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Combining Ability and Heterosis in *Gossypium hirsutum* L.

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ABSTRACT

Combining ability and heterosis were studied in a diallel cross involving five cotton genotypes for yield and quality traits. Analysis of variance components indicated that except staple strength and boll weight all characters were predominantly controlled by non-additive gene action. CIM-473 was the best combiner for seed cotton yield and its component and ACALA 1517/C for quality traits. A cross of NIAB-999 x CIM-473 and ACALA1517/ C x FVH-57 showed higher specific combining ability effects for all characters. Moreover, they involved at least one parent with positive and high general combining ability effects, therefore, they are recommended for further studies.

Key Words: *Gossypium hirsutum* L.; Combining ability; Heterosis

INTRODUCTION

High seed cotton yield is the ultimate objective of any crop breeding program. Seed cotton yield is the end product of number of yield component such as boll number, boll weight etc. Industrial demand of cotton with superior fibre trait is also source of guide line for cotton breeders.

The need to further amplify efforts for continued genetic improvement of cotton for yield and quality traits is even greater today than before in view of a low production per unit area and low fibre quality traits as compared to other advanced cotton growing countries of the world to meet the challenges of 21st century. Seed cotton yield and its quality parameters are quantitative traits, which are controlled by several genes thus showing a range of values in segregating generation. Diallel analysis is one of the most widely used techniques, which determine type of genetic variation in quantitative characters.

Diallel analysis is carried out on two techniques i.e. graphical technique (Hayman, 1954a, b; Jinks, 1954, 1956) and combining ability analysis (Griffing, 1956). Griffing model provides information on general combining ability (GCA) referring the average performance of parental line reflected in its hybrid combinations and specific combining ability (SCA), as an average performance of a particular cross. Combining ability analysis provides an ample opportunity to cotton breeders to understand the basis on which certain parental lines could be exploited in the breeding programme (Katageri & Kadapa, 1989; Khorgade *et al.,* 2000; Braden *et al.,* 2003; Christopher *et al.,* 2003; Zhang *et al.,* 2003).

The high magnitude of variance due to SCA gives us indication of non-additive type of gene action which makes interesting to estimate useful heterosis manifested by various cross combinations in particular trait. Heterosis is one of the crop breeding tools, which offers an opportunity for increasing cotton production if judiciously used. Heterosis and heterobeltiosis in cotton have been observed by various workers (Hassan *et al.,* 1999; Sayal *et al.,* 1999; Soomro 2000; Arshad *et al.,* 2001; Babar *et al.,* 2001). The magnitude of heterosis varies from cross to cross and specie-to-specie.

Keeping in view the important genetic parameters i.e. combining ability and heterosis, an endeavor has been attempted in the present studies, to determine the GCA and SCA along with reciprocal effects and heterosis of five cotton genotypes through diallel crossing scheme.

MATERIALS AND METHODS

A five parent diallel cross experiment involving two commercially grown cottons i.e.NIAB-999, CIM-473 and three lines CRIS-420, FVH-57, and ACALA 1517/C was under taken at Department of Plant Breeding, University of Agriculture, Faisalabad. All these genotypes differ from each other for important agronomic plant characters. These genotypes were crossed in a diallel fashion including direct and reciprocal crosses during 2002-03. The seeds of the F_1 along with their selfed parents were field planted during the crop season 2003-04 in such a way that distance between the rows was 75 cm and between plants was 30 cm. Lay out design was completely randomized block design with three replications. At maturity the data from middle eight competitive plants per replication were collected for the yield of seed cotton in grams, number of bolls per plant, weight per boll in grams, height of main stem (cm), monopodial branches, sympodial branches, ginning outturn (%), staple length (mm), fibre strength (g/tex), fibre fineness (μg inch^{-1}) per plant. The various laboratory tests were carried out for the collection of data for ginning percentage, staple length, fibre strength, fibre fineness. Staple length, strength and fineness of each plant were measured by using Spin Lab HVI-900. HVI-900 is a computerized high volume instrument which provides a comprehensive profile of raw fibre. Total produce of the plant was ginned and lint obtained from each sample was weighed and lint percentage was calculated by the following formula.

$$G.O.T = \frac{Weight\ of\ lint\ in\ a\ sample}{Weight\ of\ seed\ cotton\ in\ a\ sample} \times 100$$

The data were subjected to analysis of variance (Steel & Torrie, 1980). The significant or highly significant data were analyzed for combining ability using method 1 and model 2 of Griffing (1956).

Magnitude of heterosis in terms of percentage of increase (+) or decrease (-) of F_1 over mid parent (MP) and better parents (BP) for each character was calculated (Fonseca, 1968).

RESULTS AND DISCUSSION

Combining ability analysis. The estimates for GCA and SCA are presented in Table II, III, IV and V. Table I shows mean squares due to these effects. Mean squares for GCA were highly significant for all characters except ginning out turn. Mean squares for SCA effects were found to be highly significant for all characters except for ginning out turn and staple length. Mean Square for reciprocal effects were observed highly significant for plant height, ginning out turn, microniare, fibre strength; significant for yield of seed cotton and non significant for number of bolls per plant, boll weight, sympodial branches, monopodial branches and staple length (Table I). Highly significant estimates of GCA and SCA mean square have been reported earlier (Khorgade *et al.*, 2000; Barden *et al.*, 2003; Christopher *et al.*, 2003).

The estimates of variance component for GCA, SCA and reciprocal effects (Table II) showed that variance due to SCA was greater in magnitude and more important for seed cotton yield, number of bolls per plant, sympodial branches, monopodial branches and plant height. Variance due to reciprocal effects was higher in magnitude for ginning outturn and staple length. Additive gene action predominated in boll weight and fibre strength as a result of higher magnitude of GCA variance in these characters. A generally higher magnitude of variance due to SCA effects than that of GCA effects indicates the importance of non-additive type of gene action involved in the manifestation of characters under study. These results are in accordance with the finding of Khorgade *et al.* (2000), Barden *et al.* (2003) and Christopher *et al.* (2003).

The results presented in Table III are estimates of GCA of different genotypes. The variety CIM-473 with the highest magnitude appeared to be the best general combiner for yield, boll number, sympodial branches and ginning outturn. CIM-473, the highest yielding parent, produced good yielding hybrids, with higher number of bolls, sympodial branches and ginning outturn for instance, NIAB-999 x CIM-473 its reciprocal and CRIS-420 x CIM-473. ACALA 1517/C proved best general combiner with respect to Boll weight, monopodial branches, plant height, fibre length, and microniare; whereas, NIAB-999 was the best general combiner for fibre strength. The superior parent results in the superior hybrid for that character. From these results, it was concluded that CIM-473 and ACALA1517/C might prove their worth in varietal improvement programme particularly in above mentioned combination. Sufficient support in the literature is available to this observation. For instance, Irfanullah *et al.* (1994), Sayal *et al.* (1999), Goudar *et al.* (1996) and Khorgade *et al.* (2000) who reported that the best yielding parents produced the best yielding hybrids.

Estimates of SCA effects for 10 cross combinations with regard to 10 characters under study are presented in Table IV. Results reveal that the cross N-999 x CIM-473 showed the highest SCA effects for yield of seed cotton, bolls per plant, boll weight, sympodial branches. Similarly, the highest SCA effects for fibre strength and staple length were shown by the cross ACALA1517/C x FVH-57. In case of ginning outturn, the cross CIM-473 x CRIS-420 produced the highest SCA effects. The combination between N-999 x ACALA1517/C exhibited the highest SCA value for plant height. The cross CIM-473 x ACALA1517/C to be the best for microniare. The varieties CIM-473 and ACALA1517/C showing the best GCA performed to the same extent in the combinations as crosses. It was observed that superior cross combinations involved at least one high general combining parent, which is in accordance with the finding of Rauf *et al.* (2004).

Reciprocal effects are presented in Table V which showed the highest positive reciprocal effects by cross combination of NIAB-999 x CRIS-420 in case of yield of plant, number of bolls and staple length; whereas, the highest reciprocal effects were shown by cross ACALA1517/C x FVH-57 in case of sympodial branches. In case of monopodial branches and fibre strength, the cross CIM-473 x CRIS-420 produced the highest reciprocal effects. Highest reciprocal effects for plant height and ginning outtrun were shown by CRIS-420 x ACALA1517/C. The crosses NIAB-999 x FVH-57 and CIM-473 x ACALA1517/C produced highest reciprocal effects for microniare and boll weight, respectively. It is suggested that the single crosses and their reciprocals could be composited for the characters which exhibited non significant reciprocal effects. Such recommendations have been made by Khan and Khan (1985).

Table I. Mean square due to general combining ability (GCA), Specific Combining ability (SCA) and reciprocal effects (RE) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Sources of Variation	D.F	Plant Traits									
		Yield Per Plant	Boll # Per Plant	Boll weight	Sympodial Branches	Monopodial Branches	Plant Height	Ginning Out turn	Fibre Strength	Fibre Length	Microniare
GCA	4	177.75**	37.26**	0.99**	38.98**	7.87 **	1346.38**	4.56	20.24**	2.27**	0.19**
SCA	10	538.81**	32.79**	0.062 **	8.85**	1.27**	532.12**	3.36	2.49**	0.71	0.05**
RE	10	15.73*	0.77	0.0053	0.94	0.39	56.44**	12.28**	4.17**	0.96	0.06**
Error	48	6.75	0.85	0.012	0.81	0.19	20.38	2.28	1.61	0.43	0.012

Table II. Estimates of components of variance and their percentages due to general combining ability (GCA), Specific Combining ability (SCA) and reciprocal effects (RE) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Sources of Variation	Plant Traits									
	Yield per plant	Boll # per plant	Boll weight	Sympodial branches	Monopodial branches	Plant height	Ginning Out turn	Fibre Strength	Fibre Length	Microniare
GCA	-38.98*	0.27	0.09	2.96	0.65	78.51	0.09	1.75	0.15	0.014
	-9.74**	1.24	66.00	32.49	39.46	17.31	1.10	33.6	14.57	18.31
SCA	350.16	21.01	0.03	5.28	0.71	336.67	0.75	0.58	0.18	0.025
	87.45	95.00	23.49	57.91	42.96	74.22	9.23	11.09	17.89	33.47
RE	4.49	-0.004	-0.003	0.07	0.1	18.03	5.00	1.28	0.27	0.024
	1.21	-0.018	2.39	0.71	6.05	3.97	61.57	24.52	25.74	32.14
Error	6.75	0.85	0.012	0.81	0.19	20.38	2.28	1.61	0.43	0.012
	1.68	3.84	8.57	8.8	11.49	4.49	28.07	30.84	41.78	16.07
Total	400.38	22.13	0.14	9.12	1.65	453.59	8.12	5.22	1.029	0.075
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table III. Estimates of general combining ability effects (GCA) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Varieties	Plant Traits									
	Yield Per Plant	Boll # Per Plant	Boll weight	Sympodial Branches	Monopodial Branches	Plant Height	Ginning Out turn	Fibre Strength	Fibre Length	Microniare
CIM-473	5.89	1.56	-0.028	1.70	-0.29	-4.12	0.73	-1.35	0.25	-0.21
N-999	0.86	1.15	-0.28	1.05	-0.57	-8.48	-0.70	2.27	0.32	-0.004
CRIS-420	0.50	0.48	-0.072	1.11	-0.45	-0.41	0.72	0.12	-0.32	0.007
FVH-57	-1.49	0.11	-0.16	-3.13	-0.26	-7.00	-0.38	0.02	-0.67	0.037
ACALA1517/C	-5.76	-3.30	0.54	-0.73	1.57	20.01	-0.37	-1.06	0.42	0.17
CD (g_i-g_j)	2.48	0.88	0.10	0.85	0.42	4.30	1.44	1.20	0.63	0.10

Table IV. Estimates of specific combining ability (SCA) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Cross Combinations	Plant Traits									
	Yield Per Plant	Boll # PerPlant	Boll weight	Sympodial Branches	Monopodial Branches	Plant Height	Ginning Out turn	Fibre Strength	Fibre Length	Microniare
N-999 x CIM-473	29.94	6.98	0.24	3.47	-1.19	-17.90	-1.25	-1.16	0.4	-0.11
ACALA x FVH-57	14.59	2.72	0.17	0.35	-0.04	-6.11	-0.45	1.29	0.82	0.01
CRIS-420 x FVH-57	13.46	4.36	-0.12	1.94	-0.83	-25.52	-1.16	-0.84	0.02	0.06
CIM-473 x CRIS-420	6.87	1.08	0.12	0.61	-0.46	-4.43	1.40	1.07	0.77	-0.17
CRIS-420 x ACALA	4.54	1.01	-0.06	0.32	0.32	-8.37	1.10	-0.20	0.47	0.01
N-999 x CRIS-420	1.47	1.39	-0.16	0.56	-0.48	-2.88	0.55	-0.04	-0.006	-0.11
N-999 x FVH-57	-0.46	-0.45	0.14	0.75	0.27	-0.04	1.15	-1.37	-0.02	-0.06
N-999 x ACALA	-1.33	-0.65	0.04	0.40	0.27	17.02	-2.09	0.88	-0.02	-0.11
CIM-473 x FVH-57	-9.13	-2.45	0.03	-1.65	-0.02	16.44	0.33	-0.29	-0.59	0.1
CIM-473 x ACALA	-13.50	-2.91	-0.15	-1.00	0.65	0.08	0.62	0.28	-0.67	0.11
CD (S_{ij}-S_{jK})	4.95	1.75	0.20	1.71	0.83	8.60	2.87	2.41	1.25	0.20
CD (S_{ij} - S_{kl})	4.29	1.52	0.18	1.48	0.71	7.45	2.49	2.09	1.08	0.18

Heterosis and heterobeltiosis. The perusal of Table VI shows that out of the 20 crosses, most of the crosses manifested highly significant heterosis for yield of seed cotton. The cross N-999 x CIM-473 and its reciprocal proved to be best hybrids as they scored the maximum heterosis however cross FVH-57 X CRIS-420 displayed highly significant increase over better parental mean by exhibited 99.58%. This confirm the superiority of CIM-473 for its GCA effects as was observed before (Table I). Therefore, CIM-473 could be given due consideration while selecting the parents for crossing programme.

It is further evident from Table VI that only three crosses were not able to produce heterotic effect for number of boll per plant, while rest of crosses displayed highly significant increase over their mid and better parent. The maximum heterotic and heterobeltiotic effect was observed in the cross FVH-57 X CRIS-420. Rigorous selection in the segeregating generations of this cross may lead to the

Table V. Estimates of reciprocal effects (RCA) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Cross Combinations	Plant Traits									
	Yield Per Plant	Boll # Per Plant	Boll weight	Sympodial Branches	Monopodial Branches	Plant Height	Ginning Out turn	Fibre Strength	Fibre Length	Microniare
N-999 x CRIS-420	2.41	0.68	0.008	-0.90	-0.61	-3.83	0.23	1.26	0.93	-0.4
CRIS-420 x ACALA	0.89	0.28	0.01	-0.67	0.07	6.33	6.35	-0.62	-0.35	0.01
N-999 x CIM-473	0.41	0.31	-0.03	-0.30	-0.15	-3.57	0.8	1.15	0.25	0.017
CIM-473 x CRIS-420	-0.01	0.08	-0.06	0.28	0.25	5.97	-1.51	2.13	0.08	-0.17
CIM-473 x ACALA	-0.24	-0.13	-0.02	1.42	-0.83	-0.094	0.65	1.16	-0.23	0.25
N-999 x FVH-57	-1.49	-0.09	0.06	0.25	0.00	1.41	-1.32	-0.47	-0.45	-0.05
CRIS-420 x FVH-57	-2.49	-0.67	-0.03	-0.5	-0.25	-9.33	2.80	-1.88	-1.6	-0.12
ACALA x FVH-57	-3.25	-0.65	-0.007	1.67	0	5.88	1.28	1.57	-0.18	-0.20
CIM-473 x FVH-57	-3.65	-0.33	0.03	-0.5	0.17	-6.91	-2.35	-1.23	0.17	0.17
N-999 x ACALA	-6.27	-1.38	-0.06	0.5	-0.5	-2.81	0.95	-1.98	0.93	0.03
CD (r_{ij}-r_{kl})	5.20	1.84	0.22	1.80	0.87	9.03	3.01	2.54	1.31	0.22

Table VI. Heterosis (Ht.) and Heterobeltiosis (Hbt.) for various quantitative traits in upland cotton (*Gossypium hirsutum* L.)

Combination	Yield per plant		Bolls no. per plant		Boll weight		Plant height		Sympodial Branches		Monopodial Branches		Ginning out turn		Fibre length		Fibre strength		Microniare	
	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt	Ht	Hbt.
N-999 x CIM-473	111.7	66.38	88.72	57.90	14.06	5.74	-18.57	-21.0	41.38	21.70	47.09	-49.31	-2.02	-2.20	0.96	0.45	-3.91	-19.16	-6.80	-13.29
N-999 x Cris-420	90.32	83.68	94.43	77.84	-3.61	-14.57	-17.94	-29.5	27.56	19.12	-46.22	-48.95	2.59	1.58	6.15	2.13	1.47	-9.46	-15.75	-17.08
N-999 XACALA	23.35	7.18	17.17	7.75	2.71	-16.89	8.43	-6.52	29.81	14.14	-3.30	-17.07	-6.69	-6.90	4.91	0.91	-3.69	-22.03	-5.10	-5.69
N-999 XFVH-57	59.31	46.57	44.44	38.48	9.94	5.47	-5.67	-10.1	32.35	31.25	-12.34	-13.33	-3.06	-4.25	0.11	-0.44	-6.57	-14.97	0.99	-3.16
CIM-473 XN-999	110.0	65.00	84.24	54.15	15.75	7.31	-13.53	-16.6	45.19	24.99	-41.29	-43.75	-6.56	-6.7	2.66	2.13	-13.73	-27.42	-7.48	-13.92
CIM-473XCRIS-420	56.46	26.30	49.83	16.25	2.77	-2.14	-13.06	-22.8	19.52	9.46	-26.79	-25.51	3.95	2.73	5.11	0 .67	15.42	7.93	-10.03	-15.03
CIM-473 X ACALA	-8.53	-18.8	-12.5	-31.5	-0.23	-14.01	-0.96	-11.5	7.69	-16.51	-1.37	-12.19	4.02	3.63	-3.05	-7.20	4.87	0.00	0.68	-5.76
CIM-473 XFVH-57	7.06	-10.0	-0.23	-13.5	7.87	4.07	-0.67	-1.88	-4.76	-17.43	-12.90	-15.63	-4.4	-5.78	-1.18	-1.23	-10.43	-17.96	-1.07	-4.13
CRIS-420 X N-999	76.61	70.44	81.01	66.56	-4.09	-15.00	-13.23	-25.4	40.22	31.12	-22.53	-26.47	1.27	0.27	-0.47	-4.20	-8.72	-18.56	-0.32	-1.89
CRIS-420XCIM-473	56.51	26.33	48.61	15.20	3.69	-1.26	-20.16	-29.1	16.17	6.40	-36.07	-36.70	12.64	11.32	4.52	0.11	-5.40	-11.60	-3.11	-8.50
CRIS-420 XACALA	50.24	34.71	56.83	55.90	-4.76	-14.28	-11.34	-12.0	8.85	-9.55	14.06	2.43	22.95	22.00	3.87	1.56	1.53	-9.16	-2.91	-3.85
CRIS-420 XFVH-57	86.63	77.60	90.73	67.94	-3.63	-11.31	-37.09	-43.5	26.56	19.12	-40.42	-42.83	7.31	7.05	-2.93	-7.09	-14.92	-16.78	-2.01	0.68
ACALA XN-999	54.70	34.42	42.54	31.08	5.77	-14.41	11.95	-3.21	21.15	6.78	13.76	-2.44	-12.15	-12.34	-1.71	-5.46	13.90	-7.78	-6.36	-6.96
ACALAXCRIS-420	45.90	30.82	50.73	49.84	-3.57	-13.20	-18.07	-18.7	19.47	-0.73	-7.65	-17.07	-13.52	-14.19	6.46	4.09	7.84	-3.5	-0.32	-1.28
ACALA X CIM-473	-7.60	-18.0	-10.2	-29.9	-1.47	-15.08	-0.85	-11.4	-12.4	-32.11	26.02	12.18	0.32	-0.08	0.12	-4.16	10.02	4.9	2.74	-3.85
ACALA X FVH-57	52.50	43.21	42.48	26.09	3.84	-13.13	-3.91	-13.7	22.86	7.5	4.22	-9.76	1.04	0.009	3.70	-0.78	16.80	2.48	5.64	1.92
FVH-57 X N-999	24.86	53.94	46.13	40.11	14.19	9.56	-7.66	-12.0	28.58	27.5	-12.33	-13.33	4.56	3.27	1.70	1.12	-15.78	-23.35	-8.91	-12.65
FVH-57 XCRIS-420	99.58	89.94	103.2	78.98	-3.27	-10.97	-26.11	-33.7	33.60	25.74	-30.84	-33.63	-8.93	-9.16	8.34	3.71	1.86	-0.36	2.68	0
FVH-57 X CIM-473	21.69	2.22	14.04	-1.13	7.29	3.52	8.63	7.30	1.59	-11.93	-19.35	-21.88	9.07	7.53	-2.30	-2.36	1.35	-7.15	6.04	2.75
FVH-57 XACALA	67.54	57.34	48.66	31.57	9.61	-8.31	-10.83	-19.4	-5.71	-17.5	4.22	-9.76	-6.36	-7.32	4.99	0.44	1.16	-11.24	-2.33	-5.76

isolation of promising genotypes. Arshad *et al.* (2001), Babar *et al.* (2001) and Zhang *et al.* (2003) in their studies noted varying amount of heterotic effect for this character.

In case of boll weight, cross CIM-473 X NIAB-999 was on top and was followed by FVH-57 x NIAB-999 as far as heterosis is concerned. It was further noticed that the same crosses proved to be best in performance when compared with their better parents.

Three crosses i.e. FVH-57 X CIM-473, ACALA 1517/C X N-999 and its reciprocal gave highly significant positive increase over their mid parents (Table VI). When hybrid values were compared with the better parental means, only one cross i.e. FVH-57 X CIM-473 showed significant positive heterobeltiosis as far as plant height is concerned. These results find support from Khan *et al.* (1999), Sayal *et al.* (1999) and Hassan *et al.* (1999) who observed considerable amount of heterosis for plant height.
Regarding sympodial branches per plant, cross CIM-473 X N-999 and its reciprocal scored the maximum values of heterosis as well as heterobeltiosis, respectively. This finding is in agreement with those of Katageri and Kadapa (1989), Hussain *et al.* (1990) and Khan *et al.* (1991).

Table IV revealed that only three hybrids showed positive heterosis increase over their mid parent and two hybrid surpassed their better parents for monopodial branches. The cross ACALA X CIM-473 showed highly significant heterosis for this character. Katageri and Kadapa (1989) and Hussain *et al.* (1990) have reported reasonable amount of heterosis for monopodial branches.

As regards ginning outturn only two crosses i.e. CRIS-420 X CIM-473 (12.64%) and CRIS-420 X ACALA (22.95%) significant differences among F1's for heterosis and heterobeltiosis (Table V). These results are in accordance with those of Irfanullah *et al.* (1994), Zhang *et al.* (1994) and Soomro (2000).

For fibre strength, cross FVH-57 X CRIS-420 showed maximum heterosis while ACALA X CRIS-420 ranked highest in term of heterobeltiosis. Hybrid vigour being also observed Hassan *et al.* (1999) and Soomro (2000).

Regarding fibre strength, ACALA X FVH-57 scored highest heterosis while CIM-473 X CRIS-420 showed highest heterobeltiosis. Carvalho *et al.* (1994), EL-Debaby *et al.* (1997) and Khan *et al.* (1999) while studying heterosis in cotton have also reported similar results for fibre strength.

For microniare, cross FVH-57 X CIM-473 exhibited heterosis and heterobeltiosis. The breeder should be careful at the time of selecting material for microniare value as microniare expressed here is related with the weight of fibre in micrograms per inch. Greater the microniare value, lower is the fineness. All those are worse than their parents showing positive heterobeltiosis. The hybrid N-999 x CRIS-420 showed maximum negative heterosis. These results are in the agreement with earlier research findings of Carvalho *et al.* (1994), EL-Debaby *et al.* (1997), Khan *et al.* (1999) and Soomro (2000) who reported varying degree of heterosis and heterobeltiosis for micronaire.

The above results signify the importance of exploitation of both additive and non-additive gene action for attaining maximum improvement of yield and quality traits. It is suggested that high GCA parents i.e. CIM-473 and ACALA 1517/C and cross like NIAB-999 x CIM-473 should given due consideration in developing superior high yielding varieties. It is suggested that population improvement by reciprocal recurrent selection to accumulate desirable genes and breaking undesirable linkages would be more appropriate.

REFERENCES

Arshad, M., N. Illahi, M. Rashid and Z. Qamar, 2001. Estimation of useful heterosis in intraspecific F_1 Cotton hybrids. *J. Agric. Res*., 39: 101–8

Babar, S.B, A.R. Soomro, R. Anjum and M.S. Kalwar, 2001. Estimation of Heterosis, Heterobeltiosis and Economic Heterosis in Upland Cotton (*Gossypium hirsutum* L.). *Pakistan J. Biol. Sci*., 4: 518–20

Braden, C., C.W. Smith and P. Thaxton, 2003. Combining ability for near extra long fibres in upland cotton. *Beltwide Cotton Conferences.* January 6–10, *Nashville*, TN

Christopher, L., C. Jhonie, N. Jenkin, J.C. MacCarty, Jr. Clarence, E. Watson and W. Jixiang, 2003. Genetic Variances and Combining ability of Crosses of American Cultivars, Australian Cultivars, and wild cottons. *J. Cotton. Sci*., 7: 16–22

Carvalho, L.D., C.F. Moraes and C.D. Cruz, 1994. Combining ability and heterosis in upland cotton. *Revista–Ceres*., 41: 514–27

EL–Debaby, A.S., M.M. Kassem, M.M. Awaad, G.M. Hemaida, 1997. Heterosis and combining ability in intervarietal crosses of Egyptian cotton in different locations. *Egyptian J. Agric. Res*., 75: 753–67

Fonseca, S. and F.L. Patterson, 1968. Hybrid vigor in seven parent Diallel cross in common wheat (*Triticum aestivum* L.) *Crop Sci*., 8: 85–8

Gaudar, P.V.K., B.H. Katarki, P.M. Salimath and M.B. Chetti, 1996. Genetics of yield, yield attributes and their implications in breeding of cotton (*Gossypium hirsutum* L.). *Indian. J. Gen. Pl. Breed.,* 56: 147–51

Griffing, B., 1956. Concept of general and specific combining ability in relation to diallel system. *Australian J. Biol. Sci*., 9: 463–93

Hassan, G., G. Mahmood, N. Khan and A. Razzaq, 1999. Combining ability and heterobeltiosis estimates in diallel cross of cotton (*Gossypium hirsutum* L.) *Sarhad. J. Agric*., 15: 563–8

Hayman, B.I., 1954a. The theory and analysis of diallel crosses. *Genetics*, 39: 789–09

Hayman, B.I., 1954b. The analysis of variance of diallel tables. *Biometrics*, 10: 235–44

Hussain, A., M. Rafique, T. Mahmood, M.A. Khan and M.Z.U. Khan, 1990. Hybrids vigour in relation to development in cotton. (*G. hirsutum* L.). *J. Agric. Res*., 28: 205–17

Irfanullah, M.A. Khan, H.A. Sadaqat and A.A khan, 1994. Potentials of combining ability for yield and lint quality traits in cotton (*G. hirsutum* L.). *J. Agric. Res*., 32: 363–8

Jinks, J.L., 1954. The analysis of continuous variation in a diallel cross of Nicotina rustica. *Genetics*, 39: 767–88

Jinks, J.L., 1956. The F_2 and back cross generations from a set of diallel crosses. *Heredity*, 10: 1–30

Katageri, I.S. and S.N. Kadapa, 1989. Heterosis for yield components characters in boll worm tolerant *Gossypium hirsutum x g. barbadense* L. cotton hybrid. *Indian J. Genet*., 49: 107–12

Khan, M.A and A.A. Khan, 1985. Estimation of combining ability effects in *Gossypium hirsutum* crosses. *The Pakistan Cottons*, 29: 33–42

Khan, M.A., K.L. Cheema, A. Masood and H.A. Sadaqat, 1991. Combining ability studies in cotton (*Gossypium hirsutum* L.). *J. Agric. Res*., 29: 311–8

Khan, N.U., H.K. Abro, H. Gul, M.B. Kumbhar and M. Khan, 1999. Exploitation of heterosis can combat leaf curl virus (CLCV) incidence in cotton (*Gossypium hirsutum*, L.). *The Pakistan Cottons*, 43: 21–34

Khorgade, P.W., I.V. Stange and L.D. Mesham, 2000. Diallel analysis in American cotton (*Gossypium hirsutum* L.). *Indian J. Agric. Res*., 34: 172–5

Sayal, A.U., M.S. Baloch, I. Hussain and B. Khan, 1999. Exploration of heterosis and heterobeltiosis in American Cotton (*Gossypium hirsutum* L.) *J. Agric. Res*., 37: 201–8

Steel, R.G.D. and J.H. Torrie, 1980. *Principles and Procedures of Statistics, A Biometrical Approach,* 2nd ed., McGraw Hill Inc: New York

Soomro, A.R., 2000. Assessment of useful heterosis in glandless *Gossypium hirsutum* cotton strains through their performance in hybrid combination. *Pakistan J. Bot*., 32: 65–8

Zhang, J.F., Z. Deng, J.Z. Sun and J.L. Liu, 1994. Heterosis and combining ability in interspecific crosses between *Gossypium hirsutum* and *G. barbadense*. *Acta. Agron. Sincia*., 13: 9–14

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