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Heterosis and combining ability for fibre properties in upland cotton (*Gossypium hirsutum*)*

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Cotton (*Gossypium hirsutum* L.) is grown primarily for its spinnable fibres. It is the world's leading natural fibre crop. To meet textile mill requirements, both fibre quality and yield must be improved. New cotton varieties/hybrids and *Bacillus thuringiensis* (Bt) hybrids continue to be developed that are earlier in maturity and higher in yield. Fibre quality can be attributed by a set of the measurable properties that affect the spinning performance of the fibre. Among them fibre strength, fibre length and fibre fineness are the primary quality properties that influence textile processing. The heterosis in cotton has been critically reviewed by Khadi *et al.* (1993), ICAC (1997), Wu *et al.* (2004) and Tuteja *et al.* (2005). India has the distinction of spreading hybrid technology to its cotton areas. However, heterotic groups and patterns are of fundamental importance in hybrid breeding. A heterotic group denotes a group of related or unrelated genotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups.

The shift in cotton production to transgenic cultivars has exacerbated the narrowing of the genetic base of modern cottons and threatens to reduce the potential for genetic gain in lint yield (Bowman *et al.* 2003). For farmers, Bt. crops offers advantages over conventional crops in that the insecticidal proteins are produced directly by the plants, and continuously during most of the growing season, thereby reducing the material and application costs of using synthetic chemical insecticides. In order to meet future fibre quality requirements, development of genotypes for using in heterosis breeding must be addressed on priority. Hence, a study was conducted to determine the combining ability and heterosis among 12 upland cotton genotypes and their crosses.

Twelve cotton genotypes of diverse agro-ecological regions were selected as parents based on their agronomic performance and fibre properties. The 12 parents were crossed in a diallel mating design without reciprocals. The 66 F_1 and 12 parents were grown during 2006–07 at Central Institute for Cotton Research, Nagpur. The experimental design was a randomized block design with 3 replications. Individual plots consisted of single rows of 4.5 m long and 0.6 m apart. After final picking of seed cotton, lint samples were prepared using machine gin. The fibre properties were evaluated using High Volume Instrument (HVI) measurements at Ginning Training Centre, Nagpur.

Griffing's (1956) method II for diallel analysis was used and estimation of general combining ability (GCA) and specific combining ability (SCA) effects were obtained. The relative importance of GCA and SCA was calculated by the ratio $2\sigma^2 g/(2\sigma^2 g + \sigma^2 s)$ given by Baker (1978) for fixed effect model, where $\sigma^2 g$ is the estimate of GCA component and $\sigma^2 s$ that of the SCA component.

Sources of variation for GCA were significant for 2.5% span length (mm), micronaire and fibre bundle strength. But all the characters had a non-significant SCA mean square. The specific combining ability component of variance was much less than the general combining ability component. Thus, the predominance of GCA suggests that selection should be effective in improving 2.5% staple length, micronaire and fibre bundle strength. From the components, the ratios expressing the relative importance of GCA and SCA was higher for all fibre properties. This strongly implies that GCA was more important than SCA for the fibre properties. Therefore, the additive genetic variance component must comprise a considerable portion of the genetic variance for each of those properties. The conclusion agrees closely with previously reported results (Tuteja *et al.* 2003).

The GCA effects represent the average performance of parents in hybrid combinations, and thus which parents combined best with all other parents in the study. The estimate of general combining combining ability effects (Table 1)

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Table 1 Mean values and general combining ability (GCA) effects for fibre properties of 12 upland cotton genotypes

Parent	2.5% span length (mm)		Maturity		Micronaire (10^{-6} g/in)		Fibre bundle strength (g/tex)	
	Mean values	GCA	Mean values	GCA	Mean values	GCA	Mean values	GCA
'LRK 516'	26.7	0.17	49.5	–0.31	3.3	–0.23**	19.9	0.01
'PKVR'	25.8	–0.33	50.0	0.30	4.3	0.20**	18.0	–0.54*
'NH545'	25.2	–0.86**	50.0	0.19	4.0	0.09	18.2	–0.47
'Surabhi'	24.9	–0.99**	49.0	0.05	3.8	–0.01	18.6	–0.86**
'GSH2'	23.4	–0.18	49.5	0.01	3.7	–0.01	20.4	0.47
'ACCLD 163'	24.8	–0.07	51.5	0.08	4.4	0.09	18.6	–0.13
'H 1252'	26.4	0.51*	48.5	–0.85*	3.0	–0.26**	21.0	0.24
'LH 1948'	28.0	0.24	46.5	–0.20	3.8	0.09	21.3	0.14
'Sahana'	23.9	–0.58**	49.5	0.23	3.7	–0.15*	20.9	–0.23
'MCU 9'	27.9	0.49*	48.0	0.05	3.6	–0.10	21.7	0.14
'DHY 286'	26.4	0.34	51.5	0.91**	4.4	0.21**	23.1	0.86**
'Acala 1517'	29.5	1.27**	46.5	–0.45	3.9	0.09	21.5	0.37
SE(gi)		0.20		0.32		0.07		0.25
SE(gi-gj)		0.30		0.48		0.10		0.37

*P = 0.05, **P = 0.01

revealed that parents 'H 1252', 'MCU 9' and 'Acala 1517' were the good general combiners for 2.5% span length (mm). For maturity, micronaire and fibre bundle strength 'DHY 286' was good combiner. Among parents 'PKVR' and 'DHY 286' were good general combiners for micronaire.

The SCA effects represent the deviation in hybrid performance from that expected from the GCA effects of each parent. Of the 66 hybrids, only 2 crosses exhibited positive significant SCA effects and 3 crosses had shown significant mid-parent heterosis for 2.5% span length (Table 2). Thirty two crosses showed negative SCA effects for 2.5% span length. This reflects the negligible dominance effects for 2.5% span length. Cross 'GSH 2' × 'ACCLD 163' had significant positive SCA effects and mid-parent heterosis (9.47%) for 2.5% span length. Both these parents had negative gca effects. Cross combination 'ACCLD 163' × 'H 1252' showed significant positive mid-parent heterosis (8.59%) for 2.5% span length in which one of the parent 'H 1252' had significant positive gca effect. Similarly, cross combination 'ACCLD 163' × 'Sahana' showed positive SCA effects and mid-parent heterosis (9.65%) and parents involved were poor general combiners. Estimates of mid-parent heterosis for 2.5% span length were negative for 36 of the 66 F1's studied. Baker and Varhalen (1975) found heterosis for fibre quality appears almost invariably to be of little importance. Similarly, previous gene action and heterosis studies (Meredith and Bridge 1972) have indicated that there is little non-additive gene action for fibre length,

Table 2 Specific combining ability (SCA) effects (above diagonal) among 12 parents and mid-parent heterosis (below diagonal) for 2.5% span length (mm) in *Gossypium hirsutum*

Parent	'LRK 516'	'PKVR'	'NH 545'	'Surabhi'	'GSH 2'	'ACCLD 163'	'H 1252'	'LH 1948'	'Sahana'	'MCU 9'	'DHY 286'	'Acala 1517'
'LRK 516'		–0.37	–0.15	0.48	–0.53	0.01	0.08	0.95	0.98	0.01	0.10	–2.12**
'PKVR'	–2.57		–0.35	0.33	0.87	–0.79	0.43	0.20	0.03	–0.49	–0.75	0.23
'NH 545'	–2.70	–3.63		–0.25	–0.51	0.68	0.30	–1.33	0.10	–0.32	–0.43	0.60
'Surabhi'	–0.10	–0.79	–4.10		–0.12	–1.74*	–0.52	–0.99	1.58*	–0.53	0.21	0.08
'GSH 2'	–1.83	3.52	–2.87	–1.20		1.61**	0.68	–1.35	0.02	0.36	–0.15	–0.13
'ACCLD 163'	1.75	–1.48	3.40	–6.14	9.47*		1.26	–0.97	1.26	–0.16	0.24	0.91
'H 1252'	1.13	2.40	0.97	–2.05	4.73	8.59*		0.46	–0.27	–0.83	0.01	–0.17
'LH 1948'	0.46	–2.42	–9.13*	–7.77*	–6.94	–4.08	0.46		–0.50	0.34	0.48	–0.05
'Sahana'	5.34	1.51	0.81	7.08	2.94	9.65*	2.39	–2.60		–0.14	–0.50	–0.52
'MCU 9'	–2.01	–4.01	–4.33	–5.02	0.47	0.00	–3.31	–2.78	–0.19		1.09	–1.04
'DHY 286'	0.66	–2.69	–2.42	0.20	0.97	4.01	2.18	0.00	0.90	3.23		0.55
'Acala 1517'	–9.53**	–1.27	–0.82	–2.58	–1.28	3.96	–0.81	–4.01	–1.59	–6.54	1.25	

*P = 0.05, **P = 0.01

strength and fineness involved within upland cotton. Singh and Chahal (2004) and Rahman and Malik (2008) also reported large proportion of the genetic variance was composed of additive component in the control of fibre fineness, strength and staple length. It seems that for this material, breeding procedures should be used that maximize additive genetic effects.

SUMMARY

Estimates of combining ability and heterosis for fibre properties among cotton genotypes are necessary for efficient hybrid development work and in breeding programmes. This study was conducted to determine the heterosis and combining ability among 12 cotton (*Gossypium hirsutum* L.) genotypes. General combining ability (GCA) was more important than specific combining ability (SCA) effects. Combining ability analysis revealed that variances due to GCA were significant for 2.5% span length, micronaire and fibre bundle strength, indicating the preponderance of additive gene action. Parents 'H 1252', 'MCU 9' and 'Acala 1517' were the good general combiners for 2.5% span length. For micronaire, the best combiner was 'PKV Rajat' and 'DHY 286'. For fibre bundle strength, 'DHY 286' was the good combiner with high mean values. Crosses 'GSH 2' × 'ACCLD 163' and 'ACCLD 163' × 'Sahana' had significant SCA effects for 2.5% span length. Maximum mid-parent heterosis was observed in 'ACCLD 163' × 'Sahana' (9.65%), followed by 'ACCLD 163' × 'H 1252' (8.59%). The results indicated that for these fibre properties, this set of parents could be more effectively used in a selection programme to produce a variety with better fibre quality.

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