Electronic Journal of Plant Breeding, 8(2): 494-500 (June 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00075.8

Research Article

Heterosis and combining ability studies in extra long staple inter-specific (*G. hirsutum* x *G. barbadense*) hybrids of cotton

K.P.M. Dhamayanthi and K. Rathinavel
Central Institute for Cotton Research, Regional Station, Coimbatore-641 003, Tamil Nadu
E-mail: krathinavelus@gmail.com

(Received: 18 Nov 2016; Revised: 04 April 2017; Accepted: 25 April 2017)

Abstract
Forty nine inter-specific crosses were made using two tetraploid cotton species *viz*., *Gossypium hirsutum* (seven) and *G. barbadense* (seven). Heterosis over better parent and standard check were estimated for yield and yield related characters in these inter-specific F_1 hybrids. The variance due to GCA and SCA were highly significant for all the characters studied. It reveals that both additive and non additive gene effects were responsible for the traits under study. Among the females BRS-53-53 and CCH-510-4 were found to be good general combiner for boll per plant and seed cotton yield. Amongst the male parents, ICB-260 and Pima S4 were found to be the best general combiner on the basis of seed cotton yield and it's *per se* performance while, B4 was the best for the most of the yield components. The present study reveals that for improving seed cotton yield BRS-53-53 and CCH-510-4 could serve as good parents. The crosses involved with B4 and Pima S4 can be exploited to improve the fibre qualities such as 2.5% span length, tenacity and fibre fineness. Five crosses were identified as the best crosses on the basis of *per se* performance, combining ability and heterosis. The hybrids *viz*., BRS-53-53 x B4, BRS-53-53 x ICB-260, CCH-510-4 x ICB-260 and CCH-724 x B4 showed significant positive standard heterosis as well as heterobeltiosis for seed cotton yield, number of bolls per plant and boll weight.

Key words
Gossypium, heterosis, fibre qualities, extra-long staple, inter-specific hybrids

Introduction

Cotton, the king of fibre is a premier cash crop of our country grown about 9 million hectares, which represent 29 per cent of the world cotton area. India is a pioneer country for the cultivation of cotton hybrids on commercial scale. Exploitation of heterosis is one of the methods to increase cotton productivity that have stagnated in recent years. It has the potential of increasing yield from 10 to 30% and of making improvements in fibre properties. Increased yield and fibre qualities are vital to keep Indian cotton competitive with synthetics and foreign production. In India, 40 per cent of cotton production is derived from *intra*-specific hybrids of *G. hirsutum,* and 8 per cent is from inter-specific hybrids of *G. hirsutum* x *G. barbadense* (Singh and Chaudhry, 1997). Yield increase of hybrids over the better parent or best commercial cultivar (useful heterosis) has been documented earlier showed an average useful heterosis of 21.4 per cent for F_1 hybrids (Singh *et al.*, 2003). In recent years, breeding programme on hybrid cotton production has been stagnated due to high cost of manpower to carry out the interspecific hybridization.

Research on plant breeding needs to address all possibilities to increase yield, including the use of heterosis. Utilization of heterosis depends on genetic diversity between the parents, magnitude of dominance at the yield influencing loci and the genetic distance between two chosen parental genotypes (Patel *et al.,* 2012). In hybrid development programme, improving the qualitative and quantitative characters are possible by better commercial exploitation of hybrid vigour (Rajamani *et al*., 2009). The concept of combining ability is important in designing the plant breeding programmes. It is highly useful to study and compare the performance of lines in hybrid combinations. Information concerning to the different types of gene action, relative magnitude of genetic variance and combining ability estimates are significant markers to shape the genetic makeup of a crop like cotton. This important information could prove an essential strategy to the cotton breeders in screening of better parental combinations for further enhancement.

Cotton breeders have the challenge of finding good combiners by the use of heterosis. In cotton, high heterosis has been reported at interspecific and *intra*specific levels both in diploid and tetraploid cotton (Patel *et al.,* 2012). India is one of the largest producer of extra long staple cotton. In recent past, there are hundreds of ruling long and medium staple hybrids are being cultivated in South and Central Zone. But in extra long staple category, hybrids are very limited and the current production of extra long staple cotton is not sufficient to meet the domestic textile requirement of our country. There is a need to develop suitable high yielding extra long staple hybrids with desirable other fibre qualities to cater the need of the Indian Textile Industry. Hence, in the course of developing extra long staple interspecific hybrids, an attempt was made to find out the extent of heterosis for seed cotton yield and its components in 49 inter-specific F_1 hybrids obtained from seven

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diversified *G. hirsutum* female parent and seven elite male genotypes of *G. barbadense.*

Material and Methods

Thirty Seven diversified female genotypes of *Gossypium hirsutum viz*., BRS-53-53, CCH-510-4, CCH-724, CCH-4, TK-36, ENT- 4, LK-18, and seven male genotypes of *G. barbadense viz*., B-4, B-5, ICB-20, ICB-74, ICB-201, ICB-260 and Pima S-4 were identified for better fibre properties to generate 49 hybrids in a line x tester mating design along with 14 parents. The hybrid DCH-32 has been used as check. The experimental was sown in a randomized block design with three replications during kharif 2006-07 & 2007-08. Three rows of each parents and crosses were sown at a spacing of 90 cm between rows and 60 cm between plants. Ten plants were chosen from two rows of each genotype to record data on seed cotton yield (kg/ha), plant height (cm), number of monopodia/plant, number of sympodia/plant, boll weight (g), number of bolls/plant, ginning outturn, 2.5 percent span length (mm), fibre strength (g/tex) and fibre fineness (µ/inch). The expression of standard heterosis was estimated by the mean increase of hybrids over the check DCH-32 and heterobeltiosis over better parent.

Results and Discussion

The analysis of variance (ANOVA) of parents and their hybrids for the traits under study is presented in table 1. It reveals that traits were significant at $p \leq 0.01$ level of probability which indicate considerable distance among genotypes. The partioning of hybrid mean square revealed that the variance due to males and females and an interaction of males x females was significant for majority of the characters indicating the manifestation of parental genetic variability in their crosses. Mean, range, coefficient of variation for important ten characters were studied and presented in table 2. The maximum variability of 16.38 % was recorded for seed cotton yield followed by 14.31% of number of bolls/plant. The coefficient of variability for the plant height exhibited as 12.34 %. The coefficient of variation among the qualitative characters, ginning outturn, bundle strength and micronaire value expressed the least value of 2.67, 2.46 and 1.55 respectively. The highest percentage of heterosis (91.35%) over best parent was recorded in number of bolls/plant followed by seed cotton yield (73.61%) and number of sympodia/plant (64.33%).

The mean performance of parents and their hybrids for various traits under study indicated that maximum seed cotton yield (984 kg/ha) and number of bolls per plant (57.6) were produced by cross BRS-53-53 x Pima-S4 and the tallest plant (123.2 cm) produced by parents CCH-724 x B-4 while the trait sympodial branches per plant (15.5) was exhibited by cross BRS-53-53 x ICB-260.

The range and mean value among the inter-specific crosses for seed cotton yield varied from 791-2435 kg/ha. The highest and the lowest seed cotton yield was recorded in the cross combinations of BRS-53-53 x ICB-260 and LK-8 x B-5 respectively. The hybrid combination CCH-510-4 x B-4 ranked second in seed cotton yield with 2418 kg/ha, followed by BRS 53-53 x B-4 (2360 kg/ha), CCH-724 x B-4 (2313 kg/ha), BRS-53-53 x Pima S-4 (2286 kg/ha) and CCH-510-4 x ICB-260 (2207 kg/ha). Maximum number of bolls was recorded in BRS-53-53 x ICB-260 (77.2) followed by CCH-510-4 x B4 (73.4). The crosses BRS-53-53 x Pima-S-4 and CCH-724 x B-5 recorded the maximum boll weight of 5.6g and 5.1 g respectively.

Regarding ginning percentage, the hybrid CCH-510-4 x B5 had the maximum ginning outturn of 35.1 % followed by BRS-53-53 x B-4 (34.5%). Considering the fibre quality traits, the crosses BRS-53-53 x ICB-260 and BRS-53-53 x Pima-S-4 exhibited the highest value for 2.5% span length of 37.3 mm and 37.1 mm respectively. The crosses CCH-510-4 x Pima S-4 (36.8 mm) and CCH-510-4 x B-4 (36.7 mm) also have better 2.5 % span length followed by CCH-724 x B5 and CCH-4 x ICB-74 each with 36.5 mm length. The maximum fibre fineness of 4.1µ/inch was recorded in the crosses BRS-53-53 x ICB-260 and CCH-510-4 x Pima S-4 followed by CCH-510-4 x ICB-260, CCH-724 x ICB-20 and ENT-4 x B-5 each with 4.0 µ/inch.

Estimates of general and specific combining ability: The estimated general combining ability (GCA) and specific combining ability (SCA) are presented in tables 3 and 4. The estimates of *gca* and *sca* effects were ranged from -11.27 to 57.34 for seed cotton yield, -2.16 to 2.54 for sympodial branch, -2.38 to 2.94 for number of bolls per plant, -0.11 to 0.2 of boll weight, -3.26 to 2.36 for ginning outturn, -1.20 to 6.02 of 2.5 % staple length, -1.09 to 6.15 of bundle strength and -0.23 to 0.60 of micronaire respectively. Out of 14 parents (7 females and 7 males), 4 females and 3 males exhibited significant positive *gca* for seed cotton yield and number of bolls per plant, while 2 females and one male manifested significant positive *gca* effects for ginning % and 2.5% span length. Single each of female and male manifested significant and positive *gca* effects for bundle strength and micronaire. It was observed that among the females, BRS-53-53 and CCH-510-4 was found to be potential combiners.

The results indicated that partitioning of hybrid mean sum of square revealed that the variance due to male and female interaction was significant for all the characters. The parents possessed high *per se* performance coupled with good *gca* to be selected for crossing programme. Similar findings were reported by Preetha and Raveendran (2008) and Rajamani *et al*. (2009) and Srinivas *et al*. (2014). The estimates of parents over the best hybrids reveal that among the male parents, ICB-260 and Pima S4 were found to be the best general combiners on the basis of seed cotton yield. B-4 was the other male parent having good general combining ability effects for the seed cotton yield.

The heterosis for number of bolls/plant was found in positive direction in six cross combination out of 49 crosses (Table 5). The maximum heterosis for number of bolls/plant was observed in crosses BRS-53-53 x Pima-S4 (73.64) followed by BRS-53-53 x B4 (69.22%). Patel *et al* (2009) and Anita Solanke *et al.* (2015) reported high heterosis for bolls/plant in intra *hirsutum* hybrids. The heterosis for number of sympodia /plant is in positive direction in a cross; BRS-53-53 x ICB-260 (19.41%). The heterosis in ginning out turn is in positive direction in 5 cross combinations out of 49 crosses. Madhuri Sawarkar *et al.* (2015) were reported high heterosis for ginning outturn in *G. hirsutum.*

The maximum heterosis for ginning percentage was observed in CCH-510-4 x B-4 (26.14%). The heterosis for boll weight was found in positive direction in 4 combinations out of 49 crosses. The maximum heterosis for boll weight was observed in cross CCH-724 x B-4 (24.34%). The present study indicates that there is ample scope for developing productive inter-specific hybrids with desirable cross combinations for seed cotton yield and its components characters having superior fibre quality traits. These findings are in accordance with the results of Gaurav Khosla *et al.* (2007), Rajamani *et al.* (2009), Srinivas *et al.* (2014) and Madhuri Sawarkar *et al*. (2015) in intra *hirsutum* hybrids.

The present study revealed that high mean values were associated with high *gca* effects. However, it was not in all the cases hence, the choice of parents for crossing should be based on traits that have consistent and significant effects of *gca.* Similar observation was made by Patel *et al.* (2009) and Pathak and Parkash Kumar (2011) in *G. hirsutum*. The plant height, bundle strength and micronaire showed no desired heterosis effect in 49 cross combination studied. The potential female parents; BRS-53-53 and CCH-510-4 were isolated as the general combiners for seed cotton yield, number of sympodia, no of bolls/plant indicated that it could be exploited for further hybridization programme.

The estimate of *sca* effect reveals that out of 49 crosses, 17 crosses had significant positive *sca* effect for seed cotton yield. The cross BRS-53-53 x ICB-260 and CCH-510-4 x B-4 were identified as the best cross combination for number of bolls /plant, 2.5% span length, bundle strength and micronaire. Seven superior hybrids *viz*. BRS-53-53 x ICB-260, CCH-510-4 x B-4, BRS-53-53 x B-4, CCH-724 x B-4, BRS-53-53 x Pima S4, CCH-510-4 x ICB-260 and CCH-510-4 x Pima S-4 were identified on the basis of *per se* performance, combining ability and heterosis. High heterotic crosses which have shown more than 40% heterosis for seed cotton yield and its component traits could be exploited for increasing yield in inter-specific cotton hybrids. From the results it is discernable that for improving seed cotton yield BRS-53-53 and CCH-510-4 could serve as a useful base population. The crosses involved with B-4 and Pima S-4 can be exploited to improve the fibre qualities such as 2.5% span length, tenacity and fibre fineness. Out of seven best cross combinations, BRS-53-53 x B-4 and BRS-53-53x ICB-260 and CCH-724 x B-4 has been identified as superior cross combinations with improved yield, ginning percentage and fibre quality through heterosis breeding.

The present study revealed that there is tremendous scope for heterosis breeding for commercial exploitation of interspecific hybrids (H x B) and also manifestation of considerable amount of heterosis for improving productive inter-specific extra long staple cotton hybrids with desirable fibre qualities. These crosses revealed significant desirable standard heterosis simultaneously for seed cotton yield and its components studied. Hence, these crosses were found to be promising for improvement of yield through exploitation of non-additive component in breeding programmes.

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Electronic Journal of Plant Breeding, 8(2): 494-500 (June 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00075.8

Table 1. Analysis of variance for different characters in inter-specific hybrids

Source of variation	df	Plant height	Boll weight	Bolls/plant	Seed cotton yield/plant	Ginning outturn %
Replication	2	4.24	0.01	3.17	27.18	0.51
progenies	62	507.60**	17.08**	78.20**	168.19**	5.33**
hybrids	48	148.26**	9.27**	82.64**	132.60**	5.27**
Parents vs hybrids	1	7218.03**	173.91**	293.91**	55.18**	3.81**
Lines -females	6	178.63**	147.67**	133.62**	147.27**	1.97**
Tests-male	6	619.34**	28.33	255.13**	543.07**	87.41**
Line x Testers	36	86.29**	162.13**	33.41	97.32**	22.69**
Errors	124	18.29	0.43	11.64	27.56	0.33

*Significant @ 0.01 level of probability

Table 2. Mean, range, coefficient of variation and heterosis for various characters of interspecific hybrids (*G. hirsutum* x *G. barnadense*)

S. No.	Characters	Mean ± SE	CV (%)	Range	Heterosis over best parent
1	Seed cotton yield (kg/ha)	984.54 ± 127.42	16.38	719 - 2435	73.61
2	Plant height (cm)	119.01 ± 13.56	12.34	110.17 - 124.60	16.31
3	Sympods /plant	3.33 ± 0.49	9.60	1.30 - 6.00	64.33
4	Monopods /plant	9.41 ± 1.65	14.31	5.13 - 15.3	31.27
5	Boll weight (g)	3.86 ± 0.12	8.32	3.5 - 5.61	23.81
6	Bolls/plant	57.66 ± 2.53	9.16	41.24 - 77.20	91.35
7	Ginning outturn (%)	30.07 ± 1.03	2.67	28.14 - 36.01	7.26
8	2.5% span length (mm)	35.24 ± 0.08	3.5 2	34.23 - 37.20	4.11
9	Strength (g/tex)	30.05 ± 0.23	2.46	27.34 - 33.01	-24.05
10	Micronaire (µ/inch)	3.62 ± 0.03	1.55	3.05 - 4.1	35.37

Table 3. Estimates of GCA effects for yield and its components in parents

Parents	SCY (kg/ha)	Plant height (cm)	Sympod/ plant	Bolls/ plant	GOT (%)	2.5% S.L (mm)	B.S/ (g/tex)	Mic µ/inch
Lines (Females)								
BRS-53-53	57.34**	27.13**	1.28**	2.40**	1.76**	-1.61	0.62*	-0.23*
CCH-510-4	29.56**	19.54**	2.54**	2.94**	2.36**	-1.50	-2.56**	-0.35**
CCH-724	21.91*	18.51**	1.34*	1.34*	1.02*	-1.62	-1.09	0.23*
CCH-4	13.05*	-9.32	-2.16	-2.38	-4.35	6.02**	6.15**	0.05
TK-36	-27.09	-6.45	1.42*	-5.21	-3.26	4.73**	2.06**	0.14*
ENT- 4	-20.72	-11.81	2.72*	1.04*	1.31*	-5.10	-4.96*	0.60**
LK-18	-11.27	-7.53	1.37*	1.82*	1.79*	-1.20	-2.41*	-0.44**
SE±	3.91	3.73*	0.37	0.29	0.34	0.28	0.61	0.11
CD@5%	8.39	7.02	6.23	4.91	4.06	6.11	4.16	8.50
Testers (Males)								
B-4	17.08**	7.52**	0.01	0.22**	-0.06*	0.08**	2.04**	-0.30*
B-5	13.34**	5.14**	-12.95**	0.59**	-0.15	-0.17	1.85**	-0.01
ICB-20	-21.07	2.88*	21.62 **	-0.61*	0.02*	0.08**	-0.10*	0.31*
ICB-74	-10.91	0.16	-1.84	-4.27	-0.71	1.27*	1.63*	2.03**
ICB-201	1.62*	-3.46	-0.53**	1.62*	1.24**	0.67**	-2.072**	-1.01
ICB-260	13.01**	-0.47	1.81*	0.28*	3.45**	1.24**	-0.04	0.05*
Pima-S4	2.31**	0.59*	0.08	1.72*	2.19**	-4.05*	-1.07*	-0.16*
SE±	4.49	2.81	0.21	0.19	0.14	0.61	0.05	0.18
CD@5%	6.13	4.79	8.22	5.81	6.53	8.04	6.72	11.31

*, ** Significant at 5 and 1 per cent level respectively

Table 4. Estimates of *sca* effects for yield and its components in F_1 hybrids of *G. hirsutum* x *G. barbadense*

Hybrids	SCY (kg/ha)	Plant ht (cm)	Sympod /plant	Bolls/ plant	GOT (%)	2.5% S.L (mm)	B.S/ (g/tex)	Mic µ/inch
BRS-53-53 x B-4	43.16**	1.97*	0.31**	1.03	2.38**	1.47	-2.05	0.23*
BRS-53-53 x B-5	-17.35**	-0.53	3.45**	-0.51	-0.25*	4.53**	1.54*	0.32*
BRS-53-53 x ICB-20	9.62*	0.33	-1.49	1.62*	8.11**	-1.91	-0.37	-0.50
BRS-53-53 x ICB-74	-14.09*	0.54	0.82*	0.53	-0.2	1.45*	2.09**	1.37**
BRS-53-53 x ICB-201	-31.12	-0.51	-0.2	-0.42	0.31	6.13**	1.03	-0.53**
BRS-53-53 x ICB-260	51.04**	1.37**	0.31*	3.28**	1.45	-1.91	-0.51	0.43**
BRS-53-53 x Pima-S4	36.21**	22.41**	3.45**	-7.18**	-1.59**	0.37*	3.57*	0.12**
CCH-510-4 x B-4	29.34**	0.14	-1.49	3.02**	1.55*	-0.28**	0.23	-0.23
CCH-510-4 x B-5	-16.15	0.33**	0.87	0.61**	4.53*	0.74*	-0.44*	1.31**
CCH-510-4 x ICB-20	11.08	-0.45	-0.2	-2.04	-0.2	1.43	-2.07	-0.23
CCH-510-4 x ICB-74	15.06	1.38*	0.31	1.44**	0.31	3.59	1.25*	0.43*
CCH-510-4 x ICB-201	-14.22*	-0.63	3.45**	-0.38	3.45**	-1.92**	-0.36	0.12
CCH-510-4 x ICB-260	49.31**	0.23**	-1.49*	2.09	-1.48	0.37	2.38*	0.23*
CCH-510-4 x Pima -S4	39.23**	0.32**	1.45	1.03	1.95*	-0.28	1.08	0.32*
CCH-724 x B-4	-23.06*	-0.50	4.53*	-0.51**	7.53**	0.75	-0.51	-0.50
CCH-724 x B-5	-35.18**	2.35*	-1.91	3.52*	-0.2	3.25**	3.53	1.37**
CCH-724 x ICB-20	-3.66	-0.52*	0.37	0.23	0.31	-1.34	0.26	-0.53
CCH-724 x ICB-74	1.65*	0.47	-0.28	-0.42	2.45*	1.55	-0.42	0.43**
CCH-724 x ICB-201	7.34	0.12*	0.73	3.28*	-1.64	4.43**	-2.15	0.12
CCH-724 x ICB-260	45.03**	-0.25	3.15**	-7.18	1.25	-1.85*	1.46*	-0.23*
CCH-724 x Pima S-4	37.36**	1.37*	-1.34	3.02*	4.83**	0.37*	-0.38	1.31**
CCH-4 x B-4	21.55**	-0.23	0.71	0.61	-0.2	-0.28	2.09**	-0.23
CCH-4 x B-5	-17.00	0.44**	-0.29	-2.04*	0.31	0.74*	1.03	0.43
CCH-4 x ICB-20	-42.07**	0.12	0.36	1.40	6.65**	3.15**	-0.51**	0.12
CCH- 4 x ICB-74	1.68*	-0.36	3.52	-0.33	-1.24	-1.34*	3.52**	-0.38*
CCH- 4 x ICB-201	-0.85	1.35**	-1.43	2.09*	1.43	1.47*	0.23*	1.35**
CCH- 4 x ICB-260	15.19*	-0.23	0.55*	1.33	5.03**	6.53**	-0.42**	-0.23
CCH- 4 x Pima S-4	13.07*	0.38*	-0.22	-0.72	-0.27	-1.91	-2.04	0.33
TK-36 x B-4	-0.09	0.72*	0.34	1.32*	0.33	0.37	1.44*	0.72**
TK-36 x B-5	-14.35**	-0.84	3.65**	0.57	3.4**	-0.28	-0.35	-0.81
TK-36 x ICB-20	-0.61	1.32*	-1.19	-0.42	-1.27	0.77*	2.29**	1.39
TK-36 x ICB-74	-1.24*	-0.95	0.57	0.28	1.41**	3.15**	1.06	-0.93
TK-36 x ICB-201	-1.46	0.16	-0.27	-7.18	4.68**	-1.34	-0.51	0.16*
TK-36 x ICB-260	0.77*	0.42*	0.34*	3.02	-0.21	1.46*	3.52**	0.52**
TK-36 x Pima S-4	3.49*	-0.27	3.45**	0.61	0.35	5.53**	0.23	0.25*
ENT -4 x B-4	-3.11	1.35**	-1.49	-2.04	4.13**	-1.97	-0.42	0.32
ENT -4 x B-5	0.22	-0.24*	0.87	1.44**	-1.29**	0.37	-2.04*	-0.53*
ENT -4 x ICB-20	-56.38**	0.27**	-0.27	-0.38	1.36	-0.28	1.46**	1.38**
ENT -4 x ICB-74	-0.24	0.68*	0.33*	2.09*	3.53**	0.76*	-0.38	-0.53
ENT -4 x ICB-201	1.34*	-0.17	3.25**	1.03	-0.2	3.15**	2.09**	0.44**
ENT -4 x ICB-260	4.37	2.37	-1.94	6.51**	0.31	-1.35	1.03	0.12
ENT -4 x Pima -S4	-65.13**	-0.69*	0.67	-1.624	.4.45**	1.45*	-0.51	-0.23
LK-18 x B-4	-23.29**	0.35**	-0.2	-0.53	-1.49	4.53**	3.52**	1.32**
LK-18 x B-5	-5.07	0.76*	0.31	-0.42	1.45	-1.94	0.23	-0.23
LK-18 x ICB-20	-0.45	-0.27	6.45**	1.22	4.53**	0.35**	-0.42	0.47**
LK-18 x ICB-74	-2.34*	-0.39*	-1.45	-7.08	-0.2	-0.28	3.25**	0.16
LK-18 x ICB-201	1.30	-0.17	0.27*	-1.64	0.31	0.79**	-1.94*	-0.37**
LK-18 x ICB-260	-21.71**	1.19*	-0.23	3.61**	3.45**	3.16	0.67*	1.35**
LK-18 x Pima-S4	2.94	0.57*	0.81*	-2.04	-1.59*	-1.35	-0.21	-0.24**
SE±	11.27	6.19	0.61	0.43	0.22	1.06	0.15	0.26
CD@5%	8.07	5.01	9.10	4.03	6.61	4.23	5.87	4.06

*, ** Significant at 5 and 1 per cent level respectively

Electronic Journal of Plant Breeding, 8(2): 494-500 (June 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00075.8

Table 5. Estimates of heterosis over best parent of 17 promising interspecific hybrids (H x B) for different characters

Crosses	SCY kg/ha	Pl. ht (cm)	Monopod/ plant	Sympod/ plant	Bolls/ plant	Boll Wt (g)	GOT (%)	2.5% SL (mm)	B.S g/tex	Mic µ/inch
BRS-53-53x ICB -260	73.64**	-9.58*	53.24**	19.41*	33.25*	19.08**	-3.61	9.79**	16.51**	8.33**
CCH-510-4xB-4	61.22**	-8.56*	-52.67*	-14.22	7.91*	7.31*	26.14*	3.19*	-13.24	-11.25*
BRS-53-53xB-4	54.31**	-21.62**	24.65**	22.55**	49.53**	6.07*	-1.83	-4.52	5.34*	33.67**
CCH-724 x B-4	48.42**	-18.13	-29.38	-16.4	-32.61*	24.34**	6.04*	-4.08	-13.11*	-17.66*
BRS-53-53xPima-S4	37.23**	-20.34**	48.27**	1.82	89.26**	14.16**	-0.97	15.56**	-9.17	-15.62*
CCH-510-4xICB-260	32.56**	-2.67	-36.19**	-3.34	50.22**	-10.25	6.18**	7.63*	-18.13*	-12.61*
CCH-510-4xPima-S4	27.41**	9.03**	-19.26	-39.41**	-28.34*	-5.06	-1.39	-5.18	-17.91*	-8.27
TK-36xB-4	25.60**	-21.3**	-91.34**	-2.11	16.25**	18.12**	0.09	-2.69	-8.24	-10.0
CCH-724xICB-74	21.30*	-18.24*	-47.37**	25.37**	3.84*	-6.01	16.2**	6.64*	-15.81	-3.21
CCH-510-4xICB-20	19.04*	-16.71*	-26.11**	2.33	6.59**	-11.16	-1.82	-1.08	-15.28	-15.2
ENT-4xICB-260	14.56*	-22.15**	-6.44	-16.74*	22.41**	1.02	-1.76	-7.07	5.09*	13.4**
TK-36xICB-260	11.34*	-7.46	-81.27**	-19.54	-5.06	2.16	5.64*	16.03**	3.16*	-12.7*
TK-36xICB-74	8.29*	-17.59*	-61.48*	22.15*	-18.54*	-7.71	-2.57	-4.1	-10.19	-15.23*
CCH-724xICB-260	3.66*	-4.57	-14.2	-51.6	-6.51	3.05	-21.5	-2.5	-18.31*	16.43**
ENT-4xB-4	2.58*	-16.5	-36.19*	-23.18*	-36.41*	11.01*	24.21**	1.08	-23.14**	-3.87
CCH-4x B-4	2.07*	6.31**	-26.28	-26.71*	3.44**	1.35	-1.04	-3.62	-13.34*	-1.07
CCH-4xPima S-4	1.94*	-2.25	-16.33	-43.62**	-42.11	1.08	0.16	-1.07	-11.28	-8.34
SE +	**46.37**	**12.38**	**0.53**	**0.94**	**1.82**	**0.28**	**0.51**	**0.63**	**0.36**	**0.09**
CD@5%	**78.59**	**23.59**	**0.79**	**1.83**	**4.07**	**0.57**	**0.94**	**0.91**	**0.78**	**0.16**
CD@1%	**112.14**	**31.17**	**1.08**	**2.67**	**7.08**	**0.79**	**1.31**	**2.15**	**0.81**	**0.19**

*, ** Significant at 5 and 1 per cent level respectively