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Original Research Article

HETEROTIC POTENTIAL OF UPLAND COTTON HYBRIDS FOR EARLINESS AND YIELD RELATED ATTRIBUTES

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Abstract: *Cotton is a long-duration crop affecting the timely sowing of wheat in Pakistan. Information on various earliness and yield related traits are pre-requisites to develop early maturing and high-yielding cotton cultivars. Therefore, the present research was conducted to determine the heterotic potential for six earliness and six yield related parameters. For this purpose, 10 F_1 hybrids were developed by crossing between nine upland cotton cultivars. These hybrids and their parental lines were sown in the field conditions of Faisalabad, Pakistan. All the hybrids showed significant differences in observed traits. The maximum recorded heterosis values for earliness index and seed cotton yield were 66.05% and 70.39%, respectively. Hybrid VH-289 × AGC-501 showed maximum significant heterosis (66.05%), heterobeltiosis (50.43%) and standard heterosis (32.52%) for earliness index was due to the negative heterosis in days to flowering, days to first boll opening, node number for first fruiting branch and height of first fruiting branch. Hybrid ARK-3 × AGC-501 showed maximum significant heterosis (70.39%), heterobeltiosis (28.52%) and standard heterosis (72.01%) for seed cotton yield were due to the positive heterosis showed by its yield contributing traits. This study can be used for a breeding program to develop early maturing and high-yielding varieties.*

Keywords: Earliness, heterosis, heterobeltiosis and hybrids

Introduction

Cotton is the most important crop for the global production of textile fibres. It is frequently considered Pakistan's key economic pillar (Ali *et al*., 2019). Farmers are interested in high-yielding genotypes, whereas the textile sector wants cotton with a high fibre content (Kouser *et al*., 2019; Wei *et al*., 2020). Last year, Pakistan produced 8.329 million bales. Cotton represents 0.6% of Pakistan's gross domestic product and 2.4% of agricultural value added. Compared to the previous year, cotton acreage decreased by up to 6.8%, while production increased by 17.9% (Khalid *et al*., 2022). Early maturing cultivars are the principal target of numerous breeding initiatives in Pakistan because they require less irrigation, fertilizer, and other inputs (Abbas *et al*., 2016; Mandumbu *et al*., 2020; Yang *et al*., 2019). Early maturing cotton cultivars must be developed to increase wheat grain yield and make planting wheat at the ideal time easier for farmers. Growers of cotton use the term "earliness" to describe their desire to harvest their crop as quickly as possible so that it can develop and be harvested during more favorable weather conditions. In some regions, crops must mature rapidly to avoid frost damage (Puspito *et al*., 2015; Solongi *et al*., 2019; Udaya *et al*., 2020; Zafar *et al*., 2022).

Upland cotton that appears to mature quickly is based on the reduced number of nodes on the first fruiting branch, the earliest flowering period, and the boll opening 120–150 days after planting (Ramdan, 2021; Udaya *et al*., 2020). Removing a single node from the initial fruiting branch can increase cotton development by four to seven days (Rehman *et al*., 2020). Days to flower is a readily apparent indicator that can identify cultivars that mature earlier (Soomro *et al*., 2021). By accumulating all of the above traits in descending order, the earliness index accounts for significant heterotic potential, which is vital for the crop's early development (Rani *et al*., 2020). To analyze heterosis performance for the development of early maturing cotton hybrids, plant breeders must understand several earliness characteristics, including days to flowering, days to first flower bud opening, days to bolls maturity period, number of nodes on the first fruiting branch, and earliness index (Chaudhary *et al*., 2019). Due to the cotton crop's limited genetic diversity, it is essential to develop novel hybrids with superior heterosis performance. Numerous crops exhibit heterosis, which is the difference in mean value between a hybrid and its parents (Ali *et al*., 2013ab; Ali *et al*., 2016; Yehia & El-Hashash, 2019). Previous research indicates that heterosis and

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heterobeltiosis are highly expressed in cotton genotypes for several traits, including plant height, the number of sympodial branches per plant, the number of bolls per plant, the weight of each boll, the amount of seed cotton produced, the percentage of lint, and the seed index (Abro *et al*., 2021; Bankar *et al*., 2020). The three methods for calculating heterosis potential are heterosis over the mid parent, the better parent, and the best parent. Earliness-related characteristics impact crop early maturation, and cotton heterosis over the superior or ideal parent is assessed (Rana *et al*., 2021). Utilizing hybrid vigor in industrial cotton production is a popular subject. Pakistan can reap the benefits of cotton heterosis by developing early maturing cultivars and increasing production per acre (Ali *et al*., 2019; Chaudhary *et al*., 2019; Khalid and Amjad, 2018; Khalid and Amjad 2019; Malik and Rasheed 2022; Rana *et al*., 2021). Keeping heterosis in mind, the purpose of the present study is to evaluate the heterosis performance of various yield and earliness-related traits. This research will aid in selecting an early maturing and high-yield hybrid.

Materials and Methods

Collection of germplasm, crossing and sowing in the field

The present genetic studies were carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The hybrids were developed by crossing parental lines namely, FH-312, ARK-3, CIM-600, VH-289, CYTO-178 as female with LALAZAR, MNH-988, KZ-189, AGC-501 as male. Then the parental lines of upland cotton were sown in a glasshouse in October 2018 in pots to produce hybrid seed. Selective crosses were made at the time of flowering. All preventive measures were followed during the crossing to avoid any genetic contamination. It takes numerous pollinations to produce enough hybrid seeds. In May 2019, the hybrids and their parents were planted in a field during the normal growing season. The experiment was constructed using a randomized complete block design with two replications. There were 10 plants per row. The distance between rows and plants was maintained at 75 cm and 30 cm, respectively. For each genotype, standardized and uniform cultural practices were implemented.

Experimental material

Experimental material was comprised of the parental lines and their selective hybrids, which are FH-312 × AGC-501, ARK-3 × MNH-988, ARK-3 × KZ-189, ARK-3 × AGC-501, CIM-600 × KZ-189, VH-289 × LALAZAR, VH-289 × MNH-988, VH-289 × AGC-501, CYTO-178 × MNH-988 and CYTO-178 × AGC-501. For the recording of data, five guarded plants were taken as samples for each genotype in all replications for recording data, and the data were recorded for earliness-related traits and yield attributes viz., days to flowering (DAF), days to first boll opening (DFBO), boll maturity period (BMP), node no. for first fruiting branch (NFFB), the height of first fruiting branch (HFFB), earliness index (EI), no. of bolls per plant (NBP), boll weight (BW), seed cotton yield (SCY), ginning out turn (GOT), seed index (SI) and lint index (LI) in upland cotton.

Statistical analysis

The data collected from the field were subjected to determine the significant differences among the genotypes by analysis of variance as outlined by (Steel, 1997). The heterotic potential was estimated as a percent increase or decrease exhibited by each hybrid over mid-parent (MP), better parent (BP) and standard check (SC). The formulas for estimation of heterosis were given by (Fonseca & Patterson, 1968), which are $(F_1\text{-MP/MP}) \times 100$ for heterosis, $(F_1\text{-BP/BP}) \times 100$ for heterobeltiosis and $(F_1\text{-SC/SC}) \times 100$ for standard heterosis. The estimated heterosis in percentage was further tested for significance by t-test. The formulas are $(F_1\text{- MP}) / (3/2r\ \text{EMS})^{0.5}$ for heterosis, $(F_1\text{- MP}) / (2/r\ \text{EMS})^{0.5}$ for heterobeltiosis, and $(F_1\text{- MP}) / (2/r\ \text{EMS})^{0.5}$ for standard heterosis was used for calculation of t-value. Where,

F_1 = the mean of F_1 cross

MP = mid parental value

EMS = the error mean square

Results and discussion

Significance of genotypes and mean values of the traits

It has been proved that the heterotic potential is the most important tool in genetics for boosting the yield of crops whether it is self or cross pollinated and is considered important crop improvement (Abro *et al*., 2021; Bankar *et al*., 2020). The main priority for heterosis breeding is the significant increase in yield with EI. Therefore, MP (Heterosis), BP (Heterobeltiosis) and SC (Standard heterosis) were calculated through percent increase (+) or decrease (-) exhibited by hybrids over MP, BP and check variety, respectively. T-test were used to signify the heterotic potential. The analysis of variance showed highly significant genotypic differences for all the characters except for DAF and SCY (Table 1, 2). DAF and SCY showed significant differences among genotypes at 5% (Table 1 and 2). Significant mean sum of squares for all the genotypes indicated that the present study could appropriate to be done as there was considerable amount of variability in experimental material. For DAF, the maximum mean value (63.40 days) was given by ARK-3 × AGC-501 and minimum mean value (54.30 days) was given by VH-289 × MNH-988 in hybrids. Parents ranged from 63.30 days (LALAZAR) to 55.40 days (CYTO-178). Among hybrids, the maximum mean value for DFBO was given by CYTO-178 × AGC-501 (102.60 days), and the minimum mean value was given by VH-289 × MNH-988 (91.30 days), as presented in table 3.

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LALAZAR showed a maximum mean value (101.80 days) and AGC-501 showed a minimum mean value (90.60 days) for the character among parents. The maximum BMP among hybrids was given by CYTO-178 × AGC-501 (41.50 days) and the minimum value was given by VH-289 × MNH-988 (34 days). Parents ranged of 38 days (LALAZAR) to 31.50 days (CIM-600). For NFFB, cross ARK-3 × KZ-189 (13.55) showed the highest mean value, while cross VH-289 × LALAZAR (8.11) revealed the lowest mean value. LALAZAR showed a maximum mean value of (12.05), and CIM-600 showed a minimum mean value (8.35) among parents. For average HFFB, the range of mean values was observed to be highest in ARK-3 × KZ-189 (43.70 cm) and lowest in VH-289 × MNH-988 (27.60 cm) among hybrids. ARK-3 showed the highest mean value (35.45 cm), and MNH-988 showed the lowest mean value (30 cm) among parents. CIM-600 exhibited maximum EI among parents (94.35%) and the minimum value by VH-289 (44.12%). The cross VH-289 × MNH-988 showed maximum EI (85.49%), and ARK-3 × MNH-988 showed minimum value (57.63%). For NBP, the maximum mean value (39.83) was given by ARK-3 × MNH-988, and CIM-600 × KZ-189 gave the minimum mean value (10.56) among hybrids. MNH-988 showed a maximum mean value of (38.40), and CYTO-178 showed a minimum mean value (16.57) among parents. The highest average value (3.14g) was shown by VH-289 × MNH-988, and CIM-600 × KZ-189 showed the lowest mean value (2.23g) for BW among hybrids. Among parents, the maximum BW was given by LALAZAR (3.27g), and the minimum was given by ARK-3 (1.80g). Among hybrids, the highest SCY (95.74g) was given by ARK-3 × MNH-988, while the lowest mean value (24.40 g) was exhibited by CYTO-178 × AGC-501. FH-312 showed the highest average value (106.07g), and AGC-501 showed the lowest one (34.12g) among parents. The maximum mean value for GOT (43.57%) was exhibited by CIM-600 × KZ-189 and the minimum mean value by ARK-3 × KZ-189 (33.26%) among crosses. Among parents, CYTO-178 showed a maximum mean value (40.10%), and VH-289 showed a minimum value (30.52%) for GOT. Among hybrids, SI ranged from 8.20g (VH-289 × MNH-988) to 4.75g (CIM-600 × KZ-189). For parents, it ranged from 8.55g (LALAZAR) to 5.50g (CYTO-178). Among hybrids, the mean value of LI varied from 7.04g (CIM-600 × KZ-189) to 3.27g (VH-289 × LALAZAR). LALAZAR showed a maximum mean value (4.92g), and VH-289 showed a minimum mean value (2.74g) among parents. The mean values of the characters are given in table 3.

Heterosis performance

For DAF, the estimates of MP, BP and SC are shown in table 4. The MP ranged from -9.38% (VH-289 × MNH-988) to 7.50% (ARK-3 × AGC-501). Hybrid VH-289 × MNH-988 showed the highest negative MP (-9.38%), BP (-12.08%) and SC (-12.63%) for DAF (Table 4). The results are according to Abro *et al*. (2021), Rani *et al*. (2020), Solongi *et al*. (2019) and Udaya *et al*. (2020). Two hybrids VH-289 × LALAZAR and VH-289 × MNH-988 showed negative MP (-6.65% and -3.78%), BP (-9.03% and -5.48%) and SC (-9.03% and -10.31%) for DFBO. For BMP, MP ranged from -9.57% (VH-289 × MNH-988) to 24.06% (CYTO-178 × AGC-501). FH-312 × AGC-501, ARK-3 × MNH-988 and CYTO-178 × AGC-501 showed significant SH. The results are similar to the findings of Elhousary (2022) and Usharani *et al*. (2014). For NFFB, ARK-3 × MNH-988 and VH-289 × MNH-988 showed significant positive MP. ARK-3 × KZ-189 and CYTO-178 × AGC-501 indicated highly significant MP, BP and SC for FFBN. For HFFB, MP ranged from -11.28% (VH-289 × LALAZAR) to 28.78% (ARK-3 × AGC-501). The results for HFFB are according to Basbag *et al*. (2007). The hybrids ranged in EI for heterotic potential from -26.78% (ARK-3 × MNH-988) to 66.06% (VH-289 × AGC-501). VH-289 × LALAZAR and VH-289 × AGC-501 gave highly significant positive MP (43.44% and 66.05%), BP (23% and 50.43%) and SC (23% and 32.51%). VH-289 × MNH-988 showed highly significant positive MP and SC. CYTO-178 × MNH-988 and CYTO-178 × AGC-501 indicated highly significant SC (31.62%) (Table 5). The results for EI were the most important among other characters' performance for early maturing of the crop and are similar to the recorded results of Lanjewar *et al*. (2017) and Soomro *et al*. (2021). For NBP, there were two hybrids, ARK-3 × MNH-988 and ARK-3 × AGC-501, which showed positive and highly significant BP. The heterosis ranged from -3.374% (CIM-600 × KZ-189) to 43.535% (VH-289 × MNH-988) for BW.

The heterotic potential over MP and BP concluded that six hybrids were significant for BW. All the hybrids were recorded for negative heterosis over SC (Table 5). The BW results are closely associated with Mudhalvan *et al*. (2021) and Richika *et al*. (2021). The data for SCY has quite an important in relation to earliness-related traits, and the results resemble those to Anjum *et al*. (2018), Khokhar *et al*. (2018) and Salem *et al*. (2020). The recorded data varies from -53.24% (CIM-600 × KZ-189) to 70.39% (ARK-3 × AGC-501) for heterosis. ARK-3 × MNH-988 and ARK-3 × AGC-501 showed significant positive MP, BP and SC for SCY (Table 6). The hybrids ranged in GOT from 43.57% (CIM-600 × KZ-189) to 35.26% (ARK-3 × KZ-189), and the heterotic potential varies from -1.11% (CYTO-178 × AGC-501) to 20.70% (CIM-600 × KZ-189). The heterotic potential for SI is shown in Table 6. The range of the heterotic potential shown was from -19.18% (CIM-600 × KZ-189) to 39.45% (VH-289 × MNH-988). ARK-3 × MNH-988 showed significant positive heterosis over MP, and BP, followed by ARK-3 × KZ-189, ARK-3 × AGC-501, VH-289 × MNH-988, VH-289 × AGC-501 and CYTO-178 × MNH-988.

Conclusion

Maximum heterotic values for EI were shown by VH-289 × AGC-501, that's why it is considered to be an early maturing hybrid, and ARK-3 × MNH-988 and ARK-3 × AGC-501 showed maximum heterosis for seed cotton yield. Thus, these selected hybrids could be a source of genetic information in future breeding programs.

Table 1: Mean sum of squares for experiment for characters that are DAF, DFBO, BMP, NFFB, HFFB and EI in upland cotton

Source of variation	DF	DAF	DFBO	BMP	NFFB	HFFB	EI
Replication	1	0.2	3.54	0.44	0.28	79.89	4.32
Genotype	18	11.50*	26.98**	16.18**	3.91**	39.23**	333.95**
Error	18	3.96	2.18	1.36	0.18	6.5	17.12
Total	37						

Table 2: Mean sum of squares for experiment for characters that are NBP, BW, SCY, GOT, SI and LI in upland cotton

Source of variation	DF	NBP	BW	SCY	GOT	SI	LI
Replication	1	63.36	0.075	923.9	0.58	0.04	0.01
Genotype	18	152.19**	0.313**	959.80*	70.12**	2.18**	1.90**
Error	18	12.07	0.05	325.93	1.85	0.09	0.079
Total	37						

Table 3: Mean values for experiment for characters under study in upland cotton

Genotypes	DAF	DFBO	BMP	NNFB	HFFB	EI	NBP	BW	SCY	GOT	SI	LI
FH-312 X AGC-501	58.15	96.25	38.11	10.85	34.55	63.04	29	3.07	85.41	38.25	6.25	3.88
ARK-3 X MNH-988	58.7	94.95	36.25	11.7	37.85	57.63	39.8	2.49	95.74	36.42	6.6	3.77
ARK-3 X KZ-189	61.75	96.25	34.45	13.55	43.7	64.01	33.4	2.26	74.49	33.26	7.4	3.73
ARK-3 X AGC-501	63.4	100.15	36.75	12.75	42.5	58.54	34.7	2.54	86.23	34.91	7	3.73
CIM-600 X KZ-189	57.4	96.95	39.55	11.15	30.35	75.44	15.1	2.23	30.68	43.57	4.75	7.04
VH-289 X LALAZAR	55	91.65	36.65	8.11	28.9	75.9	26.3	2.89	65.73	35.32	7	3.27
VH-289 X MNH-988	54.3	91.3	34	10.25	27.6	85.49	18.6	3.14	53.74	36.49	8.2	4.58
VH-289 X AGC-501	56.85	93.65	36.8	10.2	28.8	81.76	19.2	2.67	48.3	35.67	7.75	4.28
CYTO-178 X MNH-988	57.65	94.65	37	10.9	32.7	81.21	23.9	2.96	55.18	38.77	6.5	4.11
CYTO-178 X AGC-501	61.1	102.6	41.5	12	37.55	70.63	12.3	2.39	24.4	39.37	6.7	4.34
LALAZAR	63.3	101.8	38	12.05	34.05	56.7	16.7	3.27	50.13	36.57	8.5	4.92
MNH-988	57.9	95.15	37.25	9.9	30	78.04	22.4	2.24	47.81	34.83	5.6	2.98
KZ-189	59.65	95.9	36.25	11.1	34.5	56.74	33.4	2.49	75.77	36.76	6.25	3.63
AGC-501	58.55	90.6	33.05	10	30.55	64.36	15.8	2.19	34.12	39.53	6.5	4.25
FH-312	59.4	96.75	37.35	11.15	34.1	67.61	32.1	2.56	106.07	36.87	5.8	3.38
ARK-3	59.4	95.5	36.1	11.9	35.45	71.88	39.5	1.8	67.09	31.05	6.15	2.76
CIM-600	57.65	91.15	31.5	8.35	32.7	94.35	29.9	2.12	55.51	35.42	5.9	3.23
VH-289	59.15	95.1	35.95	9.55	31.1	44.12	27	2.13	60.04	30.52	6.25	2.74
CYTO-178	55.4	91.65	36.25	10.1	30.3	74.63	19.1	2.41	48.44	40.1	5.5	4.38

Table 4: Estimation of heterosis (MP), heterobeltiosis (BP) and standard heterosis (SC) for DAF, DFBO, BMP and NFFB in upland cotton.

Hybrids	DAF			DFBO		
	MP	BP	SC	MP	BP	SC
FH-312 × AGC-501	-1.39	-2.1	-8.13	3.01*	-0.51	-5.45
ARK-3 × MNH-988	-4	-6.67	-7.26	7.11**	6.17**	-2.84
ARK-3 × KZ-189	3.73	3.52	-2.44	1.65	-0.67	-6.43
ARK-3 × AGC-501	7.50*	6.73*	0.15*	10.29**	9.45**	-1.62
CIM-600 × KZ-189	-2.13	-3.77	-9.32	3.65*	1.09*	-4.76
VH-289 × LALAZAR	-3.63	-6.79	-6.79	-6.65**	-9.03**	-9.03**

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VH-289 × MNH-988	-9.38**	-12.08**	-12.63**	-3.78**	-5.48**	-10.31**
VH-289 × AGC-501	-3.39	-3.88	-10.18	0.32	-3.05	-8
CYTO-178 × MNH-988	-2.53	-8.34	-8.92	2.43	1.61	-7.02
CYTO-178 × AGC-501	7.24*	4.35*	-3.47*	12.89**	11.94**	0.78
Hybrids		**BMP**		**NFFB**		
	MP	**BP**	**SC**	**MP**	**BP**	**SC**
FH-312 × AGC-501	10.47**	2.04**	0.30**	2.6	-2.69	-9.95
ARK-3 × MNH-988	14.20**	9.39**	7.23**	6.66*	-3.44	-7.05
ARK-3 × KZ-189	-2.07	-4.96	-9.34	19.38**	16.81**	12.44**
ARK-3 × AGC-501	13.81**	9.67**	-1.57	13.42**	5.60**	1.65*
CIM-600 × KZ-189	22.26**	14.20**	8.94	15.68**	1.35*	-6.63
VH-289 × LALAZAR	1.76	1.71	1.71	-26.24**	-32.36**	-32.36**
VH-289 × MNH-988	-9.57	-10.4	-10.52	6.94*	3.48	-13.69
VH-289 × AGC-501	5.74*	-3.03	-3.15	-5.73	-5.97	-21.57
CYTO-178 × MNH-988	2.06	-0.67	-2.63	15.65**	10.09**	-4.97
CYTO-178 × AGC-501	24.06**	17.73**	9.21**	25.49**	23.07**	6.22**

Table 5: Estimation of heterosis (MP), heterobeltiosis (BP) and standard heterosis (SC) for HFFB (cm), EI, NBP and BW (g) in upland cotton.

Hybrids		**HFFB (cm)**			**EI**	
	MP	**BP**	**SC**	**MP**	**BP**	**SC**
FH-312 × AGC-501	6.88	1.31	1.46	-3.18	-12.67	-4.31
ARK-3 × MNH-988	15.66*	6.77	11.16	-26.78	-32.62	-6.59
ARK-3 × KZ-189	24.94**	23.27**	28.34**	11.27*	-1.21	15.08*
ARK-3 × AGC-501	28.78**	19.88**	24.81**	0.65	-11.6	2.97
CIM-600 × KZ-189	-9.67	-12.02	-10.86	0.51	-20.04	22.26
VH-289 × LALAZAR	-11.28*	-15.12*	-15.12*	43.44**	23.00**	23.00**
VH-289 × MNH-988	-9.65	-11.25	-18.94	31.86**	-0.05	38.55**
VH-289 × AGC-501	-6.56	-7.39	-15.41	66.05**	50.43**	32.51**
CYTO-178 × MNH-988	8.45	7.92	-3.96	-1.65	-5.06	31.62**
CYTO-178 × AGC-501	23.41**	22.91**	10.27**	5.42	-11.3	14.46**
Hybrids		**NBP**			**BW (g)**	
	MP	**BP**	**SC**	**MP**	**BP**	**SC**
FH-312 × AGC-501	17.19	-9.81	43.21*	29.415**	20.242**	-6.099
ARK-3 × MNH-988	45.16**	34.90**	97.03**	22.942*	10.746*	-24.036
ARK-3 × KZ-189	-1.76	-13.12	65.05	5.172	-9.444	-31.041
ARK-3 × AGC-501	48.00**	17.37**	71.43**	27.280**	15.849*	-22.354
CIM-600 × KZ-189	-69.06	-72.49	-47.73	-3.374	-10.665	-31.972
VH-289 × LALAZAR	-6.69	-16.28	5.39	7.019	-11.601	-11.601
VH-289 × MNH-988	-26.87	-27.01	-8.11	43.535**	39.986**	-3.98
VH-289 × AGC-501	-33.76	-44.36	-29.95	23.214**	21.538*	-18.543
CYTO-178 × MNH-988	13.84	-5.85	18.05	26.983**	22.634**	-9.692
CYTO-178 × AGC-501	17.19	-9.81	43.21	4.032	-0.641	-26.832

Table 6: Estimation of heterosis (MP), heterobeltiosis (BP) and standard heterosis (SC) for SCY (g), GOT (%), SI (g) and LI (g) in upland cotton.

Hybrids		**SCY (g)**			**GOT (%)**	
	MP	**BP**	**SC**	**MP**	**BP**	**SC**
FH-312 × AGC-501	21.84	-19.47	70.37	2.74	-0.7	7.32
ARK-3 × MNH-988	66.64*	42.70*	90.98*	10.55**	4.55**	-0.42
ARK-3 × KZ-189	4.28	-1.68	48.59	3.98	-4.09	-3.59
ARK-3 × AGC-501	70.39*	28.52*	72.01*	-0.04	-10.77	-3.55
CIM-600 × KZ-189	-53.24	-59.49	-38.77	20.70**	18.50**	19.12**
VH-289 × LALAZAR	19.33	9.47	31.13	5.29	-3.41	-3.41
VH-289 × MNH-988	-0.35	-10.5	7.2	11.65**	4.75**	-0.23
VH-289 × AGC-501	2.6	-19.55	-3.63	1.84	-9.76	-2.46

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CYTO-178 × MNH-988	14.65	13.91	10.07	3.47	-3.31	6
CYTO-178 × AGC-501	-40.89	-49.62	-51.32	-1.11	-1.8	7.65
Hybrids		**SI (g)**			**LI(g)**	
	MP	**BP**	**SC**	**MP**	**BP**	**SC**
FH-312 × AGC-501	-2.34	-3.84	-26.9	0.82	-3.58	-16.83
ARK-3 × MNH-988	9.43*	3.73*	-25.38	27.84**	24.00**	-25.89
ARK-3 × KZ-189	30.02**	29.02**	-7.19	37.48**	22.78**	-12.27
ARK-3 × AGC-501	26.48**	23.07**	-6.43	23.97**	2.35*	-11.71
CIM-600 × KZ-189	-19.18	-21.55	-44.44	111.79**	99.91**	42.82**
VH-289 × LALAZAR	-18.91	-29.82	-29.82	-14.58	-33.5	-33.5
VH-289 × MNH-988	39.45**	31.20**	-4.09	65.40**	59.78**	-4.51
VH-289 × AGC-501	23.92**	21.53**	-7.6	25.09**	2.94*	-11.2
CYTO-178 × MNH-988	18.07**	17.96**	-23.97	24.20**	11.78*	-16.5
CYTO-178 × AGC-501	11.66**	3.07*	-21.63	9.64	2.29	-11.76

Conflict of interest

The authors declared the absence of a conflict of interest.

References

Abbas, H. G., Mahmood, A., & Ali, Q. (2016). Zero tillage: a potential technology to improve cotton yield. *Genetika*, **48**(2), 761-776.

Abro, S., Deho, Z. A., Rizwan, M., Sial, M. A., & Abro, S. (2021). Combining ability estimates for seed cotton yield and its related traits using line× tester mating design in upland cotton. *International Journal of Biology and Biotechnology* **18**, 315-319.

Ali, M. A., Farooq, J., Batool, A., Zahoor, A., Azeem, F., Mahmood, A., & Jabran, K. (2019). Cotton production in Pakistan. *Cotton Production*, 249-276.

Ali, Q., Ahsan, M., Ali, F., Aslam, M., Khan, N. H., Munzoor, M., ... & Muhammad, S. (2013a). Heritability, heterosis and heterobeltiosis studies for morphological traits of maize (Zea mays L.) seedlings. *Advancements in Life sciences*, **1**(1).

Ali, Q., Ahsan, M., & Ali, F. (2013b). Genetic advance, heritability, correlation, heterosis and heterobeltiosis for morphological traits of maize (Zea mays L). *Albanian Journal of Agricultural Sciences*, *12*(4), 689-698.

Ali, Q., Ahsan, M., Kanwal, N., Ali, F., Ali, A., Ahmed, W., ... & Saleem, M. (2016). Screening for drought tolerance: comparison of maize hybrids under water deficit condition. *Advancements in Life Sciences*, *3*(2), 51-58.

Ali, Q., Ali, A., Ahsan, M., Nasir, I. A., Abbas, H. G., & Ashraf, M. A. (2014). Line× Tester analysis for morpho-physiol bogical traits of Zea mays L seedlings. *Advancements in Life sciences*, **1**(4), 242-253.

Anjum, R., Baloch, M. J., Baloch, G. M., & Chachar, Q. (2018). 45. Combining ability estimates for yield and fibre quality traits in Bt and non-Bt upland cotton genotypes. *Pure and Applied Biology (PAB)* **7**, 389-399.

Bankar, A., Sangwan, O., Nirania, K., & Ankit, K. (2020). Combining ability analysis for seed cotton yield and its attributing traits in upland cotton (Gossypium hirsutum L.). *Journal of Cotton Research and Development* **34**, 37-45.

Chaudhary, M. T., Majeed, S., Shakeel, A., Yinhua, J., Xiongming, D., & Azhar, M. (2019). Estimation of heterosis and combining ability for some quantitative parameters in Gossypium hirsutum. *International Journal of Biosciences* **15**, 166-173.

Elhousary, A. (2022). Determination of Gene Action and Heterosis In Diallel Crosses For The F1 And F2 Cotton Generations. *Annals of Agricultural Science, Moshtohor*.

Fonseca, S., & Patterson, F. L. (1968). Hybrid Vigor in a Seven-Parent Diallel Cross in Common Winter Wheat (Triticum aestivum L.) 1. *Crop Science* **8**, 85-88.

Khalid, M., Hassan, U., Hanzala, M., Amjad, I., & Hassan, A. (2022). Current situation and prospects of cotton production in Pakistan. *Bulletin of Biological and Allied Sciences Research* **5**, 27-27.

Khalid, M., & Amjad, I. (2018). Repercussions of waterlogging stress at morpho-physiological level on cotton and ways to lessen the damage to crop yields. *Bulletin of Biological and Allied Sciences Research*, *2018*(1), 16. https://doi.org/10.54112/bbasr.v2018i1.16

Khalid, M., & Amjad, I. (2019). combining ability and heterosis studies in upland cotton (*Gossypium hirsutum* L.). *Bulletin of Biological and Allied Sciences Research*, *2019*(1), 20. https://doi.org/10.54112/bbasr.v2019i1.20

Khokhar, E. S., Shakeel, A., Maqbool, M. A., Abuzar, M. K., Zareen, S., Syeda, S. A., & Asadullah, M. (2018). Studying combining ability and heterosis in different cotton (Gossypium hirsutum L.) genotypes for yield and yield contributing traits. *Pakistan Journal of Agricultural Research* **31**.

Kouser, S., Spielman, D. J., & Qaim, M. (2019). Transgenic cotton and farmers' health in Pakistan. *PloS one* **14**, e0222617.

Lanjewar, S., Mokate, A., Aher, A., & Bharud, R. (2017). Combining ability studies for yield and yield contributing characters in cotton (Gossypium hirsutum L.). *Journal of Cotton Research and Development* **31**, 34-37.

Mandumbu, R., Nyawenze, C., Rugare, J., Nyamadzawo, G., Parwada, C., & Tibugari, H. (2020). Tied ridges and better cotton breeds for climate change adaptation. *African handbook of climate change adaptation*, 1-15.

Malik, A., & Rasheed, M. (2022). An overview of breeding for drought stress tolerance in cotton. *Bulletin of Biological and Allied Sciences Research*, *2022*(1), 22. https://doi.org/10.54112/bbasr.v2022i1.22

Mudhalvan, S., Rajeswari, S., Mahalingam, L., Jeyakumar, P., Muthuswami, M., & Premalatha, N. (2021). Combining ability estimates and heterosis analysis on major yield attributing traits and lint quality in American cotton (Gossypium hirsutum L.). *Electronic Journal of Plant Breeding* **12**, 1111-1119.

Puspito, A. N., Rao, A. Q., Hafeez, M. N., Iqbal, M. S., Bajwa, K. S., Ali, Q., ... & Husnain, T. (2015). Transformation and evaluation of Cry1Ac+ Cry2A and GTGene in Gossypium hirsutum L. *Frontiers in plant science*, **6**, 943.

Ramdan, B. (2021). Combining ability and genetic divergence in cotton (G. barbadense L.). *Menoufia Journal of Plant Production* **6**, 151-164.

Rana, S. A., Ali, A., Iqbal, M. A., & Khan, I. A. (2021). Genetics of earliness in G. hirsutum l. under different nitrogen levels. *Pakistan Journal of Agricultural Sciences* **58**.

Rani, S., Chapara, M., & Satish, Y. (2020). Heterosis for seed cotton yield and yield contributing traits cotton (Gossypium hirsutum L.). *International Journal of Chemical Studies* **8**, 2496-2500.

Rehman, A., Bashir, A., Sarwar, G., Yinhua, J., Du, X., & Azhar, M. T. (2020). Genetic Assessment of Oil Contributing Traits in Upland Cotton. *International Journal of Biosciences* **17**, 32-45.

Richika, R., Rajeswari, S., Premalatha, N., & Thirukumaran, K. (2021). Heterosis and combining ability analysis for yield contributing traits and fibre quality traits in interspecific cotton hybrids (Gossypium hirsutum L. x Gossypium barbadense L.). *Electronic Journal of Plant Breeding* **12**, 934-940.

Salem, T., Rabie, H., Mowafy, S., Eissa, A., & Mansour, E. (2020). Combining ability and genetic components of egyptian cotton for earliness, yield, and fiber quality traits. *SABRAO Journal of Breeding & Genetics* **52**.

Solongi, N., Jatoi, W., Baloch, M., Siyal, M., & Memon, S. (2019). Heterosis and combining ability estimates for assessing potential parents to develop f 1 hybrids in upland cotton. *JAPS: Journal of Animal & Plant Sciences* **29**.

Soomro, A. W., Shahzad, S., & Khan, S. (2021). Diallel analysis in upland cotton over the environments for yield, earliness, fiber quality traits and cotton leaf curl virus. *Int. J. Biol. Biotech* **18**, 147-155.

Steel, R. (1997). Analysis of variance II: multiway classifications. *Principles and procedures of statistics: A biometrical approach*, 204-252.

Udaya, V., Saritha, H., & Patil, R. S. (2020). Heterosis studies for seed cotton yield and fibre quality traits in upland cotton (Gossypium hirsutum L.). *Indian journal of agricultural research* **1**, 1-5.

Usharani, K., Vindhiyavarman, P., & Balu, P. A. (2014). Combining ability analysis in intraspecific F1 diallel cross of upland cotton (Gossypium hirsutum L.). *Electronic Journal of Plant Breeding* **5**, 467-474.

Wei, W., Mushtaq, Z., Ikram, A., Faisal, M., Wan-Li, Z., & Ahmad, M. I. (2020). Estimating the economic viability of cotton growers in Punjab Province, Pakistan. *Sage Open* **10**, 2158244020929310.

Yang, Y., Chen, M., Tian, J., Xiao, F., Xu, S., Zuo, W., & Zhang, W. (2019). Improved photosynthetic capacity during the mid-and late reproductive stages contributed to increased cotton yield across four breeding eras in Xinjiang, China. *Field Crops Research* **240**, 177-184.

Yehia, W., & El-Hashash, E. (2019). Combining ability effects and heterosis estimates through line x tester analysis for yield, yield components and fiber traits in Egyptian cotton. *Journal of Agronomy* **10**.

Zafar, M. M., Mustafa, G., Shoukat, F., Idrees, A., Ali, A., Sharif, F., ... & Li, F. (2022). Heterologous expression of cry3Bb1 and cry3 genes for enhanced resistance against insect pests in cotton. *Scientific Reports*, **12**(1), 10878.

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