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Heterosis and Combining Ability in Grain Sorghum (*Sorghum bicolor*) (L.) Moench*

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ABSTRACT

Substantial degree of heterosis was observed for all the characters. The maximum heterosis was expressed by the plant height and earhead length. The next in descending order were seed size, days to maturity, panicle width, grain yield and days to 50% bloom. Hybrids involving locals were higher yielding and early in maturity.

For grain yield and its associated characters like height, maturity and seed size, additive genetic variance was found in preponderance. Although in certain cross combinations and for yield contributing components, like panicle length and panicle width non-additive genetic variance was also observed in predominance. Thus it indicated the utility of both conventional and heterosis breeding for sorghum improvement work.

The local varieties B. P. 53, Sona-108 and Surat-1 have emerged out as good general combiners but they could not be used directly since they are tall and late in maturity. Hence these varieties are to be converted into suitable types to be used in hybrid production. Both GCA and SCA effects are of importance for grain yield in sorghum.

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INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the most important food and fodder crop of dryland agriculture in India. In Gujarat this crop is grown on an area of about 10 lakh hectares. The average grain yield is low in Gujarat State which could be due to growing sorghum mainly as fodder crop, low level of plant population and plant protection measures. There is a great potential of increasing sorghum production in Gujarat State by introducing high yielding sorghum hybrids. Since line x tester analysis technique is one of the most useful methods for screening large number of cultures, it was utilized to study heterosis, general combining ability and specific combining ability in grain sorghum.

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MATERIALS AND METHODS

Seven male parents were crossed with three male sterile lines viz. ms CK60A, ms 2219A and ms 2077A. The resultant 21 hybrids along with 10 parents were grown in a randomised block design using three replications at Sorghum Research Station, Navsari during *kharif*-1976. The fertile counter-part 'B' lines were grown as female parents in the trial. Each entry was sown in 3.75 metre long three row plot. Row to row and plant to plant distances were 60 cm and 15 cm respectively. Fertilizer at the rate of 80 kg N and 40 kg P_2O_5/ha was applied. Observations with regard to plant height, length of panicle, panicle width and grain yield per plant were collected on five randomly selected plants in each replication from central row, while data for days to 50% bloom, days to maturity and seed size were recorded on plot basis. Expression of relative heterosis and heterobeltiosis was measured as the deviation of hybrid from its mid parent and better parent values respectively. The data were subjected to genetic analysis for estimating combining abilities as per the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The results obtained from the analysis of variance revealed considerable genetic variation among males and females. The male sterile female lines also differed markedly from the male lines in respect of all the characters studied. The existence of wide variation in the males and females for different characters validated the examination of nature of combining ability and extent of heterosis.

Manifestation of heterosis:

The estimation of heterosis of different characters in relation to mid-parent (Relative heterosis) and better parent (heterobeltiosis) is given in Tables-1 and 2 respectively. For plant height, only one hybrid showed non-

TABLE 1

Percentage of heterosis ever mid-parent for some agronomic characters in sorghum.

Cross	*Days to 50% bloom*	*Days to maturity*	*Plant height*	*Panicle length*	*Panicle width*	*Seed size*	*Seed yield*
CK60Ax302	– 2.13	2.97**	12.22**	16.61**	4.08	0.77	–0.85
CK60Ax370	–6.73**	3.55**	24.15**	16.81**	20.17**	13.39**	23.09*
CK60AxCS3541	2.82*	–0.01	27.84**	26.35**	44.04**	17.65**	74.15**
CK60AxBP53	–17.09**	–5.58**	67.84**	37.85**	60.90**	7.52**	39.69**
CK60AxSona-108	– 6.91**	2.17**	39.63**	25.62**	47.70**	22.58**	35.73**
CK60AxSurat-1	– 9.28**	–2.44**	44.68**	42.24**	53.02**	18.53**	36.63**
CK60AxBC9	–17.75**	–5.30**	8.97*	39.43**	21.46**	11.52**	–3.54
2219Ax302	– 0.72	7.53**	23.86**	18.96**	2.79	3.57	25.88*
2219Ax370	– 1.48	8.11**	6.54	10.01**	–0.16	24.60**	7.64
2219AxCS3541	– 1.43	3.97**	30.83**	37.56**	35.14**	6.18*	75.93**
2219AxBP53	–15.44**	–4.65**	73.58**	44.25**	33.78**	6.13*	29.48**
2219AxSona-108	– 7.81**	3.85**	37.51**	28.40**	27.56**	19.65**	34.98**
2219AxSurat-1	– 5.87**	–2.20**	34.10**	46.04**	39.34**	17.67**	44.05**
2219AxBC9	–16.85**	–3.11**	9.08*	60.00**	31.25**	24.99**	– 6.43
2207Ax302	– 0.21	5.04**	22.85**	19.87**	14.63**	25.61**	30.00**

1	2	3	4	5	6	7	8
2077Ax370	– 0.45	7.26**	20.06**	–8.18**	9.89	30.87**	41.20**
2077AxCS3541	– 3.01**	–0.01	39.01**	14.42**	11.39	16.49**	69.87**
2077AxBP53	– 8.16**	–3.70**	31.39**	7.65	33.94**	32.62**	17.41*
2077AxSona-108	– 9.43**	–0.26	26.38**	24.28**	39.29**	35.63**	57.08**
2077AxSurat-1	– 6.12**	2.81**	33.51**	14.23**	31.99**	36.97**	37.71**
2077AxBC9	– 8.14**	–1.76**	43.07**	23.52**	57.73**	24.72**	32.78**

*, ** Significant at P=0.05 and P=0.01 respectively.

TABLE 2

Percentage of heterosis over better parent (heterobeltiosis) for some agronomic characters in sorghum.

Cross	*Days to 50% bloom*	*Days to maturity*	*Plant height*	*Panicle length*	*Panicle width*	*Seed size*	*Seed yield*
CK60Ax302	8.37	9.83	–2.32	6.66	–15.42*	– 16.23**	– 5.94
CK60Ax370	1.57	10.79**	0.98	– 1.88	–10.98*	– 0.29	– 1.25
CK60AxCS3541	14.65**	5.08**	15.63*	25.03**	20.25**	11.98**	55.24**
CK60AxBP35	19.37**	23.50**	22.13**	16.02**	23.51**	–15.37**	2.09
CK60AxSona-108	19.88**	19.36**	8.23	23.13**	8.78	0.03	–5.47
CK60AxSurat-1	23.02**	20.64**	– 1.93	19.71**	15.13*	– 6.93**	– 1.43
CK60AxBC-9	18.85**	21.90**	–24.08**	12.97*	0.0	– 4.94*	–27.93**
2219Ax302	11.89**	16.29.**	3.36	9.72*	– 8.29	–16.80**	–20.13
2219Ax370	9.18**	17.27**	–16.58**	– 6.90*	–19.92**	6.58*	–13.22
2219xCS3541	11.89**	10.75**	13.22*	37.37**	24.33**	– 2.99	57.77**
2219AxBP53	24.32**	26.72**	22.49**	20.53**	10.65*	–19.19**	– 4.97
2219AxSona-108	21.08**	23.13**	2.93	24.74**	1.63	– 5.56*	– 4.22
2219AxSurat-1	30.26**	22.81**	–11.41*	22.02*	13.79*	–10.44**	4.34
2219AxBC-9	22.70**	26.72**	–26.09**	28.68**	18.87**	2.81	–29.79**
2077Ax302	0.45	5.04**	13.27*	16.29**	3.98	2.10	21.98**
2077Ax370	0.44	7.56**	2.88	–14.02**	–10.60*	12.32.**	12.32
2077AxCS3541	–1.74	1.44	33.56**	2.77	4.26	7.94**	49.92**
2077AxBP53	17.91**	16.81**	14.97*	–17.51**	12.45*	2.11	–14.80
2077AxSona-108	14.81**	8.68**	2.80	8.64*	12.55*	8.29**	10.30
2077AxSurat-1	13.98**	11.76**	– 6.19	–12.48**	9.37	5.37*	– 1.34
2077AxBC-9	18.34**	17.37**	3.59	– 8.38*	45.28**	3.89	– 1.54

*, **Significant at P=0.05 and P=0.01 respectively.

significant heterosis over mid-parent value and consequently confirmed additive gene action. Seven crosses exhibited significant positive heterobeltiosisindicating over-dominance. Four crosses showed significant possitive heterosis and significant negative heterobeltiosis confirming partial dominance. On an overall basis, partial dominance was found to exist for tallness. This finding is in confirmation with Vasudeva Rao and Goud (1975).

For days to 50% bloom and days to maturity, most of the crosses exhibited

significant negative heterosis and positive heterobeltiosis confirming partial dominance for earliness. From an economical point of view this is in interest of breeding early hybrids or varieties from late maturing local types. These findings are in confirmation with Quinby (1963), Kirby and Atkins (1968) and Vasudeva Rao and Goud (1975).

For panicle length, thirteen crosses exceeded better parental limit indicating overdominance. Only one cross showed non-significant heterosis at midparent value which is indicative of additive type of gene action. Three crosses showed significant positive relative heterosis and significant negative heterobeltiosis confirming partial dominance. On an overall basis overdominance of substantial degree was indicated. Blum (1970) and Rao (1970) were of opinion that among the different component of panicle morphology, panicle length might play a major role in grain yield heterosis. Therefore the overdominance trend observed for panicle length seems to be of practical importance in harvesting the yield heterosis. Similarly for panicle width, ten crosses exhibited overdominance in positive direction. Five crosses showed non-significant heterosis at mid-parent value indicating additive gene action. Sixteen crosses showed significant positive relative heterosis indicting partial-dominance. But on an overall basis non-additive interaction resulted in overdominance contributing for higher heterosis for grain yield. Thus in addition to panicle length, panicle width also seems to be an important component for harvesting grain yield heterosis.

For seed size only two crosses showed non-significant heterosis indicating additive gene action while six crosses exhibited significant positive heterobeltiosis confirming the presence of overdominance for grain weight. Six crosses also recorded significant positive heterosis and significant negative heterobeltiosis which indicated partial dominance for this trait. Though on an overall basis additive gene action with partial dominance should be functioning. This finding is in confirmation with Bartel (1949).

The relative heterosis for grain yield ranged from-6.43% to 75.93%. Hybrid (2077A x Sona-108) showed the highest yield/plant but it was not the highest for heterosis at mid-parent and better parent level. On the contrary, three crosses viz. (CK60A x CS3541), (2219A x CS 3541) and (2077A x CS3541) recorded high heterosis at mid-parent and better parent level though they were low in mean performance in comparison with eight hybrids, (CK60A x BP53), (CK60A x Sona-108), (CK60A x Surat-1), (2219 A x BP 53), (2219A x Sona-108), (2219A x Surat-1), (2077A x Sona-108) and (2077A x Surat-1) where one parent is local type. This suggests that the calculation of heterosis over mid-parent and better parent has no practical significance when parents are poor yielders. The crosses with tall local types resulted into hybrids with higher mean performance though they were not differing significantly over their better parent, though they were earlier. One cross (2077A x Sona-108) was found as the highest yielding hybrid showing fairly bold lusterous grain with medium height as well as maturity. Hence this could be recommended for exploitation for commercial hybrid or for good segregant in combination with others. A second thought would be more feasible since two parents viz. 2077A and Sona-108 possess wide differences in their height and maturity.

Combining ability analysis:

In the present study, additive genetic variance was found to be predominant for five characters viz. plant height, days to 50% bloom, days to maturity, seed size and grain yield/plant. For panicle length and panicle width. non-additive genetic variance was in prepondernace. The GCA effects of the parents are given in Table 3. Among male parents Sona-108 and Surat-1 were good combiners for grain yield and its direct component panicle width and seed size. Sona-108 and Surat-1 possessed average and poor

TABLE 3

Estimates of general combining ability effects of parents for different characters in grain sorghum.

Parents	*Days to 50% bloom*	*Days to maturity*	*Plant height*	*Panicle length*	*Panicle width*	*Seed size*	*Grain yield/ plant*
Females							
1. CK60A	– 2.90**	– 3.39**	– 0.86	– 0.54	– 0.07	– 0.96**	– 1.87
2. 2219A	– 2.95**	– 1.73**	–11.74**	+ 0.77	– 0.15	– 1.57**	– 1.40
3. 2077A	+ 5.86**	+ 5.13**	+12.59**	– 0.22	+ 0.21	+ 2.53**	+ 3.27
S.E.(gi)	± 0.40	± 0.38	± 3.86	± 0.44	± 0.17	± 0.25	± 2.14
Males:							
1. 302	– 4,63**	– 5.28**	–65.44**	+ 2.08**	– 1.71**	– 2.11**	– 22.56**
2. 370	– 7.08**	– 3.62**	–51.84**	+ 1.90**	– 0.60*	– 1.24**	– 8.68*
3. CS3541	– 3.86**	–11.39**	–56.02**	+ 1.34	– 0.80*	– 5.95**	+ 2.92
4. BP-53	+ 4.70**	+ 7.72**	+79.56**	– 2.65**	+ 1.02**	+ 2.20**	+ 5.30
5. Sona-108	+ 0.81	+ 1.83**	– 7.37**	+ 0.59**	+ 1.24**	+ 2.95**	+18.86**
6. Surat-1	+ 5.70**	+ 3.38**	+79.16**	– 1.81**	+ 1.08**	+ 4.75**	+13.50**
7. BC-9	+ 4.37**	+ 7.38**	+21.94**	+ 1.43*	– 0.26	– 0.59	– 9.34**
S.E.(gi)	± 0.61	± 0.58	± 5.90	± 0,67	± 0.25	± 0.37	± 3.27

*, ** Significant at P = 0.05 and P = 0.01 respectively.

GCA effects respectively for panicle length. The GCA effects revealed distinct differences between dwarf and tall parents. The GCA effects of local tall parents particularly for yield character are of considerable magnitude and in deisrable direction. The GCA effects of dwarf parents are generally in negative direction. The experimental results revealed that tall local varieties could transmit favourable alleles for yield and plant height where as the dwarf exotic male-sterile lines and exotic x Indian derivatives should have alleles for earliness. The dwarf males derived from exotic x Indian crosses showed significant positive GCA effects for panicle length while tall local male exhibited significant negative GCA effect for this character. On the contrary, positive significant GCA effects were found in local male for panicle width while dwarf male showed significant negative GCA effects for this character. All females showed average combining ability for these characters. Three males viz. BP-53, Sona-108 and Surat-1 and Female 2077A emerged out for production of bolder grain while most of the remaining parents showed significant negative GCA

effects. Thus local varieties (BP-53, Sona-108 and Surat-1) could effectively be utilized for developing sorghum hybrid with bold grains.

In present investigation SCA effects were of lower mgnitude in comparison with GCA effects. Although SGA (Table 4) effects were sigificant for almost all the

TABLE 4

Estimates of specific combining ability effects of different crosses for grain yield and other characters in sorghum.

Cross	*Days to 50% bloom*	*Days to maturity*	*Plant height*	*Panicle length*	*Panicle width*	*Seed size*	*Grain yield*
CK60Ax302	+ 0.34	– 0.06	–10.54	– 1.21	– 0.46	– 0.90	– 5.23
CK60Ax370	– 1.54	– 1.72	+10.79	+ 2.37*	+ 0.30	– 0.73	+ 1.56
CK60AxCS3541	+ 3.57**	+ 0.05	– 6.76	– 0.67	+ 0.30	+ 2.42**	+ 2.29
CK60AxBP53	– 1.99	+ 0.28	+ 6.79	+ 0.78	+ 0.64	–0.70	+ 7.98
CK60AxSona-108	+ 2.23**	+ 1.83	+ 8.59	– 0.92	+ 0.16	+ 0.67	– 2.98
CK60AxSurat-1	– 0.66	+ 1.62	+ 16.19	– 0.74	+ 0.25	– 0.11	+ 0.31
CK60AxBC-9	– 1.99	– 1.05	–25.06*	– 1.10	– 1.18*	– 0.67*	– 3.98
2219Ax302	+ 0.39	+ 0.95	+ 9.47	– 1.72	+ 0.05	– 0.47	+ 4.57
2219Ax370	+ 1.17	+ 0.29	–11.73	– 0.54	– 0.32	+ 1.49	– 6.03
2219AxCS3541	– 0.38	+ 1.39	+ 0.58	+ 0.75	+ 0.61	+ 0.42	+ 2.96
2219AxBP53	– 1.27	– 1.38	+18.60	+ 0.94	– 0.21	– 1.48*	+ 2.11
2219AxSona-108	+ 0.62	+ 0.84	+ 8.00	– 1.37	– 0.33	– 0.56	– 2.38
2219AxSurat-1	+ 1.39	– 1.04	– 4.66	+ 0.43	+ 0.23	– 0.78	+ 4.44
2219AxBC-9	– 1.94	– 1.04	–20.24	+ 1.52	– 0.00	+ 2.23**	– 5.78
2077Ax302	– 0.75	+ 0.09	+ 1.07	+ 2.93*	+ 0.43	+ 1.37*	– 0.63
2077Ax370	+ 0.36	+ 1.43	+ 0.94	– 1.82	+ 0.05	– 0.76	+ 4.35
2077AxCS3541	– 3.19**	– 1.47	+ 6.19	– 0.09	– 0.88*	– 2.00**	– 5.25
2077AxBP-53	+ 3.25**	+ 1.09	–25.39*	– 1.74	– 0.44	+ 2.18**	–10.09
2077AxSona-108	– 2.86**	+ 2.69*	–16.60	+ 2.29	+ 0.18	– 0.10	+ 5.35
2077AxSurat-1	– 0.75	– 0.57	–11.53	– 1.18	– 0.46	+ 0.89	– 4.78
2077AxBC 9	+ 3.91**	+ 2.10*	+45.29**	– 0.42	+ 1.18*	– 1.55*	+ 9.75
SE(Sij) ±	1.06	1.01	10.22	1.16	0.44	0.65	5.66

*,** Significant at P=0.05 and P=0.01 respectively.

characters in a number of combinations. For grain yield, none of the crosses showed either positive or negative significant SCA effects though majority of the cross combinations exhibited positive direction of SCA effects for grain yield character. The SCA effects when considered along with the GCA effects revealed that all the three possible parental combinations for GCA effects i.e. high x high, high x low and low x low exhibited high SCA effects for different characters studied.

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