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HETEROSIS STUDIES FOR FIBRE QUALITY TRAITS IN DIALLEL CROSSES OF UPLAND COTTON (*GOSSYPIUM HIRSUTUM* L.)

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ABSTRACT
Diallel analysis was studied by involving nine parents and their seventy two cross combinations in upland cotton to investigate the best heterotic crosses for fibre quality traits. The hybrid Anjali x KC 2 recorded both highest positive significant relative heterosis (17.18%) and heterobeltiosis (11.81%) and hybrid MCU 5 x Surabhi exhibited highest positive significant standard heterosis (16.98%) for bundle strength. 2.5% span length in parents and their hybrids ranged from 24.03 to 33.51 mm and 27.31 to 36.90 mm, respectively. Thirty four hybrids showed significant negative heterotic effects for micronaire value and hybrid MCU 5 x KC 3 (-27.89%) displayed greater negative standard heterosis. Mean performance of elongation per cent in parents and hybrids was 5.11% and 4.87%, respectively. Out of seventy two hybrids, six cross combinations *viz.,* KC 2 x MCU 5, MCU 5 x MCU 7, Anjali x Suraj, Anjali x MCU 5, Surabhi x Anjali and KC 2 x Suraj were appeared to more promising for most of the fibre quality traits and could be exploited. The present study reveals good scope for isolation of pure lines from the progenies of heterotic F_1's as well as commercial exploitation of heterosis in upland cotton.

INTRODUCTION

Cotton is one of the principal crops of India and plays a vital role in the country's economic growth by providing substantial employment and making significant contributions to export earnings. Cotton accounts for around 59% share in the raw material consumption basket of the Indian textile industry. Thus, cotton plays a major role in sustaining the livelihood of an estimated 5.8 million cotton farmers and about 40-50 million people engaged in related activities, such as cotton processing and trade. Cotton is one of the few crops which are accessible to development of genotypes as varieties and at the same time amenable for commercial exploitation of heterosis. Hybrid cotton is an optimistic approach for significant improvement in genetic potential for yield and fibre quality traits. Cotton is highly amenable for both heterosis and recombination breeding. Heterosis has substantially remained as one of the significant developments in cotton breeding programs (Baloch, 2004; Ganapathy and Nadarajan, 2008; Khan *et al.,* 2009; Ranganatha *et al.,* 2013a; Choudhary *et al.,* 2014). Several studies have been reported on yield and yield attributing traits, but little work has been reported on the genetics and heterosis of fibre quality traits in cotton breeding. A few reports in the literature (Basal and Turgut, 2003; Rauf *et al.,* 2005; Karademir *et al.,* 2007; Karademir and Gencer, 2010; Sekhar *et al.,* 2012; Hashash, 2013; Nakum *et al.,* 2014) have determined that cotton genotypes differ in fibre quality traits.

Fibre quality of a specific cotton genotype is a composite of different characteristics, including fibre length, fibre strength, fineness and fibre elongation. These characters have their individual importance in spinning, weaving and dying units (Feng *et al.,* 2011). Fibre length and strength properties mainly influence textile processing. In addition, fibre uniformity is also of tremendous value to the textile industry. It is significantly correlated with the efficient spinning and weaving processes, which convert the fibre into fabrics. Ahuja (2003) suggested that developing high fibre length and strength cultivars or hybrids is required to current modernized spinning mills. Hereafter, it is the need of the day to improve fibre quality in the dominating *hirsutum* genotypes, to fulfill the requirements of growing processing and textile industry. The estimates of *per se* performance and heterosis provided useful information with regard to the possibilities and extent of improvement in the fibre characters of breeding material through selection. The studies on heterosis in upland cotton for improvement of fibre traits has also been done by Dukre *et al.* (2009), Karademir *et al.* (2011), Feng *et al.* (2011), Patil *et al.* (2012), Abro *et al.* (2014) and Tuteja (2014). Keeping in mind the economic importance of the use of heterosis for quality traits and its impact upon the future cotton production, a study was carried out with the objective of estimating the manifestation of heterosis for fibre quality traits in F_1 hybrids in a 9 parent diallel cross experiment.

MATERIALS AND METHODS

The genetic materials used for this study consists of nine *Gossypium hirsutum* genotypes. Crosses were made between

parents in a 9 x 9 diallel mating design including reciprocals (Griffing, 1956. Model I method I). The conventional hand emasculation and pollination method developed by Doak (1934) was followed. A complete set of 82 entries comprising of nine parents and their resultant 72 F_1's and one standard check (MCU 13) were sown during winter 2013-14 at Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. All entries were raised in a randomized block design (RBD) with two replications each comprising single row at 90 x 45 cm spacing. Recommended agronomic practices and plant protection measures were followed as per crop production manual (TNAU and Department of Agriculture). Data were recorded on five randomly selected plants per replication for all five fibre quality traits *viz.,* 2.5% span length (mm), bundle strength (g/tex), fibre fineness (micronaire value - µg/inch), uniformity ratio (%) and elongation per cent (%). Fibre quality traits were analyzed by high-volume instrument (HVI) 900 Classic installed at the Department of Cotton, TNAU, Coimbatore. The diallel analysis of heterosis was performed as suggested by Gowen, 1952. Heterosis was calculated in terms of percent increase (+) or decrease (-) of the F_1 hybrids against its mid parent, better parent and standard parent value as suggested by Fehr (1987). The statistical significance of heterosis was assessed by 't' test according to Wynne *et al.* (1970).

RESULTS AND DISCUSSION

Analysis of variance

The analysis of variance for fibre traits was presented in Table 1. The result revealed that genotypes showed highly significant differences for all the characters indicating the presence of sufficient variability in the experimental materials. Significance of variance in parents versus hybrids interaction provides adequacy for comparing the heterotic expression for all the fibre quality traits. Parents, hybrids and reciprocals also showed significant differences between all the characters studied.

Mean performance

The primary criterion to evaluate a hybrid is its mean performance. Kumar (2007) reported that *per se* performance of hybrids appeared to be useful index for judging the hybrids. Pali and Mehta (2014) suggested that parents with good *per se* performance would result in good hybrids. Range of mean performance of nine parents and seventy two hybrids for five fibre quality traits are presented in Table 2 and Table 3 respectively. Mean performance of the parents for 2.5% span length varied from 24.03 mm (MCU 7) to 33.51 mm (MCU 5). Previous studies suggested that fiber length could vary widely based on plant variety and growing conditions. Same results were also obtained by Ehsan *et al.* (2008) and Geddam *et al.* (2011). The variation in cross combinations was ranged from 27.31 mm (KC 3 x MCU 5) to 36.90 mm (KC 2 x MCU 5). Among the parents, MCU 5 (33.51 mm), Surabhi (32.06 mm) and KC 3 (30.23 mm) recorded significantly higher value than the parental grand mean. Out of seventy two hybrids, twenty hybrids recorded significantly higher mean value than the grand mean for its 2.5% span length.

Fibre fineness or micronaire and fibre strength are very important characteristic of the fiber quality of cotton and are extremely useful for textile industry. Among the parents, Surabhi recorded maximum bundle strength (24.59 g/tex) whereas, KC 2 recorded a minimum bundle strength (19.08 g/tex). The range of mean value among the cross combinations varied from 19.70 g/tex (Khandwa 2 x Suraj) to 26.48 g/tex (Surabi x MCU 5). The results are akin to the findings of Karademir *et al.* (2011). The average bundle strength of parents and hybrids was 22.14 g/tex and 23.54 g/tex, respectively. Ashokkumar *et al.* (2013) observed mean fibre strength for *G. hirsutum* crosses was 21.90 g/tex and this is lower than the value of present study. The range of variation for micronaire

Table 1: Analysis of variance showing means square for fibre quality traits

Source	d.f	2.5% span length (mm)	Bundle strength(g/tex)	Micronaire value (µg/inch)	Uniformity ratio (%)	Elongation (%)
Genotypes	80	12.69**	3.82**	0.39**	5.20**	0.52**
Parents	8	22.64**	5.38**	0.36**	4.95**	0.98**
Hybrids	71	9.18**	3.32**	0.39**	5.27**	0.46**
Parents V_s Hybrids	1	182.81**	27.02**	0.19**	1.80*	0.87*
F_1's	35	10.46**	2.61**	0.37**	5.09**	0.58**
Reciprocals	35	8.05**	3.85**	0.40**	5.28**	0.35*
F_1 V_s reciprocals	1	3.95**	9.52**	0.99**	11.65**	0.14
Error	80	0.54	0.28	0.008	0.33	0.19
Total	161	6.616	2.050	0.197	2.771	0.35

**Significant at 1 % level, *Significant at 5 % level

Table 2: Ranges for mean performance of parents in fibre quality traits

SI No.	Traits	Minimum value	Maximum value	Mean	Parents Lowest	Highest
1	2.5% span length	24.03	33.51	27.91	MCU 7	MCU 5
2	Bundle strength	19.08	24.59	22.14	KC 2	Surabhi
3	Micronaire value	3.58	4.69	4.12	Surabhi	KC 3
4	Uniformity ratio	46.81	51.73	49.10	KC 3	Anjali
5	Elongation per cent	4.40	6.70	5.11	Surabhi	Anjali

Table 3: Ranges for mean performance of hybrids in fibre quality traits

SI No.	Traits	Minimum value	Maximum value	Mean	Hybrids	
					Lowest	Highest
1	2.5% span length	27.31	36.90	31.29	KC 3 x MCU 5	KC 2 x MCU 5
2	Bundle strength	19.70	26.48	23.54	Khardwa 2 x Suraj	Surabhi x MCU 5
3	Micronaire value	3.25	4.91	4.23	MCU 5 x KC 3	Khardwa 2 x KC 2
4	Uniformity ratio	45.30	53.53	49.43	Surabhi x KC 2	KC 3 x Surabhi
5	Elongation (%)	4.10	6.05	4.87	Suraj x KC 3 Surabhi x KC 3 G.cot 16 x Surabhi	Anjali x KC 3

Table 4: Expression of heterosis in hybrids (%) for 2.5% span length, bundle strength and micronaire value

SI No	Hybrids	2.5% span length			Bundle strength			Micronaire value		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	Suraj x Surabhi	17.61**	8.33**	19.76**	7.29**	3.82	13.47**	4.09*	-1.37	-12.33**
2	Suraj x Khardwa 2	31.49**	24.80**	16.20**	6.83**	5.48*	7.82**	7.48**	0.88	2.22
3	Suraj x Anjali	20.30**	19.01**	13.23**	7.45**	2.89	5.18*	25.73**	20.62**	7.22**
4	Suraj x KC 2	19.90**	16.26**	8.24**	11.13**	1.65	3.91	9.54**	4.17*	2.67
5	Suraj x KC 3	19.64**	13.25**	18.05**	11.34**	7.07**	9.44**	-24.35**	-29.88**	-27.03**
6	Suraj x MCU 5	14.53**	3.40	19.48**	-1.25	-3.08	2.89	8.85**	6.12**	-5.67**
7	Suraj x MCU 7	34.82**	27.41**	18.62**	12.18**	11.74**	14.22**	3.90*	3.13	-8.33**
8	Suraj x G.cot 16	23.14**	22.78**	14.31**	10.13**	8.04**	10.44**	6.81**	0.66	1.11
9	Surabhi x Suraj	6.79**	-1.09	9.14**	2.21	-2.02	8.87**	2.85	1.50	-9.78**
10	Surabhi x Khardwa 2	6.24**	-6.62**	3.03	-3.77	-8.74**	1.39	7.83**	1.21	2.52
11	Surabhi x Anjali	7.06**	-0.31	10.00**	7.49**	-1.00	10.00**	5.93**	1.63	-9.67**
12	Surabhi x KC 2	17.50**	5.31*	16.21**	10.95**	-2.20	8.67**	-12.27**	-16.57**	-17.78**
13	Surabhi x KC 3	4.55*	1.66	12.18**	5.46**	-2.48	8.36**	-0.40	-7.68**	-3.88
14	Surabhi x MCU 5	0.95	-1.33	14.02**	8.34**	5.92**	17.69**	-5.13*	-7.50**	-17.78**
15	Surabhi x MCU 7	15.30**	0.94	11.38**	-2.20	-6.46**	3.92	1.51	0.75	-10.44**
16	Surabhi x G.cot 16	11.96**	2.94	13.58**	-0.64	-6.34**	4.07	14.55**	7.96**	8.44**
17	Khardwa 2 x Suraj	22.28**	14.94**	8.10**	-12.31**	-14.09**	-12.44**	0.39	-10.70**	-0.78
18	Khardwa 2 x Surabhi	9.69**	-4.10	6.02*	-6.03**	-10.98**	-2.71	-5.59**	-19.00**	-10.00**
19	Khardwa 2 x Anjali	15.14**	7.65**	2.41	9.50**	7.14**	4.75*	8.36**	-6.00**	4.44*
20	Khardwa 2 x KC 2	21.94**	18.67**	3.78	8.05**	0.86	-1.38	4.08*	-1.80	9.11**
21	Khardwa 2 x KC 3	5.07*	-5.76*	-1.76	2.23	0.45	-1.78	1.19	-2.00	8.89**
22	Khardwa 2 x MCU 5	10.76**	-4.95*	9.83**	7.66**	3.41	9.78**	-3.86*	-15.40**	-6.00**
23	Khardwa 2 x MCU 7	21.42**	21.35**	0.56	6.11**	4.21	5.69*	5.15**	-6.00**	4.41*
24	Khardwa 2 x G.cot 16	14.48**	8.42**	0.34	7.98**	7.66**	5.89*	-8.61**	-13.00**	-3.33
25	Anjali x Suraj	7.46**	6.07*	2.41	6.51**	2.03	3.98	6.40**	5.00*	-6.67**
26	Anjali x Surabhi	18.13**	10.65**	22.33**	10.11**	2.07	11.56**	-3.69	-8.75**	-18.89**
27	Anjali x Khardwa 2	16.94**	9.11**	5.34*	0.18	-2.99	-3.33	13.43**	6.47**	7.90**
28	Anjali x KC 2	17.65**	12.11**	8.24**	17.18**	11.81**	4.36	-4.21*	-8.91**	-10.22**
29	Anjali x KC 3	2.35	-1.42	2.76	4.23	3.65	-2.18	-17.10**	-23.16**	-20.00**
30	Anjali x MCU 5	-6.23**	-13.94**	-0.55	7.39**	0.90	7.11**	16.67**	13.75**	1.11
31	Anjali x MCU 7	14.97**	6.82*	3.14	7.46**	3.18	4.66*	4.53*	3.75	-7.78**
32	Anjali x G.cot 16	7.91**	5.68*	2.03	4.92*	2.24	0.56	-5.40**	-10.84**	-10.46**
33	KC 2 x Suraj	15.91**	11.07**	4.46	11.52**	1.96	3.91	5.76**	4.38	-7.30**
34	KC 2 x Surabhi	14.62**	2.00	12.75**	10.94**	-1.67	7.47**	17.15**	11.00**	-1.33
35	KC 2 x Khardwa 2	18.38**	16.60**	0.52	12.00**	3.46	3.09	4.32*	-2.08	-0.78
36	KC 2 x Anjali	13.14**	7.83**	2.59	6.62**	1.43	-5.11*	21.04**	16.13**	3.22
37	KC 2 x KC 3	4.65*	-4.40	-0.34	10.33**	4.52	-1.36	11.57**	3.42	7.67**
38	KC 2 x MCU 5	26.12**	10.10**	27.23**	19.37**	7.16**	13.76**	-11.54**	-13.75**	-23.33**
39	KC 2 x MCU 7	21.74**	19.38**	2.9	4.54*	-4.21	-2.84	10.08**	9.25**	-2.89
40	KC 2 x G.cot 16	9.61**	5.85*	-2.03	12.72**	4.74*	3.02	2.70	-3.21	-2.78
41	KC 3 x Suraj	8.44**	3.52	7.09**	11.20**	6.52**	8.56**	4.55**	-7.00**	3.33
42	KC 3 x Surabhi	12.25**	8.64**	20.11**	11.76**	3.60	13.23**	-9.91**	-22.70**	-14.13**
43	KC 3 x Khardwa 2	15.21**	4.17	7.76**	2.72	-0.54	-0.89	-4.81**	-9.00**	1.11

value in parent was in between 3.58 µg/inch to 4.69 µg/inch and parents Surabhi and KC 3 represented lowest and highest micronaire value respectively. Differences between the cultivars with respect to micronaire value were also found significant by Bolek *et al.* (2010). Among the hybrids, it ranged from 3.25 µg/inch (MCU 5 x KC 3) to 4.91 µg/inch (Khandwa 2 x KC 2). Forty three hybrids recorded significantly lesser mean values for micronaire than the grand mean. The grand mean values of micronaire value for parents and hybrids were 4.12 µg/inch and 4.23 µg/inch, respectively. Ashokkumar *et al.* (2013) observed mean micronaire for *G. hirsutum* crosses was 3.79 µg/inch and this showed that the present study significantly

Table 4: Cont.....

Sl No	Hybrids	2.5% span length			Bundle strength			Micronaire value		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
44	KC 3 x Anjali	1.41	-2.67	0.69	8.44**	8.31**	1.33	8.24**	-6.10**	4.33*
45	KC 3 x KC 2	1.70	-6.17*	-2.93	12.79**	7.62**	0.44	1.85	-3.90*	6.78**
46	KC 3 x MCU 5	-13.98**	-18.49**	-5.82*	-1.79	-7.72**	-2.05	6.82**	-6.00**	4.44*
47	KC 3 x MCU 7	9.53**	-1.37	2.03	6.87**	2.61	4.07	9.06**	-2.50	8.33**
48	KC 3 x G.cot 16	7.14**	1.50	5.00	12.22**	9.35**	7.56**	-6.51**	-11.00**	-1.11
49	MCU 5 x Suraj	8.15**	-2.54	14.25**	5.75**	3.4	10.30**	-13.11**	-14.25**	-23.78**
50	MCU 5 x Surabhi	8.72**	5.62*	23.83**	8.34**	7.04**	16.98**	-1.45	-6.62**	-16.96**
51	MCU 5 x Khardwa 2	13.12**	-3.10	13.61**	6.61**	3.10	9.98**	-12.85**	-18.20**	-17.11**
52	MCU 5 x Anjali	0.99	-8.53**	7.24**	8.24**	1.58	8.36**	-8.01**	-11.75**	-21.56**
53	MCU 5 x KC 2	7.99**	-5.74**	10.52**	2.15	-8.33**	-2.22	-17.01**	-21.08**	-22.22**
54	MCU 5 x KC 3	-1.90	-7.34**	8.64**	8.30**	2.06	8.87**	-25.27**	-30.74**	-27.89**
55	MCU 5 x MCU 7	17.01**	-0.15	17.07**	6.77**	4.15	11.07**	0.13	-0.63	-11.67**
56	MCU 5 x G.cot 16	9.78**	-1.78	15.15**	4.96*	0.87	7.59**	3.29	-2.65	-2.22
57	MCU 7 x Suraj	21.52**	14.23**	7.43**	-1.20	-1.35	0.83	0.44	-0.87	-11.89**
58	MCU 7 x Surabhi	17.46**	2.70	13.53**	3.17	-0.16	9.11**	-3.96	-9.00**	-19.16**
59	MCU 7 x Khardwa 2	23.01**	22.37**	2.32	2.95	1.65	3.91	7.36**	0.77	2.18
60	MCU 7 x Anjali	19.77**	11.98**	6.53*	3.29	-1.09	1.11	-3.58	-7.50**	-17.78**
61	MCU 7 x KC 2	19.94**	16.72**	2.07	8.85**	-0.43	1.78	-2.79	-7.55**	-8.89**
62	MCU 7 x KC 3	6.95**	-4.07	0.00	-4.15*	-7.83**	-5.78*	1.21	-6.19**	-2.33
63	MCU 7 x MCU 5	22.62**	5.22*	21.59**	7.56**	5.57*	12.07**	-12.82**	-15.00**	-24.44**
64	MCU 7 x G.cot 16	18.61**	12.33**	3.96	6.94**	4.91*	7.24**	-2.00	-7.63**	-7.22**
65	G.cot 16 x Suraj	11.84**	11.27**	4.66	1.71	-0.35	1.56	0.06	-11.00**	-1.16
66	G.cot 16 x Surabhi	3.30	-4.85*	5.19	-1.33	-6.53**	2.15	1.40	-13.00**	-3.33
67	G.cot 16 x Khardwa 2	17.07**	11.11**	3.45	0.63	-0.31	-0.67	-7.85**	-11.90**	-2.11
68	G.cot 16 x Anjali	19.31**	18.03**	12.28**	3.37	1.14	-1.11	3.05	-10.60**	-0.67
69	G.cot 16 x KC 2	12.41**	9.00**	1.47	14.04**	6.45**	4.09	-5.03**	-10.40**	-0.44
70	G.cot 16 x KC 3	0.12	-5.23*	-1.21	9.52**	7.61**	5.22*	-7.49**	-10.40**	-0.44
71	G.cot 16 x MCU 5	-4.48*	-13.76**	-0.34	-5.07*	-8.81**	-3.19	-13.64**	-24.00**	-15.56**
72	G.cot 16 x MCU 7	13.27**	7.04*	-0.34	3.88	2.02	3.47	-2.68	-13.00**	-3.33

exploited the hybrids than earlier studies.

For uniformity ratio, mean range varied from 46.81% (KC 3) to 51.73% (Anjali). The parent, Anjali recorded significantly greater mean value than the grand mean. Among 72 hybrids, 19 hybrids exhibited significantly higher uniformity ratio when compared to the grand mean (49.43%), the highest value was observed for the cross KC 3 x Surabi (53.53%). Sekhar *et al.* (2012) observed grand *per se* uniformity ratio for diploid cotton hybrids was 50.13%, and this is higher than the present results. In case of elongation per cent, mean performance of parents showed that Anjali (6.70%) recorded the highest mean performance. For cross combinations, mean range varied from 4.10% (Suraj x KC 3, Surabi x KC 3 and G.cot 16 x Surabi) to 6.05% (Anjali x KC 3). Among the hybrids, four hybrids recorded significantly higher mean values when compared to the grand mean. The grand mean values for parents and hybrids were 5.11% and 4.87%, respectively.

Expression of heterosis for fibre quality traits

Heterosis for fibre traits is presented in Table 4 and Table 5. The results indicated that the phenomenon of heterosis was of a general occurrence for almost all the characters, under study. However, the magnitude of heterosis varied with traits. In cotton 2.5 per cent span length is a new criteria for measurement of fibre length. The hybrid Suraj x MCU 7 recorded the maximum positive significant relative heterosis (34.82%) and heterobeltiosis (27.41%) followed by Suraj x Khandwa 2 with 31.49% and 24.80%, respetively. The hybrid KC 3 x MCU 5 recorded the minimum negative significant relative heterosis (-13.98%), heterobeltiosis (-18.49%) and standard heterosis (-5.82%). The promising hybrid for 2.5 per cent span length was KC 2 x MCU 5 because it recorded high values for three type of heterosis. Thirty eight hybrids registered significant positive (desirable) heterobeltiosis and thirty nine hybrids showed significant positive standard heterosis. Same results were also obtained by Zangi *et al.* (2009), Karademir and Gençer (2010), Feng *et al.* (2011) and Patel *et al.* (2014).

The hybrid Anjali x KC 2 recorded both highest positive significant relative heterosis (17.18%) and heterobeltiosis (11.81%) whereas, hybrid Khandwa 2 x Suraj recorded lowest negative significant relative heterosis (-12.31%), heterobeltiosis (-14.09%) and also standard heterosis (-12.44%) for bundle strength. Among the hybrids, forty eight, nineteen and thirty four hybrids recorded a positive significant heterosis over the mid parent, better parent and standard check, respectively. Hybrid vigour was also studied by Jyotiba *et al.* (2010), Saravanan and Koodalingam (2011), Babu *et al.* (2011) and Abro *et al.* (2014). The hybrid MCU 5 x Surabhi exhibited highest positive significant standard heterosis with 16.98%. Tuteja and Banga (2011) observed positive standard heterosis in all the conventional hybrids, and few of male sterility based hybrids for fibre strength, and these are conformed in the present study results.

Micronaire value is an important fibre quality trait in judging lint quality of cotton. Mid parental heterosis ranged from -25.27% (MCU 5 x KC 3) to 25.73% (Suraj x Anjali). Twenty three hybrids exhibited a negative significant relative heterosis.

Table 5: Expression of heterosis in hybrids (%) for uniformity ratio and elongation percent

SI No.	Hybrids	Uniformity ratio			Elongation per cent		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
1	Suraj x Surabhi	1.39	-2.35*	1.06	11.90	6.82	6.58
2	Suraj x Khardwa 2	3.03**	1.43	0.35	-0.57	-8.42	-1.36
3	Suraj x Anjali	-2.59*	-7.05**	-1.92	-8.41	-26.87**	11.11
4	Suraj x KC 2	2.72*	-0.22	1.46	-3.33	-13.00	-1.36
5	Suraj x KC 3	6.37**	6.16**	1.76	-9.39	-18.81*	-7.03
6	Suraj x MCU 5	1.47	-0.79	-0.47	0.52	-13.51	8.84
7	Suraj x MCU 7	5.79**	3.50**	3.71**	6.82	-2.08	6.58
8	Suraj x G.cot 16	3.37**	1.50	0.95	-9.19	-20.00*	-4.76
9	Surabhi x Suraj	-2.68*	-6.37**	-2.61*	18.34*	12.36	13.38
10	Surabhi x Khardwa 2	-5.31**	-7.63**	-3.92**	7.43	-1.05	6.58
11	Surabhi x Anjali	-4.51**	-5.19**	0.04	-14.02*	-31.34**	4.31
12	Surabhi x KC 2	-10.17**	-11.18**	-7.61**	-2.22	-12.00	-0.23
13	Surabhi x KC 3	-3.05**	-7.03**	-3.29**	-9.39	-18.81*	-7.03
14	Surabhi x MCU 5	-7.78**	-9.41**	-5.77**	-10.99	-23.42**	-3.63
15	Surabhi x MCU 7	-2.24*	-4.03**	-0.17	0.00	-8.33	-0.23
16	Surabhi x G.cot 16	-3.89**	-5.99**	-2.22	-8.11	-19.05*	-3.63
17	Khardwa 2 x Suraj	5.48**	3.47**	3.41**	-5.82	-11.00	0.91
18	Khardwa 2 x Surabhi	-1.25	-2.95*	0.44	-7.45	-13.00	-1.36
19	Khardwa 2 x Anjali	-1.23	-3.84**	1.47	-23.08**	-32.84**	2.04
20	Khardwa 2 x KC 2	2.60*	1.73	3.44**	-6.00	-6.00	6.58
21	Khardwa 2 x KC 3	2.77**	0.47	0.41	-4.48	-4.95	8.84
22	Khardwa 2 x MCU 5	-0.75	-0.95	-0.62	-14.69*	-18.92*	2.04
23	Khardwa 2 x MCU 7	1.68	1.55	1.75	4.08	2.00	15.65
24	Khardwa 2 x G.cot 16	0.00	-0.23	-0.29	-2.44	-4.76	13.38
25	Anjali x Suraj	0.27	-4.42**	1.37	-8.30	-25.00**	19.05*
26	Anjali x Surabhi	-0.04	-1.25	4.73**	-0.88	-19.29**	28.12**
27	Anjali x Khardwa 2	0.79	-2.60*	3.30**	-6.38	-21.43**	24.72**
28	Anjali x KC 2	0.63	-1.44	4.53**	-5.00	-18.57**	29.25**
29	Anjali x KC 3	-0.56	-5.52**	0.20	0.41	-13.57*	37.19**
30	Anjali x MCU 5	-1.37	-4.04**	1.77	-5.18	-15.00*	34.92**
31	Anjali x MCU 7	-0.56	-3.31**	2.55*	-5.93	-20.71**	25.85**
32	Anjali x G.cot 16	-0.36	-3.45**	2.40*	-2.86	-15.00*	34.92**
33	KC 2 x Suraj	3.89**	0.91	2.91*	-2.65	-8.00	4.31
34	KC 2 x Surabhi	2.84**	2.09	5.65**	-3.19	-9.00	3.17
35	KC 2 x Khardwa 2	1.31	-0.20	1.77	0.51	-2.00	11.11
36	KC 2 x Anjali	0.73	-0.96	4.51**	-17.09**	-27.61**	9.98
37	KC 2 x KC 3	-2.59*	-5.70**	-3.83**	2.49	1.98	16.78
38	KC 2 x MCU 5	3.34**	2.50*	4.53**	-1.42	-6.31	17.91*
39	KC 2 x MCU 7	-0.03	-0.90	1.06	3.06	1.00	14.51
40	KC 2 x G.cot 16	0.94	-0.30	1.67	-4.39	-6.67	11.11
41	KC 3 x Suraj	5.07**	4.92**	0.86	-4.76	-10.00	2.04
42	KC 3 x Surabhi	9.54**	5.50**	9.18**	2.13	-4.00	8.84
43	KC 3 x Khardwa 2	2.30*	0.71	-0.37	-1.54	-4.00	8.84

The lowest (-30.74%) and highest (20.62%) values of heterobeltiosis was recorded in MCU 5 x KC 3 and Suraj x Anjali, respectively. Forty three hybrids exhibited negative significant expression of heterobeltiosis. The range of standard heterosis varies from -27.89% (MCU 5 x KC 3) to 9.11% (Khandwa 2 x KC 2) for this trait. Twelve hybrids were found to record positively significant heterosis and thirty four hybrids exhibited negatively significant standard heterosis. The decrease in micronaire value is an indication of fibre fineness. These observations are in the agreement with earlier research findings of Thangaraj (2001), Rauf *et al.* (2005), Rajamani *et al.* (2009), Karademir and Gencer (2010) and Sekhar *et al.* (2012) who reported varying degree of heterosis for micronaire. The extent of heterosis for uniformity ratio ranged from -10.17% to 9.54% and -11.18% to 7.82% over mid parent and better parent, respectively. Among 72 hybrids, 27 showed significant positive heterosis over mid parent while 17 hybrids indicated significant positive heterobeltiosis. The standard heterosis varies from -7.61% (Surabhi x KC 2) to 9.18% (KC 3 x Surabhi). Among the hybrids, twenty four hybrids showed a positive significant standard heterosis. Karademir *et al.* (2009) observed significant negative and positive heterosis for uniformity ratio, and this is in conformity to our results.

For elongation per cent, the mid parental heterosis ranges from -23.08% (Khandwa 2 x Anjali and G.Cot 16 x Anjali) to 18.34% (Surabhi x Suraj). Among 72 hybrids, only Surabhi x Suraj (18.34) exhibited a positive significant relative heterosis whereas negative expression over mid parent was observed in eleven hybrids. The hybrid Surabhi x Suraj depicted the highest positive heterobeltiosis of 12.36%. None of the hybrids recorded a positive significant heterobeltiosis. Eighteen hybrids noticed with positive significant standard heterosis, the highest value was observed for the cross Anjali x KC 3 (37.19%).The

Table 5: Cont.....

SI No.	Hybrids	Uniformity ratio			Elongation per cent		
		d_i	d_{ii}	d_{iii}	d_i	d_{ii}	d_{iii}
44	KC 3 x Anjali	3.51**	-1.23	4.22**	-6.84	-18.66**	23.58*
45	KC 3 x KC 2	5.42**	2.40*	4.12**	-4.00	-4.00	8.84
46	KC 3 x MCU 5	-2.37*	-4.54**	-4.23**	-10.90	-15.32	6.58
47	KC 3 x MCU 7	5.40**	3.11**	3.32**	-1.02	-3.00	9.98
48	KC 3 x G.cot 16	4.52**	2.62*	2.08	-19.02*	-20.95*	-5.9
49	MCU 5 x Suraj	2.47*	0.51	0.45	-7.18	-19.17 **	9.98
50	MCU 5 x Surabhi	4.17**	2.38*	5.96**	-17.31*	-28.33**	-2.49
51	MCU 5 x Khardwa 2	-5.83**	-6.31**	-6.36**	1.40	-9.17	23.58*
52	MCU 5 x Anjali	-6.08**	-8.56**	-3.52**	-18.11**	-22.39**	17.91
53	MCU 5 x KC 2	-1.07	-1.92	-0.27	-13.64*	-20.83**	7.71
54	MCU 5 x KC 3	-1.99	-4.18**	-4.24**	-18.55**	-25.00**	2.04
55	MCU 5 x MCU 7	7.96**	7.82**	8.04**	1.85	-8.33	24.72**
56	MCU 5 x G.cot 16	-5.57**	-5.80**	-5.85**	-6.67	-12.50	19.05*
57	MCU 7 x Suraj	5.40**	3.39**	3.32**	6.88	1.00	14.51
58	MCU 7 x Surabhi	-0.85	-2.55*	0.85	-3.19	-9.00	3.17
59	MCU 7 x Khardwa 2	-1.13	-1.63	-1.69	12.82	10.00	24.72**
60	MCU 7 x Anjali	-4.11**	-6.65**	-1.50	-9.40	-20.90**	20.18*
61	MCU 7 x KC 2	1.26	0.39	2.08	-2.00	-2.00	11.11
62	MCU 7 x KC 3	5.63**	3.27**	3.20**	4.48	3.96	19.05*
63	MCU 7 x MCU 5	4.59**	4.39**	4.73**	-19.43**	-23.42**	-3.63
64	MCU 7 x G.cot 16	0.52	0.29	0.22	-3.41	-5.71	12.24
65	G.cot 16 x Suraj	3.82**	1.84	1.77	-1.59	-7.00	5.44
66	G.cot 16 x Surabhi	-1.24	-2.94*	0.45	-12.77	-18.00*	-7.03
67	G.cot 16 x Khardwa 2	0.29	-0.21	-0.28	-0.51	-3.00	9.98
68	G.cot 16 x Anjali	0.68	-1.98	3.43**	-23.08**	-32.84**	2.04
69	G.cot 16 x KC 2	-3.29**	412**	-2.51*	-1.00	-1.00	12.24
70	G.cot 16 x KC 3	5.29**	2.94*	2.88*	9.45	8.91	24.72**
71	G.cot 16 x MCU 5	-4.60**	-4.79**	-4.48**	5.21	0.00	25.85**
72	G.cot 16 x MCU 7	2.52*	2.38*	2.59*	5.10	3.00	16.78

same result assembled by other researchers Karademir and Gencer (2010), Kanimozhi (2012), Ashokkumar *et al.* (2013) and Ranganatha *et al.* (2013b).

In the present experiment crosses KC 2 x MCU 5, MCU 5 x MCU 7, Anjali x Suraj, Anjali x MCU 5, Surabhi x Anjali and KC 2 x Suraj appeared to more promising for fibre quality traits to exploitation of heterosis. Increasing the fibre quality traits are a valuable addition to cotton cultivars or hybrids, and it will be very useful for textile industries. Above crosses could be tested for stability performance before exploitation of hybrid vigour for commercial cultivation.

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