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HETEROSIS STUDIES FOR YIELD AND YIELD CONTRIBUTING TRAITS OF UPLAND COTTON IN LINE X TESTER DESIGN

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ABSTRACT

A Line x Tester analysis was conducted in upland cotton with 56 hybrids along with their parents to estimate the magnitude of heterosis for yield and yield contributing characters. The analysis revealed presence of considerable variation among all the parents and hybrids. Seed cotton yield recorded highest average heterosis (12.62 %) followed by number of bolls per plant (10.61 %) and number of sympodia per plant (2.23 %). Highest heterotic effect for seed cotton yield was observed in cross Galama x IC 356932 for both relative heterosis (113.14 %) and heterobeltiosis (94.23 %) followed by BC 68-2 x HAG 1055 (91.00 % and 85.86% respectively) which also exhibited highest heterosis over mid parent (86.95 %) and better parent (82.48 %) for number of bolls per plant, an important yield contributing character. The hybrid NA 1325 x L 604 recorded highest *per se* performance for yield (218.5 g) was found to exhibit highest heterosis (56.12 %) over commercial check. Therefore, from the present study, it is clear that, the hybrids Galama x IC 356932, BC 68-2 x HAG 1055 and NA 1325 x L 604 could be used in future breeding programme for obtaining good transgressive segregants for important yield contributing traits and commercial exploitation of heterosis.

INTRODUCTION

Upland cotton (*Gossypium hirsutum* L.) is most commonly cultivated fiber crop grown in more than 80 countries and plays a major role in boosting our national economy. India is the major cotton exporting country and is the second largest producer of textiles and garments. The Indian textile industry contributes about 14% to industrial production, 4% to the gross domestic product (GDP) and 27% to the country's foreign exchange inflows. Cotton is a major raw material for the Indian textile industry, constituting about 65% of its requirements and is primarily used by the textile industry to produce thread, fabrics, linen and apparel. Heterosis is a basic tool in improvement of any crop in the form of F_1 generation which provides detailed information about the desirable parental combinations in any breeding programmes and reflects a high degree of heterotic response (Khan, 2002). 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. Therefore, use of hybrids is one of the means for improvement of the yield and other yield contributing characters in cotton. As it is known, the use of hybrid cultivars has represented a great advance in the development of the modern agriculture.India is the pioneer country in the world for commercial exploitation of heterosis in cotton and conspicuous heterosis in cotton is also reported by many workers *viz.,* Khadi *et al.* (1993), Wu *et al.* (2004), Abro *et al.* (2009), Choudhary *et al.* (2014), Komal *et al.* (2014) and Usharani *et al.* (2015). World's first hybrid H4 developed at Surat cotton research station is the fabulous example for successful utilization of hybrid vigour on commercial scale. Many researchers reported hybrid vigor for yield and yield contributing characters in intra-*hirsutum* cotton hybrids. Panhwar *et al.* (2002), Ahmad *et al.* (2002), Tuteja and Agrawal (2013), Muhammad *et al.* (2014), Solanki *et al.* (2014) and Shah *et al.* (2015) reported desirable and significant heterosis for seed cotton yield and yield attributing traits like number of sympodia, number of bolls per plant, boll weight and number of seeds per boll in upland cotton. Even though release of several hybrids during the last decade has contributed to a quantum jump in cotton productivity, the yield levels of hybrids appear to have reached stagnation. This might be due to lack in identification or development of specific combiners for important yield contributing characters in hybrid populations and use of less diversified genotypes in hybridization programme. Therefore, for commercial exploitation of heterosis in cotton, pre-requisites are identification of parents which show good heterosis on crossing and production of high yielding hybrids. Keeping in view the importance of heterosis, present study was undertaken in line x tester design using 7 lines, 8 testers and their resultant 56 hybrids to identify best performing cross combinations with an objective to estimate mid parental, better parental and standard heterosis for evaluating the genetic potential and variability present in the parents and hybrids for various yield contributing characters.

MATERIALS AND METHODS

The experimental material comprised of seven lines (CPD 420, Galama, NA 1325, L 389, IC 357063, BC 68-2 and AKH 9331) and eight testers (HAG 1055, LK 861, L 604, JK 344, 4084, IC

356932, LRA 5166 and L 761) and their fifty six crosses along with a check hybrid NHH 44. All 56 hybrids along with the parents and check were evaluated in R.B.D with three replications at College Farm, College of Agriculture, Rajendranagar, Hyderabad during *kharif*, 2007. Each entry was sown in two rows of 5 m length with a spacing of 120 cm between the rows and 60 cm within the row. Observations were recorded on five randomly selected plants for each genotype in each replication. The characters studied were number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight, number of seeds per boll and seed cotton yield per plant. The mean data of 5 plants over 3 replications were used for statistical analysis following the method suggested by Panse and Sukhatme (1985). The Line x Tester analysis of heterosis was performed according to Kempthorne (1957) using the WINDOWSTAT statistical package. Heterosis was expressed as per cent increase or decrease observed in the F_1 over the mid-parent (Relative heterosis), better parent (Heterobeltiosis) and standard check (Standard heterosis) as per the following formula suggested by Fehr (1987).

$$\text{Heterosis over mid parent (\%)} = \frac{\bar{F}_1 \quad \overline{MP}}{BP} \quad 100$$

$$\text{Heterosis over better parent (\%)} = \frac{\bar{F}_1 \quad \overline{BP}}{\overline{BP}} \quad 100$$

$$\text{Heterosis over standard check (\%)} = \frac{\bar{F}_1 \quad \text{Mean of check}}{\text{Mean of check}} \quad 100$$

Where,

$\bar{F}_1$ = Mean of F_1

$\overline{MP}$ = Mean of parents

$\overline{BP}$ = Mean of better parent

RESULTS AND DISCUSSION

The analysis of variance revealed that the parents and hybrids differed significantly for all the traits under study indicating the presence of considerable genetic variability among the genotypes. The magnitude of heterosis provides a basis for genetic diversity and a guide to the choice of parents for developing superior F_1 hybrids, so as to exploit hybrid vigor and or for building better gene pools to be employed in population improvement. For commercial point of view, the superiority of new hybrids for yield should be judged by comparing their performance with the best cultivated hybrid or variety.

To draw the valid conclusions regarding the extent of heterosis for various characters, the overall mean of parents, F_1s and standard check were computed to obtain average and standard heterosis for all the traits studied and presented in Table 1. The degree of heterosis varied considerably for seed cotton yield and its component traits. The highest percentage of average heterosis was observed for seed cotton yield (12.62%) followed by number of bolls per plant (10.61%) and number of sympodia per plant (2.23%). Highest percentage of standard heterosis was obtained in boll weight (11.06%) followed by seed cotton yield per plant (3.41%), whereas negative standard heterosis was observed for number of monopodia per plant (-19.61%), number of bolls per plant (-5.71%), number of seeds per boll (-3.25%) and number of sympodia per plant (-0.43%). The mean values of crosses and all three types of heterosis for the traits under study were presented in Table 2 and 3 respectively.

The mean values of parents and hybrids for number of monopodia per plant were 1.47 and 1.23 respectively. The mean values for hybrids ranged from 0.53 (Galama x JK 344) to 2.20 (CPD 420 x HAG 1055). The range of heterosis varied from -70.91 to 71.43 per cent, -74.19 to 57.89 per cent and -65.36 to 43.79 per cent over mid parent, better parent and standard check respectively. Two crosses exhibited significant positive heterosis over mid parent, whereas, only one cross recorded significant positive heterosis for each better parent and commercial check. The hybrid CPD 420 x L 761 was found to exhibit highest mid parental heterosis as well as heterobeltiosis and the cross CPD 420 X HAG 1055 recorded significant mid parental and standard heterosis in desirable direction. These results are in conformity with the findings of Potdukhe (2001), Komal *et al.* (2014) and Shah *et al.* (2015).

For the trait number of sympodia per plant the overall mean of parents and hybrids was 15.71 and 16.06 respectively, while the check NHH 44 recorded 16.13. Among the crosses, the mean values ranged from 14.07 (L 389 x IC 356932) to 18.47 (CPD 420 x JK 344). Most of the crosses exhibited significant heterosis over mid parent, better parent and standard check with ranged from -12.40 (NA 1325 x L 761) to 20.47 (AKH 9331 x HAG 1055) per cent, -17.90 (L 389 x IC 356932) to 15.42 (CPD 420 x JK 344) per cent and from -12.77 (L 389 x IC 356932) to 14.51 (CPD 420 x JK 344) per cent respectively. Out of 21 significant crosses, 16 showed positive heterosis and 5 crosses exhibited negative heterosis over mid parent. Significant and positive heterosis was recorded in four crosses over better parent indicating the involvement of over dominant type of gene action in these crosses, whereas, seven crosses surpassed the standard check in desirable direction. The hybrid CPD 420 x JK 344 recorded highest positive and significant heterosis over both better parent (15.42 %) and standard check (14.51 %), whereas the cross L 389 x IC 356932 registered lowest significant heterosis over both better parent (-17.90 %) and standard check (-12.77 %). Similar findings were reported by Babar *et al.*(2001), Natera *et al.*(2007), Solanki *et al.* (2014), Komal *et al.* (2014),

Table 1: Average and standard heterosis for seed cotton yield and its contributing characters

Heterosis	No. of monopodia/plant	No. of sympodia /plant	No. of bolls /plant	Boll weight	No. of seeds/ boll	Seed cotton yield/plant
Average heterosis (%)	-16.33	2.23	10.61	-1.91	-2.07	12.62
Standard heterosis (%)	-19.61	-0.43	-5.71	11.06	-3.25	3.41

Table 2: Mean perpformance of 56 crosses for seed cotton yield and its components

Crosses mean	No. of monopodia/plant	No. of sympodia/plant	No. of bolls/plant	Boll weight (g)	No. of seeds/ boll	Seed cotton yield/plant (g)
CPD 420 X HAG 1055	2.20	14.93	38.00	4.68	30.00	196.55
CPD 420 X LK 861	1.33	16.67	35.80	4.76	26.71	186.76
CPD 420 X L 604	1.60	18.20	31.13	5.17	31.97	175.45
CPD 420 X JK 344	1.93	18.47	34.33	5.32	29.11	167.73
CPD 420 X 4084	1.67	16.73	28.13	3.59	22.69	107.35
CPD 420 X IC 356932	1.40	18.13	34.27	4.24	23.93	175.26
CPD 420 X LRA 5166	2.00	14.93	30.07	5.40	31.20	171.50
CPD 420 X L 761	2.00	16.47	26.00	5.88	30.64	137.72
Galama X HAG 1055	1.47	15.47	34.27	4.42	23.55	176.29
Galama X LK 861	1.13	17.53	38.33	4.48	24.44	171.97
Galama X L 604	0.80	14.60	37.07	4.34	23.91	154.55
Galama X JK 344	0.53	16.73	31.20	4.03	23.53	157.70
Galama X 4084	1.80	16.87	34.93	4.37	24.89	149.29
Galama X IC 356932	1.60	15.80	38.20	4.75	30.33	192.12
Galama X LRA 5166	1.00	16.87	36.60	4.76	26.63	202.62
Galama X L 761	0.93	17.60	25.60	5.00	23.92	139.26
NA 1325 X HAG 1055	1.33	15.33	24.27	4.50	24.99	115.51
NA 1325 X LK 861	0.60	16.00	30.40	4.78	28.07	125.69
NA 1325 X L 604	1.47	15.33	38.20	5.32	27.78	218.57
NA 1325 X JK 344	1.00	15.33	28.40	3.84	25.44	134.95
NA 1325 X 4084	1.33	17.87	35.80	5.08	32.64	204.25
NA 1325 X IC 356932	1.27	15.47	26.33	4.68	26.84	134.92
NA 1325 X LRA 5166	1.60	17.20	33.60	4.79	27.28	191.11
NA 1325 X L 761	0.93	14.60	26.47	5.08	26.43	136.04
L 389 X HAG 1055	0.80	14.27	27.53	4.46	24.72	136.43
L 389 X LK 861	1.33	14.93	33.47	5.30	28.39	169.54
L 389 X L 604	1.00	15.93	31.27	4.02	25.02	119.77
L 389 X JK 344	0.87	15.13	24.73	3.71	18.94	112.64
L 389 X 4084	1.00	16.07	35.07	3.81	25.53	121.61
L 389 X IC 356932	0.93	14.07	31.47	4.61	27.67	145.15
L 389 X LRA 5166	1.00	16.80	30.20	4.24	26.70	141.17
L 389 X L 761	1.00	16.67	23.07	5.44	25.35	117.81
IC 357063 X HAG 1055	1.20	14.93	22.40	4.06	20.80	76.23
IC 357063 X LK 861	1.53	17.20	32.80	4.52	24.84	139.17
IC 357063 X L 604	1.00	16.07	26.07	4.21	23.35	91.49
IC 357063 X JK 344	1.67	16.07	26.28	3.98	25.44	135.20
IC 357063 X 4084	1.60	16.40	23.87	3.95	24.15	98.54
IC 357063 X IC 356932	1.33	15.47	25.47	3.67	22.84	125.14
IC 357063 X LRA 5166	1.73	15.07	27.53	4.51	25.07	118.40
IC 357063 X L 761	1.13	15.80	24.93	4.57	21.98	113.43
BC 68-2 X HAG 1055	0.87	15.80	34.27	5.18	30.22	195.20
BC 68-2 X LK 861	1.60	15.67	37.60	4.70	27.86	164.81
BC 68-2 X L 604	1.13	14.33	32.40	4.85	30.69	143.52
BC 68-2 X JK 344	0.60	16.47	27.47	4.00	28.04	119.98
BC 68-2 X 4084	1.33	16.20	30.60	4.59	28.62	147.95
BC 68-2 X IC 356932	0.87	15.67	29.53	4.08	24.69	107.50
BC 68-2 X LRA 5166	1.60	16.40	31.93	4.73	31.83	168.31
BC 68-2 X L 761	1.13	17.20	32.60	4.96	28.66	173.95
AKH 9331 X HAG 1055	1.27	17.27	31.13	5.45	28.86	182.95
AKH 9331 X LK 861	1.47	15.47	30.00	5.53	29.18	154.44
AKH 9331 X L 604	1.13	15.40	22.93	4.82	31.44	92.60
AKH 9331 X JK 344	0.93	14.73	22.60	3.73	22.42	81.26
AKH 9331 X 4084	0.67	16.87	31.53	4.60	28.20	134.22
AKH 9331 X IC 356932	0.67	15.73	21.00	5.22	30.91	90.23
AKH 9331 X LRA 5166	0.80	16.67	28.07	4.81	18.39	145.30
AKH 9331 X L 761	0.73	15.60	26.07	5.20	24.11	119.98
Parental mean	1.47	15.71	27.34	4.71	27.02	128.54
Cross mean	1.23	16.06	30.24	4.62	26.46	144.77
NHH 44 (check)	1.53	16.13	32.07	4.16	27.35	140.00
CV	30.13	4.40	8.12	8.79	8.84	10.68
SE±	0.22	0.40	1.39	0.24	1.36	8.72
CD (5%)	0.62	1.14	3.88	0.66	3.79	24.37

Table 3: Heterosis over mid parent (MP), better parent (BP) and standard check (SH) for number of monopodia per plant, number of sympodia per plant and number of bolls per plant

Cross	No. of monopodia/plant			No. of sympodia/plant			No. of bolls/plant		
	MP	BP	SH	MP	BP	SH	MP	BP	SH
CPD 420 X HAG 1055	53.49**	37.50	43.79*	-4.27	-6.67	-7.44*	60.34**	50.00**	18.49**
CPD 420 X LK 861	-4.76	-13.04	-13.07	1.83	-0.40	3.35	19.73**	3.87	11.63
CPD 420 X L 604	2.13	-14.29	4.58	14.47**	13.75**	12.83**	5.30	-7.89	-2.93
CPD 420 X JK 344	34.88	20.83	26.14	16.39**	15.42**	14.51**	15.99**	1.38	7.05
CPD 420 X 4084	13.64	0.00	9.15	4.58	4.58	3.72	-2.99	-13.88*	-12.29*
CPD 420 X IC 356932	-2.33	-12.50	-8.50	9.46**	5.84	12.40**	48.13**	35.26**	6.86
CPD 420 X LRA 5166	25.00	3.45	30.72	-9.86**	-12.84**	-7.44*	17.14*	15.64*	-6.24
CPD 420 X L 761	71.43**	57.89*	30.72	-2.37	-7.14*	2.11	-6.25	-13.72*	-18.93**
Galama X HAG 1055	-20.00	-29.03	-3.92	3.57	1.75	-4.09	63.17**	55.29**	6.86
Galama X LK 861	-37.04*	-45.16**	-26.14	11.68**	4.78	8.68*	40.93**	11.22	19.52**
Galama X L 604	-59.32**	-61.29**	-47.71*	-4.16	-7.59*	-9.49**	37.97**	9.66	15.59*
Galama X JK 344	-70.91**	-74.19**	-65.36**	10.09**	6.36	3.72	15.99*	-7.87	-2.71
Galama X 4084	-3.57	-12.90	17.65	10.00**	5.42	4.59	32.83**	6.94	8.92
Galama X IC 356932	-12.73	-22.58	4.58	-0.63	-7.78*	-2.05	86.95**	82.48**	19.11**
Galama X LRA 5166	-50.00**	-51.61**	-34.64	6.08	-1.56	4.59	59.36**	40.77**	14.13*
Galama X L 761	-40.43*	-54.84**	-39.22	8.64**	-0.75	9.11*	2.26	-15.04*	-20.17**
NA 1325 X HAG 1055	-13.04	-16.67	-13.07	-0.43	-1.71	-4.96	-11.22	-25.56**	-24.32**
NA 1325 X LK 861	-60.00**	-60.87**	-60.78**	-1.03	-4.38	-0.81	-9.34	-11.80*	-5.21
NA 1325 X L 604	-12.00	-21.43	-3.92	-2.34	-2.95	-4.96	15.06**	13.02*	19.11**
NA 1325 X JK 344	-34.78	-37.50	-34.64	-2.13	-2.54	-4.96	-14.54**	-16.14**	-11.44
NA 1325 X 4084	-14.89	-20.00	-13.07	13.08**	11.67**	10.79**	9.70	9.59	11.63
NA 1325 X IC 356932	-17.39	-20.83	-16.99	-5.50	-9.73**	-4.09	-1.62	-19.22**	-17.90**
NA 1325 X LRA 5166	-5.88	-17.24	4.58	5.09	0.39	6.63	14.68*	3.07	4.77
NA 1325 X L 761	-26.32	-36.36	-39.22	-12.40**	-17.67**	-9.49**	-15.62**	-18.81**	-17.46**
L 389 X HAG 1055	-41.46*	-50.00*	-47.71*	-2.95	-6.14	-11.53**	5.09	-9.23	-14.16
L 389 X LK 861	0.00	-13.04	-13.07	-3.45	-10.76**	-7.44*	3.29	-2.90	4.37
L 389 X L 604	-33.33	-46.43**	-34.64	6.22	0.84	-1.24	-2.49	-7.50	-2.49
L 389 X JK 344	-36.59	-45.83*	-43.14*	1.11	-3.81	-6.20	-22.95**	-26.97**	-22.89**
L 389 X 4084	-28.57	-40.00*	-34.64	6.40	0.42	-0.37	11.32*	7.35	9.35
L 389 X IC 356932	-31.71	-41.67*	-39.22	-10.21**	-17.90**	-12.77**	22.76**	3.74	-1.87
L 389 X LRA 5166	-34.78	-48.28**	-34.64	7.23*	-1.95	4.15	7.22	-0.44	-5.83
L 389 X L 761	-9.09	-11.76	-34.64	4.38	-6.02	3.35	-23.70**	-23.96**	-28.06**
IC 357063 X HAG 1055	-20.00	-25.00	-21.57	-3.66	-5.49	-7.44*	-5.62	-11.81	-30.15**
IC 357063 X LK 861	4.55	0.00	0.00	5.74	2.79	6.63	9.58	-4.84	2.28
IC 357063 X L 604	-38.78*	-46.43*	-34.64	1.69	1.69	-0.37	-11.94*	-22.88**	-18.71**
IC 357063 X JK 344	11.11	4.17	9.15	1.90	1.69	-0.37	-11.3	-22.39**	-18.05**
IC 357063 X 4084	4.35	-4.00	4.58	3.14	2.50	1.67	-17.80**	-26.94**	-25.57**
IC 357063 X IC 356932	-11.11	-16.67	-13.07	-6.07*	-9.73**	-4.09	9.93	0.26	-20.58**
IC 357063 X LRA 5166	4.00	-10.34	13.07	-8.50**	-12.06**	-6.57	7.13	5.90	-14.16*
IC 357063 X L 761	-8.11	-19.05	-26.14	-5.77	-10.90**	-2.05	-10.2	-17.26**	-22.26**
BC 68-2 X HAG 1055	-27.78	-45.83*	-43.14*	6.76*	3.95	-2.05	51.85**	48.55**	6.86
BC 68-2 X LK 861	37.14	4.35	4.58	0.64	-6.37	-2.85	30.71**	9.09	17.24**
BC 68-2 X L 604	-15.00	-39.29*	-26.14	-5.08	-9.28*	-11.16**	13.95*	-4.14	1.03
BC 68-2 X JK 344	-50.00*	-62.50**	-60.78**	9.29**	4.66	2.11	-3.51	-18.90**	-14.34*
BC 68-2 X 4084	8.11	-20.00	-13.07	6.58*	1.25	0.43	9.81	-6.33	-4.58
BC 68-2 X IC 356932	-27.78	-45.83**	-43.14*	-0.63	-8.56*	-2.85	34.24**	28.03**	-7.92
BC 68-2 X LRA 5166	17.07	-17.24	4.58	4.02	-4.28	1.67	30.16**	22.82**	-0.44
BC 68-2 X L 761	21.43	6.25	-26.14	7.05*	-3.01	6.63	22.18**	7.85	1.65
AKH 9331 X HAG 1055	-5.00	-20.83	-16.99	20.47**	13.60**	7.07*	49.92**	41.09**	-2.93
AKH 9331 X LK 861	12.82	-4.35	-3.92	2.43	-7.57*	-4.09	11.25	-12.96*	-6.45
AKH 9331 X L 604	-22.73	-39.29*	-26.14	5.24	-2.53	-4.53	-13.89*	-32.15**	-28.50**
AKH 9331 X JK 344	-30.00	-41.67*	-39.22	0.91	-6.36	-8.68*	-15.25*	-33.27**	-29.53**
AKH 9331 X 4084	-51.22*	-60.00**	-56.21**	14.48**	5.42	4.59	20.97**	-3.47	-1.68
AKH 9331 X IC 356932	-50.00*	-58.33**	-56.21**	2.83	-8.17*	-2.48	3.96	0.32	-34.52**
AKH 9331 X LRA 5166	-46.67*	-58.62**	-47.71*	8.93**	-2.72	3.35	23.46**	7.95	-12.47*
AKH 9331 X L 761	-31.25	-31.25	-52.29*	0	-12.03**	-3.29	5.11	-13.50*	-18.71**

Muhammad *et al.* (2014) and Hanif *et al.* (2015).

The mean value for number of bolls per plant among the parents was 27.34. Among the hybrids, AKH 9331 x IC 356932 recorded least number of bolls per plant (21.00), whereas the cross Galama x LK 861 recorded the highest (38.33) with an overall mean of 30.24. The range of heterosis over mid parent ranged from -23.70 (L 389 x L 761) to 86.95 (Galama x IC 356932) per cent and over better parent it varied between

Table 3 contd: Heterosis over mid parent (MP), better parent (BP) and standard check (SH) for boll weight, number of seeds per boll and seed cotton yield per plant

Cross	Boll weight			No. of seeds/boll			Seed cotton yield/plant		
	MP	BP	SH	MP	BP	SH	MP	BP	SH
CPD 420 X HAG 1055	-11.94*	-12.73*	12.5	0.31	-1.21	9.69	83.80**	80.58**	40.39**
CPD 420 X LK 861	-3.26	-11.43	14.42	-2.84	-9.29	-2.34	33.55**	9.32	33.40**
CPD 420 X L 604	5.51	-3.60	24.28**	19.01**	8.59	16.89*	41.00**	25.30**	25.32**
CPD 420 X JK 344	9.58	-0.93	27.88**	4.87	-1.14	6.44	36.43**	22.40*	19.81*
CPD 420 X 4084	-29.58**	-33.17**	-13.70	-24.77**	-26.50**	-17.04*	-19.22*	-31.60**	-23.32**
CPD 420 X IC 356932	-14.67*	-21.06**	1.92	-14.09*	-18.73**	-12.50	68.72**	61.02**	25.19**
CPD 420 X LRA 5166	9.09	0.62	29.81**	8.63	5.95	14.08*	42.92**	30.76**	22.50*
CPD 420 X L 761	6.56	3.77	41.35**	11.83	4.06	12.03	4.84	-10.50	-1.63
Galama X HAG 1055	-3.67	-16.13*	6.25	-16.65**	-22.44**	-13.89*	89.16**	67.85**	25.92**
Galama X LK 861	7.01	0.37	7.69	-5.41	-6.52	-10.64	36.38**	0.67	22.84*
Galama X L 604	3.83	-2.40	4.33	-5.19	-8.56	-12.58	39.62**	10.37	10.39
Galama X JK 344	-2.22	-7.07	-3.13	-9.85	-9.98	-13.97*	44.42**	15.08	12.64
Galama X 4084	0.15	-9.34	5.05	-12.69*	-19.37**	-8.99	25.30**	-4.87	6.64
Galama X IC 356932	12.24	4.16	14.18	15.75*	15.48*	10.90	113.14**	94.23**	37.23**
Galama X LRA 5166	12.88	5.07	14.42	-1.61	-4.86	-2.63	90.69**	54.50**	44.73**
Galama X L 761	4.42	-11.77*	20.19*	-7.10	-8.50	-12.54	18.40*	-9.50	-0.53
NA 1325 X HAG 1055	-5.99	-14.67*	8.17	-4.48	-17.71**	-8.63	-9.93	-23.74**	-17.49*
NA 1325 X LK 861	9.10	7.10	14.90	18.24*	9.96	2.63	-22.01**	-26.43**	-10.22
NA 1325 X L 604	21.86**	19.89**	27.88**	20.14**	14.37	1.57	49.96**	44.30**	56.12**
NA 1325 X JK 344	-10.97	-11.38	-7.69	5.97	-2.39	-6.98	-6.45	-10.91	-3.61
NA 1325 X 4084	11.59	5.53	22.12*	23.59**	5.75	19.34**	32.45**	30.15**	45.89**
NA 1325 X IC 356932	5.64	2.56	12.50	11.34	2.21	-1.86	7.77	-10.93	-3.63
NA 1325 X LRA 5166	8.42	5.59	15.14	9.22	-2.56	-0.26	35.24**	26.16**	36.51**
NA 1325 X L 761	2.07	-10.24	22.12*	11.74	4.25	-3.36	-10.90	-11.59	-2.83
L 389 X HAG 1055	-11.94*	-15.37*	7.21	-11.17	-18.60**	-9.62	-0.15	-18.91*	-2.55
L 389 X LK 861	13.73*	9.05	27.40**	11.72	11.19	3.80	0.00	-0.76	21.10*
L 389 X L 604	-13.48*	-17.22*	-3.37	0.94	-1.05	-8.52	-22.30**	-28.81**	-14.45
L 389 X JK 344	-19.39**	-23.73**	-10.82	-26.22**	-27.33**	-30.75**	-26.20**	-33.05**	-19.54*
L 389 X 4084	-21.28**	-21.60**	-8.41	-9.07	-17.29**	-6.65	-25.20**	-27.72**	-13.14
L 389 X IC 356932	-2.02	-5.01	10.82	7.35	5.36	1.17	8.66	-13.73	3.68
L 389 X LRA 5166	-9.72	-12.76	1.92	0.21	-4.63	-2.38	-5.69	-16.09*	0.84
L 389 X L 761	3.39	-3.94	30.77**	0.13	0.00	-7.31	-26.85**	-29.98**	-15.85
IC 357063 X HAG 1055	-22.71**	-23.02**	-2.40	-26.75**	-31.51**	-23.95**	-32.55**	-37.00**	-45.55**
IC 357063 X LK 861	-6.68	-13.52*	8.65	-4.35	-5.96	-9.18	-4.62	-18.53*	-0.59
IC 357063 X L 604	-12.97*	-19.52**	1.20	-7.90	-11.61	-14.63*	-29.90**	-34.66**	-34.65**
IC 357063 X JK 344	-16.70**	-23.79**	-4.33	-3.05	-3.70	-6.98	4.79	-1.34	-3.43
IC 357063 X 4084	-21.30**	-24.36**	-5.05	-15.68**	-21.76**	-11.7	-29.09**	-37.21**	-29.61**
IC 357063 X IC 356932	-24.89**	-29.66**	-11.78	-13.28*	-13.53	-16.49*	13.80	3.41	-10.61
IC 357063 X LRA 5166	-7.51	-13.65*	8.41	-7.86	-10.45	-8.34	-6.09	-9.72	-15.43
IC 357063 X L 761	-16.01**	-19.25**	9.86	-15.07*	-16.78*	-19.63**	-17.47*	-26.29**	-18.98*
BC 68-2 X HAG 1055	1.70	-1.64	24.52**	0.46	-0.47	10.49	91.00**	85.86**	39.43**
BC 68-2 X LK 861	0.25	-4.47	12.98	0.72	-6.50	1.86	21.99**	-3.52	17.72*
BC 68-2 X L 604	3.52	-1.56	16.59	13.47*	2.98	12.21	19.90*	2.49	2.51
BC 68-2 X JK 344	-13.53*	-18.69**	-3.85	0.38	-5.91	2.52	1.51	-12.44	-14.30
BC 68-2 X 4084	-5.71	-6.70	10.34	-5.65	-7.28	4.64	15.45	-5.72	5.68
BC 68-2 X IC 356932	-13.98*	-17.13*	-1.92	-11.91*	-17.14**	-9.73	8.43	8.18	-23.21**
BC 68 2 X LRA 5166	0.04	-3.93	13.70	10.15	6.81	16.38*	46.02**	28.33**	20.22*
BC 68-2 X L 761	-6.30	-12.42*	19.23*	3.94	-3.81	4.79	37.37**	13.04	24.25**
AKH 9331 X HAG 1055	17.33**	3.42	31.01**	-3.61	-4.95	5.52	75.05**	74.19**	30.68**
AKH 9331 X LK 861	30.42**	23.99**	32.93**	6.00	-1.16	6.69	12.39	-9.60	10.31
AKH 9331 X L 604	13.95*	8.56	15.87	16.88**	6.52	14.95*	-24.11**	-33.87**	-33.86**
AKH 9331 X JK 344	-10.81	-14.07	-10.34	-19.33**	-24.05**	-18.03*	-32.57**	-40.70**	-41.96**
AKH 9331 X 4084	4.07	-4.56	10.58	-6.61	-8.65	3.11	2.87	-14.48	-4.13
AKH 9331 X IC 356932	21.63**	14.39	25.48**	10.82	4.71	13.02	-11.06	-13.24	-35.55**
AKH 9331 X LRA 5166	12.47	6.10	15.63	-36.04**	-37.69**	-32.76**	23.58*	10.79	3.79
AKH 9331 X L 761	7.40	-8.18	25.00**	-12.14*	-18.34**	-11.85	-6.95	-22.03**	-14.30

MP: Mid parent, BP: Better parent, SH: Standard Heterosis

-33.27 (AKH 9331 x JK 344) and 82.48 (Galama x IC 356932) per cent. Most of the crosses exhibited significant heterosis over mid and better parents for this trait. Compared to significant positive heterosis over better parent (11 crosses), more number of crosses (25) showed significant positive heterosis over mid parent. The cross Galama x IC 356932 recorded highest positive significant heterosis over both mid and better parents (86.95 and 82.48 per cent respectively).

Table 4: Heterosis for superior five crosses based on yield *per se* performance

Cross	per se yield (g)	Heterosis	No. of monopodia/ plant	No. of sympodia/ plant	No. of bolls/plant	Boll weight	No. of seeds/boll	Seed cotton yield/plant
NA 1325 X L 604	218.5	MP	-12.00	-2.34	15.06**	21.86**	20.14**	49.96**
		BP	-21.43	-2.95	13.02*	19.89**	14.37	44.30**
		SH	-3.92	-4.96	19.11**	27.88**	1.57	56.12**
NA 1325 X 4084	204.2	MP	-14.89	13.10**	9.70	11.59	23.59**	32.45**
		BP	-20.00	11.70**	9.59	5.53	5.75	30.15**
		SH	-13.07	10.80**	11.63	22.12*	19.34**	45.89**
Galama X LRA 5166	202.6	MP	-50.00**	6.08	59.36**	12.88	-1.61	90.69**
		BP	-51.61**	-1.56	40.77**	5.07	-4.86	54.50**
		SH	-34.64	4.59	14.13*	14.42	-2.63	44.73**
CPD 420 X HAG 1055	196.5	MP	53.49**	-4.27	60.34**	-11.94*	0.31	83.80**
		BP	37.50	-6.67	50.00**	-12.73*	-1.21	80.58**
		SH	43.79*	-7.44*	18.49**	12.50	9.69	40.39**
BC 68-2 X HAG 1055	195.2	MP	-27.78	6.71*	51.85**	1.70	0.46	91.00**
		BP	-45.83*	3.95	48.55**	-1.64	-0.47	85.86**
		SH	-43.14*	-2.05	6.86	24.52**	10.49	39.43**

MP: Mid parent; BP: Better parent; SH: Standard heterosis

Such high heterotic response would be useful for obtaining more number of bolls per plant which ultimately results in higher yields. The range of standard heterosis varied from -34.52 to 19.52 per cent. Highest significant positive standard heterosis was recorded for Galama x LK 861 (19.52 %). These findings are in agreement with the reports of Babar *et al.* (2001), Natera *et al.* (2007), Patel *et al.* (2012), Solanki *et al.* (2014), Muhammad *et al.* (2014), Komal *et al.* (2014), Hanif *et al.* (2015) and Shah *et al.* (2015).

The overall mean of parents and crosses for the trait boll weight was 4.71 and 4.62 g respectively. Among the parents and crosses, CPD 420 x L 761 recorded the maximum value of 5.88 g. Heterosis over mid parent ranged from -29.58 (CPD 420 x 4084) to 30.42 (AKH 9331 x LK 861) per cent. Out of 21 hybrids exhibited significant relative heterosis only 6 crosses showed positive heterosis. For heterobeltiosis the values ranged from -33.17 (CPD 420 x 4084) to 23.99 (AKH 9331 x LK 861) per cent. Twenty one crosses exhibited significantly negative heterobeltiosis and only two crosses recorded positive significant heterosis over better parent. The crosses AKH 9331 x LK 861 and CPD 420 x 4084 recorded highest positive and negative significant heterosis respectively over both mid and better parents. 16 crosses were found to be significantly superior in desirable direction over standard check and would be exploited in developing varieties that ultimately would affect in increasing the yield, and none of the hybrids exhibited significant negative heterosis. The cross CPD 420 x L 761 registered highest value of 41.35 per cent over the check. Similar results were coded by Soomro and Baloch (2005), Patel *et al.* (2012), Solanki *et al.* (2014), Muhammad *et al.* (2014), Komal *et al.* (2014), Pushpam *et al.* (2015) and Shah *et al.* (2015).

The mean value for number of seeds per boll in parents and crosses was recorded as 27.02 and 26.46 respectively, while for the check the value was 27.35. The mean values of crosses ranged from 18.39 (AKH 9331 x LRA 5166) to 32.64 (NA 1325 x 4084). The expression of mid parental heterosis ranged from -36.04 (AKH 9331 x LRA 5166) to 23.59 (NA 1325 x 4084) per cent. A range of -37.69 (AKH 9331 x LRA 5166) to 15.48 (Galama x IC 356932) per cent heterobeltiosis and -32.76 (AKH 9331 x LRA 5166) to 19.34 (NA 1325 x 4084) per cent standard heterosis was observed. Seven crosses over mid parent, one cross over better parent and five crosses over check recorded significant heterosis in desirable direction indicating the involvement of dominant genes in these crosses. The crosses NA 1325 x 4084 and CPD 420 x L 604 were observed to be exhibit both heterobeltiosis and standard heterosis. Similar results were noticed by Singh and Singh (1993), Kumaresan *et al.* (1999) and Ahmad *et al.* (2002).

The mean of crosses (144.77 g) for the trait seed cotton yield per plant was higher compared to parental mean (128.54 g) and the check (140.00 g). The hybrid IC 357063 x HAG 1055 recorded the lowest value of 76.23 g and the hybrid NA 1325 x L 604 recorded the highest yield of 218.57 g followed by the crosses NA 1325 x 4084 (204.25 g) and Galama x LRA 5166 (202.62 g). Mid parental heterosis ranged from -32.57 (AKH 9331 x JK 344) to 113.14 (Galama x IC 356932) per cent. A total of 24 crosses accounted for significant positive heterosis and 12 crosses for significant negative heterosis over mid parental value. The estimates of heterobeltiosis ranged from -40.70 (AKH 9331 x JK 344) to 94.23 (Galama x IC 356932) per cent. Out of 56 crosses, 14 crosses exhibited significant positive and 17 crosses had significant negative values over better parent. Top five crosses having significant and positive high heterobeltiotic effects were Galama x IC 356932 (94.23 %), BC 68-2 x HAG 1055 (85.86 %), CPD 420 x HAG 1055 (80.58 %), AKH 9331 x HAG 1055 (74.19 %) and Galama x HAG 1055 (67.85 %). Therefore, these crosses would be of greater value if exploited in breeding programme that could results in obtaining desirable transgressive segregants giving rise to new populations. Crosses Galama x IC 356932 and AKH 9331 x JK 344 recorded significantly highest positive and negative heterosis respectively over both mid parent and better parent. Standard heterosis over check ranged from -45.55 (IC 357063 x HAG 1055) to 56.12 per cent (NA 1325 x L 604). Out of 30 crosses showing significant heterosis over check, 19 were found to be positively significant and 11 were negatively significant. Similar findings were reported by Panhwar *et al.* (2002), Tuteja *et al.* (2004), Soomro *et al.* (2006), Natera *et al.* (2007), Patel *et al.* (2012), Solanki *et al.* (2014) Muhammad *et al.* (2014), Komal *et al.* (2014), Hanif *et al.* (2015) and Shah *et al.* (2015). A total of 14 crosses exhibited all three types of heterosis significantly in desired direction indicated the preponderance of additive gene action.

For commercial point of view, the superiority of new hybrids for yield should be judged by comparing their performance with the best cultivated hybrid/s or variety. The hybrid NHH 44 therefore used as standard check in order to obtain information regarding superiority of new hybrids over the best cultivated hybrid. The highest yielding hybrid NA 1325 x L 604 (218.57 g) which exhibited the highest standard heterosis of 56.12 per cent also exhibited considerable amount of relative heterosis (49.96 %) and heterobeltiosis (44.30 %). All the hybrids that have shown high degree of standard heterosis for yield, also exhibited substantial level of relative heterosis and heterobeltiosis for yield and one or more of its components. Most of crosses were found to out yield their parents. This encourages heterosis from wide range of parental combinations. Accumulation of favorable genes is the main reason for high vigour in hybrids. High heterosis might be obtained with parents of diverse origin in the presence of adequate favorable environment for expression of heterosis and in the absence of mutual cancellation of components of heterosis. Generally parents with high order of expression of the characters when combined produce hybrids with high expression (Gilbert, 1958). In the present study, where the *per se* performance for yield of best five crosses considered (Table 4), the hybrids NA 1325 x 4084 and NA 1325 x L 604 exhibited high *per se* performance for yield with considerable levels of all three types of heterosis for seed cotton yield, where parents involved in these crosses recorded substantial yield levels, whereas the hybrid resulting from low yielding parents, Galama and IC 356932 exhibited substantial increase in yield with highest percent of relative heterosis and heterobeltiosis. Such situation could be attributable to high inter-allelic interaction canceling the individual effects of each other.

In conclusion, the hybrids Galama x IC 356932, AKH 9331 x LK 861, CPD 420 x JK 344, NA 1325 x L 604, NA 1325 x 4084, BC 68-2 x HAG 1055 and CPD 420 x HAG 1055 which recorded high heterotic values for seed cotton yield and its component traits also exhibited high *per se* performance for yield and one or two its attributing traits. Hence, these crosses could be utilized successfully in further breeding programmes for exploitation of heterosis and developing desirable genotypes for improving yield parameters.

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