
PMS 7A x RS 29	-4.72**	-4.30*	3.73	12.25	-7.40	-8.54	58.70**	26.9**	25.17**	9.30
PMS 37 A x RS 29	-3.72**	-5.33**	3.79	12.21	-7.52	-12.39	51.23**	21.01*	25.81**	9.28
PMS 7 A x KR 200	-5.88**	-4.00**	2.50	15.87	-0.95	-6.09	-8.75	-13.44	9.07	7.73
PMS 8 A x KR 200	-9.95**	-8.29**	9.35	12.41	3.64	0.66	14.50	-9.30	16.36**	5.83
PMS 28 A x IB 12	-7.56**	-7.56**	14.84	-22.64	-5.16	-7.67	-6.53	-35.76	15.94**	-4.57
PMS 28 A x KR 200	-9.28**	-6.66**	5.14	8.11	0.04	-6.44	21.38*	-11.42	32.46**	11.15

PMS 8 a x KR 192	-10.40**	-8.75**	-4.20	-6.41	-8.46	-11.08	23.35*	0.44	24.50**	12.5**
SE ±	1.12	1.29	3.19	3.68	04.3	0.50	25.53	29.48	32.58	37.62
CD at 5%	2.19	2.52	6.25	7.21	0.84	0.98	50.03	57.78	63.85	73.53

Crosses	Ear head breadth		Grain yield		Fodder yield		1000 seed wt.		Ear head weight	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
PM 5 9 A x KR 196	14.49**	11.26**	19.03**	1.59	23.75**	3.74	5.35**	-1.71	49.03**	32.92**
PMS 7 A x KR 199	-4.63	-6.49	-4.26	-6.07	-6.07	-19.29	-4.93	-5.18	-8.27	-13.90
PMS 28 A x KR 43	22.13**	12.67**	55.20*	28.11**	6.92	1.79	17.59**	3.01	100.29**	84.46**
PMS 28 A x KR 191	20.00**	11.42**	15.00**	-4.74	37.33**	34.02**	0.0	-13.53	163.44**	150.47**
PMS 7 A x KR 191	-4.16	-6.75	3.34	-4.28	-10.23	-24.62	-2.39	-3.37	19.87	11.20
PMS 7 A x KR 196	-17.24	-18.91	-19.07	-23.21	-25.33	-42.91	-4.64	-4.90	-21.68	-29.14
PMS 28 A x RS 29	12.12**	2.77	21.76**	-3.25	71.82**	45.43**	5.00*	-8.15	38.57**	17.83**
PMS 7A x RS 29	9.58**	8.10**	9.27**	6.54	30.21**	-0.43	-1.01	-13.49	44.25**	37.66**
PMS 37 A x RS 29	3.54	1.38	4.09	3.63	43.63**	22.85**	8.93**	1.07	33.47**	16.12**
PMS 7 A x KR 200	-13.28	-16.21	-43.19	-43.98	-16.93	-2.16	-1.62	-3.42	-13.74	-20.44
PMS 8 A x KR 200	2.94	1.44	-2.5	-14.93	-11.56	-15.67	-7.74	-8.28	40.94**	25.45**
PMS 28 A x IB 12	14.04**	13.11**	36.17**	8.29*	5.82	3.78	11.92**	-0.22	58.73**	53.46**
PMS 28 A x KR 200	20.93**	13.04**	29.23**	-0.23	37.91**	32.27**	13.13**	-2.87	31.17**	25.45**
PMS 8 a x KR 192	3.64**	5.97	-0.93	-11.96	-0.23	-17.21	3.69	1.00	64.00**	42.09**
SE ±	0.15	0.17	2.75	3.18	7.15	8.26	0.54	0.62	7.37	8.51
CD at 5%	0.29	0.33	5.39	6.23	14.01	16.18	1.05	1.21	14.44	16.67

Crosses	Total Chlorophyll content		Relative water content		Free sugar content		Protein content		Ear head length	
	MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
PM 5 9 A x KR 196	0.16	-4.6	-7.20	-9.40	-16.93	-37.19	1.80**	1.35*	26.18	20.00**
PMS 7 A x KR 199	-6.58	-11.59	-9.12	-6.80	-21.31	-33.71	0.61	0.24	-0.01	-1.55
PMS 28 A x KR 43	16.86**	8.54**	-0.88	-4.83	45.79**	18.78**	-0.67	-1.46	30.12**	25.45**

PMS 28 A x KR 191	1.9	-2.53	0.87	-1.15	-8.71	-19.63	3.93**	3.30**	27.72**	26.82**
PMS 7 A x KR 191	-13.11	-20.28	3.75**	3.34**	11.11**	-7.97	578**	5.26**	4.00	0.89
PMS 7 A x KR 196	-63.05	-31.88	-3.62	-4.46	-8.91	-30.91	6.46**	6.00**	-7.10	-7.30
PMS 28 A x RS 29	15.52**	14.24**	4.35**	4.34**	-9.27	-23.03	7.73**	7.21**	-3.80	-12.63
PMS 7A x RS 29	8.25**	2.60	1.53**	-0.10	0.35	-19.66	6.39**	6.00**	10.82**	-2.65
PMS 37 A x RS 29	11.63**	7.03**	0.91*	0.82	-18.03	29.77	1.10*	0.73	16.45**	15.13
PMS 7 A x KR 200	13.52**	4.63**	1.27**	0.85	10.79**	-9.94	1.59**	1.47*	2.31	-7.53
PMS 8 A x KR 200	22.78**	4.86**	-5.26	-8.41	10.20**	-5.26	0.79	0.36	22.32**	8.76**
PMS 28 A x IB 12	1.74	-5.67	9.28**	7.91**	1.87	-20.46	0.73	0.0	26.82**	25.06**
PMS 28 A x KR 200	23.55**	18.67**	2.23**	0.16	-0.33	-14.03	-0.61	-0.85	40.56**	31.50**
PMS 8 a x KR 192	16.56**	11.43**	-4.03	-8.64	-5.45	-14.47	-0.79	-1.33	14.02**	7.03**
SE ±	0.038	0.044	0.41	0.47	0.021	0.024	0.046	0.053	0.61	0.71
CD at 5%	0.074	0.086	0.80	0.92	0.041	0.047	0.09	0.10	1.19	1.39

* and ** indicate significance at 5 and 1 per cent respectively.

Table 3. Range of mid parent heterosis and better parent heterosis for yield and other characters and number of hybrids showing significant heterosis.

Characters	Range		No of hybrids showing desirable significant heterosis	
	MP	BP	MP	BP
1. Days to 50 % flowering	-10.52 to 3.72	-8.75 to -8.29	13	11
2. Plant height	-12.29 to 36.72	-6.51 to 47.24	3	4
3. Number of leaves per plant	-8.46 to 9.61	15.18 to 7.67	1	-
4. Flag leaf area	-29.01 to 100.99	-51.16 to 86.35	7	4
5. Third leaf area	-9.54 to 50.76	-27.00 to 47.12	9	4
6. Ear head length	-7.10 to 40.56	-12.63 to 31.5	8	7
7. Ear head bread	-17.24 to 22.13	-16.21 to 13.11	8	6
8. Grain yield / plant	-43.19 to 55.20	-43.98 to 28.11	7	2
9. Fodder yield per plant	-25.33 to 71.82	-42.91 to 45.43	6	4
10. Thousand seed weight	-7.74 to 17.59	-13.53 to 30.1	6	1

11. Weight of ear head	-21.68 to 163.44	-29.14 to 150.47	10	10
12. Total chlorophyll content	-63.05 to 23.55	-31.88 to 18.67	8	7
13. Relative water content (%)	-9.12 to 9.28	-9.4 to7.91	7	3
14. Free soluble sugar content	-21.31 to 45.79	-37.19 to 18.78	4	1
15. Protein content of seed	-0.79 to 7.73	-1.46 to7.21	8	7

Table 4. Crosses having high average heterosis and hetrobeltiosis for different characters are as follows

Sl. No	Characters	Crosses
1	Days to 50 per cent flowering	PMS 28 A x IB 12
2	Plant height	PMS 7A x KR 196, PMS 7A x KR 199 and PMS 7 A x KR 191
3	Number of leaves/plant	PMS 28A x KR 191
4	Area of flag leaf	PMS 7 A x RS 29
5	Area of 3rd leaf	MS 9A x KR 196
6	Ear head length	PMS 28 A x C 43, PMS 28 A x KR 200
7	Ear head breadth	PMS 28 A x C 43 and MS 9A x KR 196
8	Grain yield/plant	PMS 28 A x C 43 and PMS 28 A x KR 200
9	Fodder yield/plant	PMS 28 A x RS 29 and PMS 28 A x KR 200
10	1000 seed weight	PMS 28 A x C 43 and PMS 28 A x KR 200
11	Weight of ear head	PMS 28 A x C 43 and PMS 28 A x KR 191
12	Chlorophyll content	PMS 28 A x C 43, PMS 28 A x KR 200, and PMS 8 A KR 192
13	Relative water content	PMS 28 A x IB 12 and PMS 7 A x KR 191
14	Free sugar content	PMS 28 A x C 43
15	Protein content	PMS 28 A x RS 29, PMS 7 A x KR 196, PMS 7 A x RS 29