academicresearchJournals

Vol. 3(6), pp. 128-136, June 2015
DOI: 10.14662/ARJASR2015.033

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Heterotic Studies in 8 × 8 Diallel Crosses of Upland Cotton

Kashif Ali Shah[1]*, NaqibUllah Khan[1], Liaqat Shah[2], Asif Ali[2], Aaqil Khan[3], Xu Ying[3], Zaheer Abbas[1]

[1]Department of Plant Breeding and Genetics, The University of Agriculture Peshawar, Pakistan
[2]Key Lab of Crop Biology, School of Life Sciences, Anhui Agricultural University, Hefei 230036, China
[3]School of Agronomy, Anhui Agricultural University, Hefei 230036, China
Corresponding author E-mail: kashifgenetics@gmail.com

Accepted 8 May 2015

To study the genetic variability in 8 × 8 diallel cross of upland cotton among different morpho-yield traits, an experiment involving eight cotton (*Gossypium hirsutum* L.) cultivars and their 56 F_1 crosses were grown at The University of Agriculture Peshawar, Pakistan during May, 2009. Mean values for days to flowering varied from 57.00 to 71.67 among parental genotypes while mean values ranged from 51.33 to 65.33 days in F_1 hybrids. Mean values for monopodia plant^{-1}among the parental genotypes and F_1 hybrid varied from 0.30 to 1.13 and 0.22 to 1.59, respectively. Mean values for seed cotton yield plant^{-1} varied from 40.48 to 117.50 g among parental cultivars while 42.11 to 243.10 g in F_1 hybrids.The cross combination SLH-284 × CIM-506 showed desirable negative values heterosis over mid and better parents for days to first flowering (-20.00 and -27.45%). The F_1 hybrid CIM-499 × CIM-473 exhibited promising mid and better parent heterosis values for bolls sympodia^{-1} (110.12 and 101.37%). The cross combination CIM-473 × CIM-554 showed superior heterosis over both parents for bolls plant^{-1} (101.10 and 77.00%) and boll weight (25.87 and 18.28%). The F_1 hybrid CIM-707 × CIM-496 demonstrated promising mid and better parent heterosis values seed for cotton yield plant^{-1} (86.95 and 84.86%) and desirable negative values for monopodia plant^{-1} (-56.44 and -67.76%). The above mentioned F_1 crosses can be further studied for their stability in F_2 generation for hybrid cotton production.

Key words: heterosis; F_1 crosses; morphological traits; yield traits; upland cotton

INTRODUCTION

Cotton belongs to genus *Gossypium* and family *Malvaceae*. Upland cotton (*Gossypium hirsutum*L.), a tetraploid species most commonly cultivated worldwide followed by *G.barbadense* and both species are also called “new world cotton”. The *G. hirsutum* originated in Mexico and it is also thought to be originated in the high lands of Georgia and that is why also called upland cotton. Two additional diploid cultivated species are *G.arboreum* and *G.herbaceum*, called “old world cotton” or “Asiatic cotton”. Cotton is the most important industrial crop, accounting for more than 95% of world fiber production. Being a major cash crop of Pakistan, it plays a key role in the national economy of the country. It earns 45 to 60% foreign exchange depending upon production and consumption. Beside earning huge amount of foreign exchange through its export and providing fiber for inland textile industry, it also provides food (oil) and feed (seed cake) for humans and animals consumption.

Hybrid cotton is a good approach for significant improvement in genetic potential for yield and fiber quality traits and has attracted attention of cotton breeders for commercial growing of hybrid generation (Khan *et al.* 1999). However, the efforts have not delivered the expected results due to self-pollination which has some different implications on hybrid seed production in comparison to cross pollinated crops. In countries like India and china, where labor is cheaper, the successful hybrid cotton is produced on large scale since 1960s reported by Khan *et al.* (2007a). The F_1 hybrids with high heterosis were also associated with higher inbreeding depression, so the moderate type of heterosis has some stability in advanced generations (Soomro, 2000). Keeping in view the importance of heterosis, the present study was undertaken, including an 8-parent complete diallel cross of *G. hirsutum* L. to signal out the best performing F_1 hybrids for further exploitation in future breeding program with the objectives to estimate heterosis over mid and better parents for various morpho-yield traits of upland cotton to evaluate the genetic potential and variability of F_1 hybrids and their parental lines for yield and its contributing traits.

MATERIALS AND METHODS

Breeding material comprised of eight different *G. hirsutum* genotypes having broad genetic base and varied by date of release, pedigree, seed cotton and fiber yield as well as fiber quality traits. The cultivars were SLH-284, CIM-446, CIM-473, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707 and were crossed in a complete diallel fashion during 2008 to generate 56 F_1 cross combinations.The experimental work comprised of 8 × 8 diallel hybrids and their parents to study the heterosis over mid and better parents, genetic variability and genetics potentialwas carried out during 2009 under the prevailing environmental conditions of The University of Agriculture Peshawar. Peshawar lies between 34°, 02′ North latitude and 71°, 37′ East longitude. The experiment was conducted in a randomized complete lock (RCB) design with three replications. Each sub-plot was having single row with 3.25 meter length. Thinning was performed twice after 15 and 25 days of germination when the plant height was 10 and 20 cm, respectively to ensure single plant per hill. All the recommended cultural practices and inputs including fertilizer, hoeing, irrigation and pest control were applied same for all the entries from sowing till the harvesting and the crop was grown under uniform conditions to minimize environmental variability to the maximum possible extent. Picking was made during the months of October and November, 2009 on single plant basis.Data were recorded on the following parameters viz., days to first flowering, monopodia per plant, bolls per sympodia, bolls pre plant, boll weight (g), seed cotton yield (g plant^{-1}).

The data recorded was subjected to analysis of variance (ANOVA) technique according to Steel and Torrie (1980) by using Mstatc computer software to test the null hypothesis of no differences between various F_1 populations and their parental line means.Least Significant Difference (LSD) test was used for means separation and comparison. Heterosis was calculated in terms of percent increase (+) or decrease (-) of the F_1 hybrids against its mid and better parent values as suggested by Fehr (1987).

$$Mid - Parent\ Heterosis = \frac{F_1 - MP}{MP} \times 100$$

$$Better - Parent\ Heterosis = \frac{F_1 - BP}{BP} \times 100$$

RESULTS AND DISCUSSION

Days to first flowering

Analysis of variance regarding days to first flowering showed highly significant differences among all the genotypes (Table 1). Breeders are interested in early maturing genotypes to accommodate the wheat sowing in time. The negative heterosis was observed in 50 and 52 F_1 hybrids over mid and better parents, respectively. However, the mid parent positive heterosis shown by six hybrids with the range of 0.30 to 12.64%, while over better parents four F_1 genotypes revealed positive heterosis for days to flowering ranged from 0.57 to 12.00%. The maximum mid parent heterosis of 12.64% and 7.21% was observed in hybrids CIM-506 × CIM-554 and CIM-499 × CIM-506, respectively, and the same former hybrid showed better parent heterosis (12.00%) by taking more days to first flowering (Table 2). These results are in accordance with those of Ye and Zhu (2006) and Natera*et al.* (2007).Days to flowering ranged from 57.00 to 71.67 days among the parental genotypes, while 51.33 to 65.33 in F_1cross combinations. The F_1 hybrid CIM-554 × CIM-473 demonstrated lowest days to flowering (51.33 days) and were also found statistically at par with one parent and 40 F_1 hybrids ranged from 52.00 to 57.00. While, the maximum days were taken by the cultivar SLH-284 (71.67 days) and were also at par with one parent and six F_1 hybrids ranged from 59.67 to 65.33 days (Table 2). All other genotypes have medium days to first flowering. Alishah*et al.* (2008) and Shakeel*et al.* (2008) also obtained similar results and indicated significant variability among different upland cotton genotypes for this particular trait.

Table 1. Mean squares, F vales and CV% for various parameters.

Parameters	Mean Squares	F Values	C.V (%)
Days to flowering	39.77	5.40**	4.83
Monopodia per plant	0.39	32.62**	12.94
Bolls per sympodia	1.15	11.65**	13.08
Bolls per plant	176.46	22.78**	10.80
Boll weight	0.17	1.80**	8.56
Seed cotton yield per plant	3652.93	17.23**	14.65

** = Highly significantat 1% levels of probability

Table 2. Mean performance,heterosis over mid parents(MPH) and better parents (BPH).

Genotypes	Days to flowering				Monopodia plant^{-1}			
	MEAN	F_1 hybrids	MPH (%)	HPH (%)	MEAN	F_1 hybrids	MPH (%)	HPH (%)
SLH-284 × CIM-446	62.67	62.67	-6.70	-12.56	1.42	1.42	98.32	25.07
SLH-284 × CIM-473	56.67	56.67	-11.91	-20.93	0.96	0.96	89.57	33.75
SLH-284 × CIM-496	56.67	56.67	-13.04	-20.93	0.50	0.50	4.60	-24.24
SLH-284 × CIM-499	54.33	54.33	-15.77	-24.19	0.49	0.49	-26.86	-52.95
SLH-284 × CIM-506	52.00	52.00	-20.00	-27.45	1.25	1.25	135.40	63.19
SLH-284 × CIM-554	55.67	55.67	-13.92	-22.32	0.84	0.84	146.24	118.28
SLH-284 × CIM-707	55.00	55.00	-14.95	-23.26	1.03	1.03	160.86	108.27
CIM-446 × SLH-284	54.33	54.33	-19.12	-24.19	0.66	0.66	-8.19	-42.10
CIM-446 × CIM-473	52.00	52.00	-13.09	-17.03	0.91	0.91	-1.46	-19.42
CIM-446 × CIM-496	55.33	55.33	-8.80	-11.71	1.07	1.07	19.35	-5.56
CIM-446 × CIM-499	57.00	57.00	-5.00	-9.05	0.67	0.67	-38.41	-41.13
CIM-446 × CIM-506	57.33	57.33	-5.24	-8.52	1.15	1.15	21.43	1.77
CIM-446 × CIM-554	57.33	57.33	-4.72	-8.52	1.00	1.00	31.93	-11.74
CIM-446 × CIM-707	56.67	56.67	-5.82	-9.57	0.80	0.80	-1.41	-29.13
CIM-473 × SLH-284	60.33	60.33	-6.23	-15.82	0.67	0.67	31.89	-6.94
CIM-473 × CIM-446	56.00	56.00	-6.41	-10.64	0.72	0.72	-22.29	-36.45
CIM-473 × CIM-496	56.00	56.00	-3.17	-4.55	0.39	0.39	-43.04	-45.42
CIM-473 × CIM-499	58.33	58.33	2.04	1.74	0.35	0.35	-60.52	-66.51
CIM-473 × CIM-506	57.00	57.00	-1.15	-2.28	0.93	0.93	25.57	21.80
CIM-473 × CIM-554	53.33	53.33	-6.99	-7.53	0.83	0.83	51.04	15.69
CIM-473 × CIM-707	53.33	53.33	-6.99	-7.53	0.73	0.73	20.56	1.81
CIM-496 × SLH-284	58.00	58.00	-11.00	-19.07	0.60	0.60	25.52	-9.09
CIM-496 × CIM-446	57.00	57.00	-6.05	-9.05	0.63	0.63	-30.17	-44.75
CIM-496 × CIM-473	52.67	52.67	-8.93	-10.23	0.45	0.45	-34.78	-37.50
CIM-496 × CIM-499	54.00	54.00	-6.90	-7.96	0.22	0.22	-73.66	-78.41
CIM-496 × CIM-506	55.33	55.33	-5.42	-5.69	0.31	0.31	-56.52	-59.53
CIM-496 × CIM-554	54.00	54.00	-7.17	-7.96	0.55	0.55	4.70	-17.27
CIM-496 × CIM-707	52.67	52.67	-9.46	-10.23	0.76	0.76	32.01	15.61
CIM-499 × SLH-284	53.00	53.00	-17.83	-26.05	1.03	1.03	55.46	0.00
CIM-499 × CIM-446	52.33	52.33	-12.78	-16.50	1.30	1.30	20.04	14.74
CIM-499 × CIM-473	54.00	54.00	-5.54	-5.81	0.82	0.82	-6.90	-21.01
CIM-499 × CIM-496	55.00	55.00	-5.17	-6.26	1.33	1.33	56.76	28.46
CIM-499 × CIM-506	62.00	62.00	7.21	6.29	0.84	0.84	-7.06	-19.07
CIM-499 × CIM-554	57.67	57.67	0.30	0.00	0.35	0.35	-50.14	-65.83

Table 2. Continuation of Table 2

CIM-499 × CIM-707	57.00	57.00	-0.87	-1.16	1.37	1.37	78.74	32.33
CIM-506 × SLH-284	61.00	61.00	-6.15	-14.89	1.35	1.35	154.80	76.63
CIM-506 × CIM-446	59.67	59.67	-1.37	-4.79	1.57	1.57	65.03	38.31
CIM-506 × CIM-473	58.00	58.00	0.58	-0.57	1.18	1.18	58.41	53.66
CIM-506 × CIM-496	57.33	57.33	-2.00	-2.28	0.33	0.33	-54.28	-57.44
CIM-506 × CIM-499	58.33	58.33	0.86	0.00	1.59	1.59	76.76	53.92
CIM-506 × CIM-554	65.33	65.33	12.64	12.00	1.39	1.39	141.95	81.46
CIM-506 × CIM-707	54.00	54.00	-6.90	-7.42	0.90	0.90	42.00	16.97
CIM-554 × SLH-284	52.00	52.00	-19.59	-27.45	0.78	0.78	128.57	102.61
CIM-554 × CIM-446	53.00	53.00	-11.92	-15.43	1.25	1.25	64.91	10.33
CIM-554 × CIM-473	51.33	51.33	-10.47	-10.99	0.39	0.39	-28.74	-45.42
CIM-554 × CIM-496	52.00	52.00	-10.61	-11.37	1.14	1.14	119.18	73.18
CIM-554 × CIM-499	52.67	52.67	-8.40	-8.67	0.76	0.76	7.34	-26.43
CIM-554 × CIM-506	52.33	52.33	-9.78	-10.29	0.54	0.54	-5.48	-29.11
CIM-554 × CIM-707	52.67	52.67	-8.67	-8.67	1.31	1.31	198.07	164.11
CIM-707 × SLH-284	55.00	55.00	-14.95	-23.26	0.69	0.69	75.00	39.72
CIM-707 × CIM-446	53.67	53.67	-10.80	-14.36	0.98	0.98	20.69	-13.24
CIM-707 × CIM-473	52.00	52.00	-9.30	-9.83	0.91	0.91	49.67	26.39
CIM-707 × CIM-496	52.67	52.67	-9.46	-10.23	1.39	1.39	140.48	110.61
CIM-707 × CIM-499	58.00	58.00	0.87	0.57	0.33	0.33	-56.44	-67.76
CIM-707 × CIM-506	53.00	53.00	-8.62	-9.14	1.40	1.40	121.87	82.77
CIM-707 × CIM-554	59.00	59.00	2.31	2.31	0.50	0.50	13.77	0.81
SLH-284	71.67				0.30			
CIM-446	62.67				1.13			
CIM-473	57.00				0.72			
CIM-496	58.67				0.67			
CIM-499	57.33				1.03			
CIM-506	58.33				0.77			
CIM-554	57.67				0.38			
CIM-707	57.67				0.49			
LSD (0.05)	5.79				0.06			

Monopodia per plant

Overall, 17 hybrids showed negative heterosis over mid parent heterosis. The most negative heterosis was noticed in the hybrids i.e. CIM-496 × CIM-499, CIM-473 × CIM-499 and CIM-473 × CIM-496 having values -73.66 & -78.41, -60.52 & -66.51, and -43.04% & -45.42%, over mid and better parents, respectively. The lowest mid parent positive heterotic performance (4.60%) was recorded in cross SLH-284× CIM-496 and highest value (198.06%) was recorded in cross CIM-554 × CIM-707 for monopodia per plant. The better parent heterosis was 0.81 (CIM-707 × CIM-554) to 164.11% (CIM-554 × CIM-707) (Table 2). In case of better parent, out of 56 hybrids 26 showed negative heterobeltiosis for this trait. The results are in accordance with the findings of Khan *et al.* (2000).Mean square data regarding monopodia per plant showed highly significant differences (Table 1). Monopodia per plant were 0.30 to 1.13 among the parentalcultivars, while 0.22 to 1.59 in F_1hybrids.The lowest monopodia per plant was observed in cross combination CIM-496 × CIM-499 (0.22) which was also found statistically at par with five parental cultivars and 14 hybrids with the range of 0.30 to 0.66 (Table 2). The maximum monopodia per plant were observed in hybrid CIM-506 × CIM-499 (1.59) which was also found statistically equal with 13 other F_1 genotypes ranged from 1.18 to 1.57 (Table 2). All other genotypes showed average value of monopodia per plant. Hussain*et al.* (2000) and Iqbal*et al.* (2006) also obtained similar results and indicated variability for monopodia per plant among different cotton cultivars.

Bolls per sympodia

Two-third F_1 hybrids showed positive mid parent heterosis, however for bolls per sympodia the lowest positive value of 0.56% was observed in CIM-707 × CIM-496 and the highest value was recorded in hybrid CIM-499 × CIM-473 (110.12%). In same series, three other hybrids viz; CIM-506 × CIM-554, CIM-473 × CIM-554 and CIM-446 × CIM-554 mentioned also reasonable heterosis ranged from 45.54 to 95.93%. In case of better parent heterosis half of the hybrids showed positive heterosis for the stated trait; however it ranged from 0.40% (SLH-284× CIM-707) to 101.37% (CIM-499 × CIM-473). The hybrids i.e. CIM-506 × CIM-554, CIM-506 × CIM-496 and CIM-496 × CIM-446 manifested also maximum better parent heterotic values i.e. 88.00, 40.03 and 39.10%, respectively (Table 3). Bolls per sympodia varied from 1.54 to 3.02 among the parental genotypes, while 1.52 to 4.48 in F_1 hybrids.The F_1 hybrid CIM-506 × CIM-554 manifested maximum bolls per sympodia (4.48), followed by 10 other cross combinations with the range of 3.02 to 3.67. The minimum bolls per sympodia were authenticated bytwo cross combinations CIM-499 × CIM-707 (1.52) and CIM-707 × CIM-506 (1.53) and were also found statistically at par with three parent cultivars and 21 F_1 hybrids having range of 1.54 to 2.19 (Table 3). All other genotypes showed average values for boll per sympodia. Khan *et al.* (2009a) obtained similar results and indicated greater variability among different genotypes for bolls per sympodia.

Bolls per plant

The 35 out 56 F_1 hybrids showed positive heterosis for said yield contributing trait, however, the mid parent heterosis values for bolls per plant was minimum for hybrid CIM-499×SLH-284 (0.06%) and maximum for hybrid CIM-473 × CIM-554 (101.10%). The three other hybrids CIM-499 × CIM-473 (73.51%), SLH-284 × CIM-554 (59.95%) and CIM-546 × CIM-499 (58.03%) also showed significant heterosis for said important trait. The 21 hybrids showed positive heterosis over better parents for bolls per plant and was ranged from 0.75% (CIM-446×SLH-284) to 77.00% (CIM-473 × CIM-554). It was followed by three other hybrids (CIM-707 × CIM-496, CIM-496 × SLH-284 and SLH-284 × CIM-554) which revealed also maximum heterosis ranged from 40.95 to 52.62% (Table 3). These results are in concurrence with those of Ye and Zhu (2006).Regardingthe mean performance, bolls per plant were varied from 11.75 to 34.71 among the parent cultivars, while 13.30 to 47.33 in F_1 cross combinations. The maximum bolls per plant were revealed by cross CIM-473 × CIM-554 (47.33) and were also found statistically at par with three cross combinations SLH-284 × CIM-554 (40.81), CIM-446 × CIM-496 (37.18) and CIM-446 × CIM-554 (36.73). The minimum bolls per plant were exhibited by parental genotype CIM-499 (11.75) and were also found statistically closely related with three parents and 22 F_1 genotypes (13.30 to 22.20)while remaining genotypes showed medium values for boll per plant (Table 3). Khan and Azhar (2000) and Elisddig*et al.* (2007) also reported similar results and indicated variability for boll per plant among different cotton cultivars.

Boll weight

Overall 53 hybrids showed positive mid parent heterosis. The mid parent heterosis was ranged from 0.11% (SLH-284× CIM-707) to 29.06% (CIM-554 × CIM-446). The top promising hybrid was followed by two other hybrids viz; CIM-473 × CIM-554 and CIM-554 × SLH-284 with maximum heterosis 25.87 and 26.10%, respectively. For better parent heterosis, 49 F_1 hybrids showed high positive values for this yield contributing trait and varied from 0.20% (CIM-446× CIM-473) to 18.28% (CIM-473 × CIM-554). The other three hybrids (CIM-496 × CIM-707, CIM-554 × CIM-446 and CIM-554 × SLH-284) also showed remarkable heterosis ranged from 17.11 to 17.70% (Table 4). Remaining hybrids exhibited negative heterosis in both categories. The results are in accordance with the findings of Soomro*et al.* (1996) and Campbell *et al.* (2008). Boll weight was ranged from 2.89 to 3.53 g among the parental cultivars, while 3.21 to 4.14 g in F_1 hybrids.The maximum boll weight was recorded in F_1hybrid CIM-554 × CIM-446 (4.14 g) which was also found statistically at par with four other hybrids ranged from 3.94 to 4.12 g. In F_1hybrids, 37 other genotypes ranged from 3.49 to 3.91 g were also found equal with above four promising genotypes. The lowest boll weight was observed in parental genotype CIM-554 (2.89 g) which was also found statistically at par with 29 other genotypes ranged from 3.21 to 3.53 (Table 4). The remaining genotypes showed average boll weight. Soomro*et al.* (2008) also observed the same results about genetic variability among the different upland cotton genotypes for boll weight.

Seed cotton yield plant^{-1}

The maximum number of 39 F_1 hybrids showed positive mid parent heterosis for yield and ranged from 2.87 (CIM-473× CIM-506) to 156.16% (CIM-506 × CIM-554). The three other F_1 hybrids CIM-473 × CIM-554 (117.79%), CIM-707 × CIM-496 (86.95%) and CIM-496 × SLH-284 (76.11%) also showed significant heterosis for said important trait.More than half of the hybrids were superior to the best parent utilized in the crosses. Minimum heterobeltiosis for seed cotton yieldper plant was recorded minimum for the hybrid CIM-499 × CIM-554(0.06%) and was maximum in the cross CIM-506 × CIM-554 (135.11%). The said promising F_1 hybrid was followed by three other hybrids (CIM-496 × SLH-284, CIM-707 × CIM-496 and CIM-473 × CIM-554) with the values ranged from 62.68 to 97.69% (Table 4). These findings are in the agreement with those ofKhan *et al.* (2000), Soomro (2000) and Campbell *et al.* (2008). Mean square data regarding monopodia per plant demonstrated highly significant differences (Table 1). Seed cotton yield per plant ranged from 40.48 to 117.50

Table 3. Mean performance,heterosis over mid parents(MPH) and better parents (BPH).

Genotypes	Boll sympodia^{-1}				Bolls plant^{-1}			
	MEAN	F_1 hybrids	MPH (%)	HPH (%)	MEAN	F_1 hybrids	MPH (%)	HPH (%)
SLH-284 × CIM-446	3.02	3.02	20.15	18.57	36.16	36.16	22.58	4.18
SLH-284 × CIM-473	2.73	2.73	31.11	9.96	33.89	33.89	51.90	39.52
SLH-284 × CIM-496	2.62	2.62	8.32	5.77	32.41	32.41	44.46	33.43
SLH-284 × CIM-499	1.86	1.86	-7.61	-25.12	16.67	16.67	-7.49	-31.37
SLH-284 × CIM-506	3.67	3.67	51.06	48.10	27.88	27.88	1.64	-8.80
SLH-284 × CIM-554	3.02	3.02	29.21	21.65	40.81	40.81	59.95	52.62
SLH-284 × CIM-707	2.49	2.49	4.69	0.40	26.39	26.39	15.72	8.65
CIM-446 × SLH-284	3.00	3.00	19.36	17.79	34.97	34.97	18.54	0.75
CIM-446 × CIM-473	2.62	2.62	24.11	2.98	29.65	29.65	7.74	-14.58
CIM-446 × CIM-496	3.50	3.50	42.69	37.53	37.18	37.18	34.49	7.12
CIM-446 × CIM-499	2.17	2.17	6.34	-14.68	20.27	20.27	-12.74	-41.60
CIM-446 × CIM-506	2.62	2.62	6.29	2.87	28.64	28.64	-12.25	-17.49
CIM-446 × CIM-554	3.45	3.45	45.54	35.34	36.73	36.73	19.54	5.82
CIM-446 × CIM-707	2.91	2.91	20.77	14.37	30.53	30.53	8.98	-12.04
CIM-473 × SLH-284	2.37	2.37	13.94	-4.44	30.87	30.87	38.37	27.09
CIM-473 × CIM-446	2.27	2.27	7.26	-10.99	22.20	22.20	-19.33	-36.04
CIM-473 × CIM-496	2.28	2.28	12.94	-3.39	27.18	27.18	32.88	32.07
CIM-473 × CIM-499	1.76	1.76	9.13	4.58	16.45	16.45	2.56	-19.09
CIM-473 × CIM-506	1.97	1.97	-3.03	-17.33	25.59	25.59	0.55	-16.29
CIM-473 × CIM-554	2.84	2.84	46.93	29.82	47.33	47.33	101.10	77.00
CIM-473 × CIM-707	1.91	1.91	-3.61	-16.25	16.67	16.67	-19.95	-21.81
CIM-496 × SLH-284	3.01	3.01	24.30	21.37	34.96	34.96	55.83	43.93
CIM-496 × CIM-446	3.54	3.54	44.32	39.10	32.00	32.00	15.75	-7.81
CIM-496 × CIM-473	1.91	1.91	-5.66	-19.30	18.71	18.71	-8.53	-9.09
CIM-496 × CIM-499	2.01	2.01	2.84	-15.07	14.88	14.88	-7.95	-27.70
CIM-496 × CIM-506	2.12	2.12	-10.66	-11.04	18.75	18.75	-26.69	-38.67
CIM-496 × CIM-554	2.35	2.35	3.23	-0.55	24.43	24.43	3.25	-8.64
CIM-496 × CIM-707	1.92	1.92	-17.11	-18.62	15.76	15.76	-24.77	-26.08
CIM-499 × SLH-284	1.95	1.95	-2.84	-21.25	18.03	18.03	0.06	-25.77
CIM-499 × CIM-446	2.21	2.21	8.15	-13.23	21.91	21.91	-5.68	-36.88
CIM-499 × CIM-473	3.38	3.38	110.12	101.37	27.67	27.67	72.51	36.10
CIM-499 × CIM-496	2.50	2.50	27.95	5.67	27.30	27.30	46.26	6.72
CIM-499 × CIM-506	1.64	1.64	-16.54	-31.31	24.91	24.91	17.72	-18.51
CIM-499 × CIM-554	2.07	2.07	10.83	-5.62	24.75	24.75	28.60	-7.44
CIM-499 × CIM-707	1.52	1.52	-20.36	-33.25	14.39	14.39	-12.97	-32.50
CIM-506 × SLH-284	3.29	3.29	35.43	32.78	34.39	34.39	25.37	12.50
CIM-506 × CIM-446	2.85	2.85	15.50	11.78	33.16	33.16	1.59	8.47
CIM-506 × CIM-473	1.96	1.96	-3.67	-17.88	20.31	20.31	-20.20	-33.56
CIM-506 × CIM-496	3.34	3.34	40.62	40.03	28.35	28.35	10.85	-7.26
CIM-506 × CIM-499	2.44	2.44	24.24	2.27	33.44	33.44	58.03	9.39
CIM-506 × CIM-554	4.48	4.48	95.93	88.00	36.01	36.01	25.67	17.80
CIM-506 × CIM-707	1.69	1.69	-27.60	-29.21	16.61	16.61	-35.98	-45.67
CIM-554 × SLH-284	2.53	2.53	8.48	2.14	21.60	21.60	-15.34	-19.22
CIM-554 × CIM-446	2.74	2.74	15.81	7.70	32.02	32.02	4.21	-7.75
CIM-554 × CIM-473	2.11	2.11	8.89	-3.79	25.52	25.52	8.43	-4.56
CIM-554 × CIM-496	1.69	1.69	-25.90	-28.61	19.63	19.63	-17.03	-26.59
CIM-554 × CIM-499	2.20	2.20	18.12	0.59	23.79	23.79	23.62	-11.03
CIM-554 × CIM-506	1.94	1.94	-15.15	-18.59	28.52	28.52	-0.47	-6.71
CIM-554 × CIM-707	2.37	2.37	5.98	3.95	33.59	33.59	15.71	7.25
CIM-707 × SLH-284	1.72	1.72	-27.81	-30.77	16.08	16.08	-29.49	-33.80
CIM-707 × CIM-446	2.63	2.63	9.16	3.38	13.30	13.30	-52.53	-61.68
CIM-707 × CIM-473	1.55	1.55	-21.81	-32.06	16.98	16.98	-18.46	-20.36
CIM-707 × CIM-496	2.33	2.33	0.56	-1.27	30.05	30.05	43.44	40.95

Table 3. Continuation of Table 3

CIM-707 × CIM-499	1.71	1.71	-10.24	-24.77	18.90	18.90	14.30	-11.35
CIM-707 × CIM-506	1.53	1.53	-34.46	-35.92	21.63	21.63	-16.63	-29.24
CIM-707 × CIM-554	1.86	1.86	-16.86	-18.45	17.73	17.73	-26.22	-33.69
SLH-284	2.48				24.29			
CIM-446	2.55				34.71			
CIM-473	1.68				20.33			
CIM-496	2.36				20.58			
CIM-499	1.54				11.75			
CIM-506	2.38				30.57			
CIM-554	2.19				26.74			
CIM-707	2.28				21.32			
LSD (0.05)	0.67				1.607			

Table 4. Mean performance,heterosis over mid parents(MPH) and better parents (BPH).

Genotypes	Boll weight (g)				Seed cotton yield plant^{-1} (g)			
	MEAN	F_1 hybrids	MPH (%)	HPH (%)	MEAN	F_1 hybrids	MPH (%)	HPH (%)
SLH-284 × CIM-446	3.69	3.69	6.87	9.50	125.40	125.40	25.02	6.72
SLH-284 × CIM-473	3.91	3.91	17.59	16.13	129.10	129.10	68.14	55.34
SLH-284 × CIM-496	3.47	3.47	4.78	3.12	115.30	115.30	50.19	38.73
SLH-284 × CIM-499	3.74	3.74	11.55	10.99	59.46	59.46	-3.78	-28.46
SLH-284 × CIM-506	3.79	3.79	14.21	12.56	133.20	133.20	42.83	28.82
SLH-284 × CIM-554	3.56	3.56	13.94	5.82	139.70	139.70	64.83	61.69
SLH-284 × CIM-707	3.30	3.30	0.11	-2.08	93.37	93.37	22.88	12.35
CIM-446 × SLH-284	3.84	3.84	11.30	14.05	136.80	136.80	36.38	16.43
CIM-446 × CIM-473	3.54	3.54	3.87	0.20	112.90	112.90	20.14	-3.91
CIM-446 × CIM-496	3.72	3.72	9.44	5.21	155.70	155.70	65.70	32.51
CIM-446 × CIM-499	4.12	4.12	20.01	16.61	75.48	75.48	-4.44	-35.76
CIM-446 × CIM-506	3.74	3.74	9.95	5.86	107.80	107.80	-2.40	-8.26
CIM-446 × CIM-554	3.96	3.96	23.46	12.17	153.60	153.60	50.66	30.72
CIM-446 × CIM-707	3.47	3.47	2.86	-1.70	112.80	112.80	21.06	-4.00
CIM-473 × SLH-284	3.64	3.64	9.47	8.11	114.30	114.30	48.87	37.53
CIM-473 × CIM-446	3.67	3.67	7.78	3.96	83.04	83.04	-11.64	-29.33
CIM-473 × CIM-496	3.73	3.73	14.11	13.71	108.50	108.50	54.03	54.01
CIM-473 × CIM-499	3.22	3.22	-2.66	-3.39	55.08	55.08	-0.69	-21.82
CIM-473 × CIM-506	3.38	3.38	3.25	3.05	89.42	89.42	2.87	-13.52
CIM-473 × CIM-554	3.88	3.88	25.87	18.28	170.80	170.80	117.79	97.69
CIM-473 × CIM-707	3.51	3.51	7.95	6.91	62.53	62.53	-10.23	-11.24
CIM-496 × SLH-284	3.75	3.75	13.26	11.46	135.20	135.20	76.11	62.68
CIM-496 × CIM-446	3.96	3.96	16.59	12.09	133.10	133.10	41.65	13.28
CIM-496 × CIM-473	3.66	3.66	11.97	11.57	69.10	69.10	-1.90	-1.92
CIM-496 × CIM-499	3.58	3.58	8.60	7.41	55.17	55.17	-0.51	-21.67
CIM-496 × CIM-506	3.55	3.55	8.73	8.56	68.36	68.36	-21.35	-33.89
CIM-496 × CIM-554	3.61	3.61	17.46	10.74	94.42	94.42	20.41	9.28
CIM-496 × CIM-707	3.84	3.84	18.43	17.70	65.44	65.44	-6.04	-7.09
CIM-499 × SLH-284	3.58	3.58	6.78	6.24	69.53	69.53	12.52	-16.34
CIM-499 × CIM-446	3.53	3.53	2.74	-0.17	63.43	63.43	-19.70	-46.02
CIM-499 × CIM-473	3.21	3.21	-2.87	-3.60	90.12	90.12	62.48	27.92
CIM-499 × CIM-496	3.50	3.50	6.17	5.01	69.52	69.52	25.36	-1.29
CIM-499 × CIM-506	3.51	3.51	6.32	5.31	85.31	85.31	18.58	-17.50
CIM-499 × CIM-554	3.83	3.83	23.15	14.91	86.45	86.45	36.27	0.06
CIM-499 × CIM-707	3.26	3.26	-0.50	-2.19	42.11	42.11	-22.97	-38.85

Table 4. Continuation of Table 4

CIM-506 × SLH-284	3.55	3.55	6.98	5.44	136.30	136.30	46.16	31.82
CIM-506 × CIM-446	3.69	3.69	8.57	4.53	136.40	136.40	23.49	16.09
CIM-506 × CIM-473	3.36	3.36	2.55	2.35	66.59	66.59	-23.39	-35.60
CIM-506 × CIM-496	3.48	3.48	6.68	6.51	101.10	101.10	16.32	-2.22
CIM-506 × CIM-499	3.37	3.37	2.17	1.20	103.70	103.70	44.15	0.29
CIM-506 × CIM-554	3.62	3.62	17.49	10.61	243.10	243.10	156.16	135.11
CIM-506 × CIM-707	3.30	3.30	1.79	1.01	70.17	70.17	-18.53	-32.14
CIM-554 × SLH-284	3.94	3.94	26.10	17.11	96.95	96.95	14.39	12.21
CIM-554 × CIM-446	4.14	4.14	29.07	17.27	139.10	139.10	36.44	18.38
CIM-554 × CIM-473	3.61	3.61	17.12	10.05	104.10	104.10	32.74	20.49
CIM-554 × CIM-496	3.74	3.74	21.59	14.63	76.36	76.36	-2.62	-11.62
CIM-554 × CIM-499	3.53	3.53	13.50	5.91	97.50	97.50	53.69	12.85
CIM-554 × CIM-506	3.70	3.70	20.29	13.24	113.00	113.00	19.07	9.28
CIM-554 × CIM-707	3.47	3.47	13.74	7.86	112.20	112.20	44.53	29.86
CIM-707 × SLH-284	3.43	3.43	4.14	1.87	63.83	63.83	-16.00	-23.20
CIM-707 × CIM-446	3.49	3.49	3.45	-1.13	99.67	99.67	6.97	-15.17
CIM-707 × CIM-473	3.52	3.52	8.17	7.13	109.60	109.60	57.35	55.57
CIM-707 × CIM-496	3.41	3.41	5.15	4.51	130.20	130.20	86.95	84.86
CIM-707 × CIM-499	3.69	3.69	12.53	10.62	63.55	63.55	16.24	-7.71
CIM-707 × CIM-506	3.35	3.35	3.14	2.35	64.09	64.09	-25.59	-38.02
CIM-707 × CIM-554	3.67	3.67	20.19	13.98	102.00	102.00	31.39	18.06
SLH-284	3.37				83.11			
CIM-446	3.53				117.50			
CIM-473	3.28				70.45			
CIM-496	3.26				70.43			
CIM-499	3.33				40.48			
CIM-506	3.27				103.4			
CIM-554	2.89				86.40			
CIM-707	3.22				68.86			
LSD (0.05)	0.65				31.09			

g among the parental cultivars, while 42.11 to 243.10 g in F_1 hybrids.The F_1 hybrid CIM-506 × CIM-554 showed maximum seed cotton yield (243.1 g). It was statistically at par with three other F_1 cross combination i.e. CIM-446 × CIM-554 (153.60 g), CIM-446 × CIM-496 (155.70 g) and CIM-473 × CIM-554 (170.80 g). The lowest seed cotton yield was noted in parent cultivar CIM-499 (40.48 g) and F_1hybrid CIM-499 × CIM-707 (42.22 g) and was found statistically close with three parent cultivars and 14 F_1 genotypes with range of 55.08 to 70.45 g (Table 4). The other genotypes showed medium values for seed cotton yieldper plant.Khan *et al.* (1991) and Ali *et al.* (1998) studies revealed greater variability for this trait among different upland cotton genotypes.

REFERENCES

Ali B., I.A. Khan and K. Aziz, (1998). Study pertaining to the estimation of variability, heritability and genetic advance in upland cotton. Pak. J. Biol. Sci. 1(4): 307-308.

Alishah O., M.B.B. Najjar and L. Fahmideh, (2008). Correlation, path coefficient analysis of some quantitative and agronomic traits in cotton (*G. hirsutum*). Asian. J. Biol. Sci. 1(2): 61-68.

Campbell B.T., D.T. Bowman and D.B.Weaver, (2008). Heterotic effects in top crosses of modern and obsolete cotton cultivars. Crop Sci. 48(2): 593-600.

Elsiddig A.A., M.M.S. Ahmed and A.E. Ibrahim, (2007). Variability, heritability and association of some characters in upland cotton (*G. hirsutum* L.). Univ. of Khartoum J. Agril. Sci. Sudan. 15(2): 191-203.

Fehr W.R., (1987). Principles of cultivar development. Theory and technique.Macmillan Pub. Comp. Inc., New York. 115-119.

Hussain S.S., F.M. Azhar and I. Mahmood,(2000). Path coefficient and correlation analysis of some important plant traits of *G. hirsutum* L. Pak. J. Biol. Sci. 3(9): 1399-1400.

Iqbal M., K. Hayat, R.S.A. Khan, A. Sadiq and N. Islam, (2006). Correlation and path coefficient analysis for earliness and yield traits in cotton (*G. hirsutum* L.). Asian J. Plant Sci. 5(2): 341-344.

Khan A.I. and F.M. Azhar, (2000). Estimates of heritabilities and pattern of association among different characters of *G. hirsutum* L. Pak. J. Agric. Sa. 37(1-2): 7-10.

Khan M.A., M. Hussain, M.A. Khan and R.A. Kainth, (1991). Estimation on heritable variation in four crosses of upland cotton (*G. hirsutum* L.). J. Agric Res. 29(3): 305-310.

Khan N.U., G. Hassan, K.B. Marwat, Farhatullah, S. Batool, K. Makhdoom, I. Khan, I.A. Khan and W. Ahmad, (2009a). Genetic variability and heritability in upland cotton. Pak. J. Bot. 41(4): 1695-1705.

Khan N.U., G. Hassan, M.B. Kumbhar, S. Kang, I. Khan, A.Parveen, U. Aiman, (2007a). Heterosis and inbreeding depression and mean performance in segregating generations in upland cotton. Eur. J. Sci. Res. 17: 531-546.

Khan N.U., H.K. Abro, M.B. Kumbhar, G. Hassan and M. Khan, (1999). Exploitation of heterosis can combat cotton leaf curl virus (CLCuV) incidence in cotton (*G. hirsutum*). The Pak. Cottons 43: 21-33.

Natera J.R.M., A. Rondon, J. Hernandez and J.F.M. Pinto, (2007). Genetic studies in upland cotton (*G. hirsutum* l.) and heterotic effects. Pak. J. Bot., 39(2): 385-395.

Shakeel A., F.M. Azharand I.A. Khan, (2008). Variability in cotton (*G. hirsutum*) genotypes for earliness. J. Agric. Res. 46(3): 215-222.

SoomroA.R., (2000). Assessment of useful heterosis in glandless *G. hirsutum* cotton strains through their performance in hybrid combination. Pak. J. Bot. 32: 65-68.

Soomro A.R., M.H. Chann, A.A. Chann, G.H. Kalwar., G.N.Dayo and A.H. Memon, (1996). Study of heterosis in intra- specific crosses of upland cotton. The Pak. Cotton 43(3, 4): 41-46.

Soomro Z.A., A.S. Larik, N.U. Khan, M.J. Baloch, S. Mari, S. Memon and N.A. Panwar, (2008). Genetic variability studies on quantitative traits in upland cotton. Sarhad J. Agric. 24(24): 587-591.

Steel R.G.D and J.H. Torrie, (1980). Principles and procedures of statistics, a biological approach, 2nd edition. McGraw Hill, Inc. New York, Toronto, London.

Ye Z.H and J. Zhu, (2006).Heterosis study on developmental behavior of flowering and boll setting in upland cotton. Agric. Sci. in China 5(1): 23-32.