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ESTIMATION OF HETEROSIS FOR YIELD AND YIELD RELATED COMPONENTS IN COTTON (GOSSYPIUM HIRSUTUM L.)

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ABSTRACT

Cotton is known as the king of fiber crops and belongs to the family Malvaceae. In the world, it is cultivated as the most significant natural fiber and cash crop. A line x tester analysis was designed pointing towards the identification of best heterotic crosses for yield, fibre quality and economically important traits in upland cotton (*Gossypium hirsutum* L.). The current research was conducted at Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, six parents and nine crosses of cotton under RCBD Design with three replications. Data were collected on the plant's height, first fruiting branch, first effective boll-bearing branch's node number, monopodial and sympodial branches, no of fruiting nodes on each plant, weight and no of bolls, internodal distance, the yield of seed cotton per plant, the seed index, the lint index, the length and strength of the fiber, the uniformity ratio and micronaire value. Analysis of variance shown significant difference among all the studied traits. According to our findings for mean performance cross Kehkshan X CIM-602 best combiner for plant height, number of fruiting branches and fiber length, MNH-998 X CIM-602 best combiner for number of boll per plant, FH-215 X MNH-998 best combiner for GOT% while for better parent heterosis Kehkshan X CIM-602 shown maximum se performance and positive significantly associated with plant height, number of sympodial branches and seed index, MNH-998 X Kehkshan shown highest mid parent heterosis and significantly associated with number of bolls per plant and cross FH-215 X Kehkshan shown maximum se performance for mid parent heterosis which is significantly associated with lint index, micronaire value and seed index, While better parent heterosis FH-215 X Kehkshan shown maximum heterobeltiosis and positively significant associated with plant height, number of monopodial branches, sympodial branches and seed index. Therefore, CIM-622 X CIM-602 shown maximum heterobeltiosis and significant associated with seed cotton yield per plant. The best performer crosses could be utilized in future cotton breeding programme for development of new variety to boost up cotton industry.

***Keywords*:** Cotton, Hybrid, Line X Tester, Heterosis

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1. INTRODUCTION

Cotton is also referred to as "white gold," and main source of natural fiber. The cotton fiber is pure cellulose and their plant was grown like a shrub in nature. The cotton fiber is used to make yarn which is further utilized for making towels, curtains, and socks, etc. Its fiber also utilized in textile industry for cloth making (Stewart and Rossi 2010). A substantial amount of oil (16-27%) is haul out from cotton seed and seed cake is used in the livestock industry. The extracted oil from cotton seed is used as vegetable oil for making fries etc. because the taste of cotton seed oil is like to coconut oil. Moreover, it is an basic source of fat, vitamins and antioxidants (Dowd et al. 2010). Upland cotton shares around 90% of the world's cotton production, whereas only 3% is made up of Egyptian cotton (Fang et al. 2017). According to the Food and Agriculture Organization of the United Nations (FAO), the total cultivated area of cotton worldwide in 2021 was approximately 33.32 million hectares having production 25.58 million metric tons while in Pakistan total cultivated area of cotton was around 2.47 million hectares having their production is 8.93 million metric tons (FAO, 2021). Cotton has a significant position in the economy and agriculture of Pakistan. In Pakistan, during 2020-21 it is contributing 0.6% share in GDP of Pakistan and 3.1 % of the total value added in agriculture (GOP, 2020-21). The population of world is continuously increasing therefore; it is essential to enhance the productivity of crops to fulfill the requirement of textile industry. The utilization of many breeding tools in the cotton crop to enhanced their production to fulfill the demand of textile sector (Farooq et al. 2014). The information on the association between the traits should be available for plant breeder to understand the genetic basis of yield related parameters.

All the yield-related parameters are associated with each other in a way that increases or decreases in one characters directly affects others. Thus, assessment of phenotypic and genotypic association among these traits are helpful to initiate the breeding programs. The information on the correlation among several plant traits is helpful in the selection of suitable breeding programme (Teklewold et al. 2000). Phenotypic correlation demonstrates the visual observation although genotypic correlation estimates the inheritance of traits (Desalegn et al. 2009). Hybrid cotton is a positive approach for significant improvement in genetic potential for fibre quality and yield or yield related traits. Cotton is highly amenable for both heterosis and recombination breeding. Heterosis has considerably remained as one of the significant developments in cotton breeding method (Ranganatha et al. 2013; Choudhary et al. 2014). Numerous studies have been conducted on yield and yield related traits, but some work has been reported on the genetics and heterosis of yield fibre quality traits in cotton breeding. Many scientists described that cotton genotypes differ in fibre quality traits. Fibre quality of a specific cotton genotype is a combination of different characteristics, comprising fibre strength, fibre length, fineness or micronaire and fibre elongation. These parameters have their individual significance in spinning, weaving and dying units (Feng et al. 2011). Fibre length and strength properties mainly influence textile processing. In addition, fibre uniformity is also of remarkable value to the textile sector. It is significantly associated with the effective spinning and weaving processes, which change the fibre into fabrics. Ahuja, (2003) suggested that developing high fibre length and strength variety or hybrids is required to current modernized spinning mills. Hereafter, it is the need of the day to improve fibre quality in the dominating hirsutum genotypes, to fulfill the requirements of growing processing and textile sector. The estimates of per se performance and heterosis provided useful information with regard to the possibilities and extent of improvement in the fibre characters of breeding material through selection. The studies on heterosis in upland cotton for improvement of fibre traits has also been done by (Feng et al. 2011; Patil et al. 2012; Abro et al. 2014; Tuteja and Banga 2014). Keeping in view that the basic objectives of this study to estimates the heterosis among various morphological and fibers parameters using Line × Tester analysis, for the development of superior cross combination which can be utilized in the future cotton breeding programs.

2. MATERIALS AND METHODS

2.1. Plant Material and Experimental Site

The plant material consisted of six cotton lines collected from the Department of Plant Breeding and Genetics. The experiment was conducted in the experimental area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. The experimental site lies at 31º latitude and 73º longitudes while the elevation of land is about 184.2 m above sea level. The texture of the experimental soil was loamy.

2.2. Crossing Scheme

The six cotton varieties were crossed to develop nine F1 hybrids. The detail of parents and crosses are given in Table 1.

Table 1: Description of experimental material

Sr. No.	Varieties & Crosses
1	Kehkashan
2	CIM-602
3	CIM-622
4	MNH-998
5	FH-215
6	VH-367
7	Kehkashan × CIM-602
8	CIM-622 × Kehkashan
9	CIM-622 × CIM-602
10	MNH-998 × CIM-602
11	FH-215 × Kehkashan
12	FH-215 × CIM-602
13	FH-215 × MNH-998
14	VH-367 × CIM-622
15	VH-367 × FH-215

2.3. Development of Crosses

During the winter season 2020-21, six varieties were planted in pots and placed in the greenhouse. Six different varieties were crossed to developed hybrids between February and March 2021. Hand pollination and emasculation were used to develop hybrids. Crossing was initiated one week after flower initiation. Flower buds that would likely open the following day were picked for emasculation. To avoid natural outcrossing, the anthers of the selected buds were carefully removed with the aid of forceps. Emasculation was performed from 3 to 6 PM. The next morning, between 9 and 11 AM, male parent pollen was used to pollinate the emasculated buds. One flower of the male parent fertilized four to five flower buds of the female parent. To avoid cross-pollination with unwanted pollen after pollination, the staminal column was once more wrapped with a straw tube of a white color. The white straw tubes were removed four days after pollination, when fertilization was complete. In order to generate enough crossed bolls for each cross combination, considerable care was taken to guarantee that the parents were not nicked.

2.4. Evaluation of Parents and Crosses

In 3rd June 2021, F_1 hybrids along with the parents were planted in a randomized complete block design with three replications. Each replication consisted of a single row for each entry containing 10 plants. Row-to-row and plant-to-plant distances were maintained at 75 and 30cm, respectively. All the recommended agronomic practices were done during the whole experiment. Five guarded plants were randomly selected from each F_1 progeny and the parents from each replication for data collection.

2.5. Data Collection

Parameters included in this study are Plant height (cm), Number of monopodial branches, No of Sympodial branches, Number of fruiting nodes per plant, Node number for 1st fruiting branch, Node no for first effective boll bearing branch, Number of bolls per plant, Boll weight (g), Height node ratio (cm), Seed index, Seed cotton yield per plant, Ginning Out Turn, Fiber Length, Fiber Strength, Micronaire value and Uniformity Ratio. Furthermore, lint index, ginning out turn and earliness index was measured by following formulas:

$$\text{Lint index} = \frac{\text{weight of 100 seeds x ginning outturn percentage x100}}{\text{100 – ginning outturn percentage}}$$

$$\text{GOT\%} = \frac{\text{lint weight (g) x 100}}{\text{Seed cotton yield (g)}}$$

$$\text{Earliness index} = \frac{\text{seed cotton weight of 1}^{\text{st}}\text{ harvest x 100}}{\text{Seed cotton weight from all harvested}}$$

Statistical Analysis

Recorded data for all parameters was subjected to analysis of variance for all the character as described by (Steel et al. 1997). The percent increase (+) or decrease (-) of F^1 over mid and better parents was determined using following formula (Mather and Jink. 1982).

$$\text{Mid Parent Heterosis} = \frac{\text{(F1-MP)}}{\text{(F1-MP)}} \text{ X 100} \qquad \text{Better Parent Heterosis} = \frac{\text{(F1-BP)}}{\text{(F1-BP)}} \text{ X 100}$$

3. RESULTS

Mean square of the line × tester analysis observed significant ($p \leq 0.05$) genetic differences among the genotypes for Node for first effective boll bearing branches and fiber strength, whilst highly significant differences were shown ($p \leq 0.01$) between the genotypes for plant height, number of monopodial branches, number of sympodial branches, Number of fruiting nodes per plant, Node number for 1st fruiting branch, Number of bolls per plant, Boll weight, Seed index, Seed cotton yield per plant, Ginning Out Turn, Fiber Length, Micronaire value, Uniformity Ratio, Lint index and Earliness index. Moreover, non-significant ($p \geq 9.05$) difference among the genotypes for height node ratio. So it is reporting that maximum genetic variability among the studied materials which can be utilized in future for the development of improved cotton varieties Table 2.

According to the mean performance Table 3 and 4 for parents and crosses highest values of plant height has (114.55) showed by CIM-622 and the lowest value was (94.23) exhibited by Kehkashan and VH-367. In F1 crosses, (119.38) was highest value by Kehkshan×CIM-602 and (89.66) was lowest plant height recorded for FH-215×kehkshan. The parents VH-367 showed the highest values of number of sympodial branches were (25.3) and the lowest value was (19.30) revealed by CIM-602. In F1 crosses, Kehkshan×CIM-602 was highest number of sympodial branches (29.9) and FH-215×kehkshan has lowest number of sympodial branches (18). According to our findings Parent CIM-622 achieved the highest values of number of monopodial branches has (2.8) and CIM-602 and FH-215 has the lowest value of number of monopodial branches (1.5). While F1 cross CIM-622×Kehkshan has the highest mean of number of monopodial branches (3.1) and (1.2) was lowest mean by FH-215×kehkshan. Therefor parent, VH-367 has the maximum mean value for Number of fruiting nodes per plant (25.3) and CIM-602 has the lowest Number of fruiting nodes per plant (19.3), whilst in F1 crosses Kehkshan×CIM-602 has the highest number of Number of fruiting nodes per plant (29.9) and FH-215×kehkshan has the lowest Number of fruiting nodes per plant (18). In parents CIM-602 has the maximum mean value for Node number for 1st fruiting branch (8.9) and FH-215 has the lowest mean value for Node number for 1st fruiting branch (7.2). Moreover, in F1 crosses MNH-998×CIM-602 has the maximum mean value for Node number for 1st fruiting branch (7.62) and FH-215×kehkshan and CIM-622×CIM-602 revealed the lowest Node number for 1st fruiting branch (6.4). The parent VH- 367 attained the maximum Node number for first effective boll bearing branch (11.9) and parent MNH-998 had the lowest Node number for first effective boll bearing branch (9.6), while in F1 crosses FH-215×CIM-602 achieved the maximum Node number for first effective boll bearing branch (11) and CIM-622×Kehkshan has the lowest mean value (7.75). According to our results, maximum Number of bolls per plant was recorded in parent VH-367 (21.7) which is consider as high yielding and minimum Number of bolls per plant was recorded in MNH-998 (10.7). While in F1 crosses, MNH-998×CIM-602 has the maximum Number of bolls per

Table 2: Analysis of variance for different characters in upland cotton

Source of Variation	Replications (D. F.= 2)	Genotypes (D. F.= 14)	Error(D. F.= 28)	Total (D. F.= 44)
Plant Height	579.3	295.09**	63.4	
Number of monopodial branches	0.43	1.04**	0.11	
No of Sympodial branches	10.08	43.23**	8.99	
Number of fruiting nodes per plant	10.08	43.23**	8.99	
Node number for 1st fruiting branch	5.61204	1.57741**	0.46061	
Node for first boll bearing branch	0.15000	3.91307*	1.48036	
Number of bolls per plant	26.40	34.09**	9.95	
Boll weight	0.01	0.5**	0.19	
Height node ratio	0.14	0.14ns	0.12	
Seed index	1.35	2.72**	0.60	
Seed cotton yield per plant	321.64	540.41**	120.13	
Ginning Out Turn	16.56	96.23**	14.52	
Fiber Length	1.37	5.09**	2.77	
Fiber Strength	11.97	7.73*	3.83	
Micronaire value	0.03	0.57**	0.11	
Uniformity Ratio	4.21	5.13**	1.12	
Lint index	41.89	7223.45**	396.35	
Earliness index	0.516	779.731**	109.360	

Table 3: Mean performance of parents for different characters in upland cotton

Parents	Kehkashan	CIM-602	CIM-622	VH-367	MNH-998	FH-215
Plant Height	94.23	100.84	114.55	94.23	96.77	92.96
Number of monopodial branches	1.73	1.50	2.80	1.60	1.76	1.50
No of Sympodial branches	21.700	19.300	22.800	25.300	19.800	21.100
Number of fruiting nodes per plant	21.700	19.300	22.800	25.300	19.800	21.100
Node number for 1st fruiting branch	7.80	8.90	8.10	8.20	7.90	7.20
Node for first effective boll bearing branch	10.300	10.500	10.700	11.900	9.600	10.600
Number of bolls per plant	19.100	20.800	18.600	21.700	10.700	18.000
Boll weight	2.86	2.5	2.0	3.7	2.8	3.50
Height node ratio	3.55	3.49	3.45	3.2	3.3	3.2
Seed index	6.5	8.5	6.50	8.50	7.50	7.0
Seed cotton yield per plant	54.990	51.720	37.640	78.990	30.780	62.710
Ginning Out Turn	41.773	39.680	46.513	45.233	43.173	39.783
Fiber Length	26.400	26.650	25.100	26.550	29.350	24.650
Fiber Strength	26.200	26.200	25.700	26.400	27.450	26.150
Micronaire value	5.20	4.80	5.25	4.95	5.1	4.30
Uniformity Ratio	81.90	83.25	84.35	84.05	82.35	83.25
Lint index	223.40	297.21	280.23	316.79	258.71	242.43
Earliness index	59.131	60.837	78.585	42.628	68.119	74.096

Table 4: Mean performance of F1 hybrids for different characters in upland cotton

F1 hybrids	MNH-998 X CIM-602	FH-215 X Kehkshan	CIM-622 X CIM-602	VH-367 X FH-215	FH-215 X CIM-602	CIM-622 X Kehkshan	VH-367 X CIM-622	FH-215 X MNH-998	Kehkshan X CIM-602
Plant Height	108.20	89.66	110.74	108.71	113.03	116.33	114.55	92.71	119.38
Number of monopodial branches	2.00	1.20	2.63	1.96	2.23	3.10	1.30	1.90	2.80
No of Sympodial branches	28.125	18.000	27.400	21.700	26.100	25.675	18.900	19.300	29.900
Number of fruiting nodes per Plant	28.125	18.000	27.400	21.700	26.100	25.675	18.900	19.300	29.900
Node number for 1st fruiting branch	7.62	6.40	6.40	6.60	7.00	6.80	6.90	7.60	7.20
Node for first boll bearing branch	10.650	8.800	9.900	9.900	11.000	7.750	8.100	8.800	10.600
Number of bolls per plant	24.800	17.200	21.600	20.800	22.800	22.900	17.100	19.000	21.800
Boll weight	2.5	2.9	3.46	3.07	3.03	3.30	3.32	3.30	2.52
Height node ratio	2.82	3.38	3.39	3.71	3.72	3.38	3.32	3.47	3.19
Seed index	7.50	9.00	6.5	8.50	8.50	6.50	7.50	7.00	9.00
Seed cotton yield per plant	64.480	50.660	75.190	64.040	67.050	75.560	56.880	65.630	55.120
Ginning Out Turn	45.777	45.733	48.080	42.860	37.743	41.127	36.427	60.253	46.480
Fiber Length	25.050	26.200	25.900	25.900	26.550	25.400	23.750	26.650	27.450
Fiber Strength	26.900	26.850	27.100	25.050	24.150	25.600	29.200	30.750	27.300
Micronaire value	5.1	5.5	5.45	4.95	4.65	4.00	4.55	5.20	5.40
Uniformity Ratio	81.95	83.10	83.85	85.20	85.80	84.25	81.50	84.85	84.90
Lint index	275.02	344.13	210.47	320.89	282.59	225.21	211.52	298.18	371.84
Earliness index	51.674	75.653	46.827	37.991	70.350	71.595	75.394	67.867	25.141

plant (24.8) and VH-367×CIM-622 has the minimum Number of bolls per plant (17.1). The results in Table 3 and 4 showed that the parent VH-376 attained a higher value for Boll Weight (3.7) and lower value in parent CIM-622 (2). While in F1 crosses, (3.4) was highest mean exhibited by CIM-622×CIM-602 and (2.5) was lowest mean showed by MNH-998×CIM -602 for Boll Weight. According to our results maximum height node ratio was reported in parent Kehkashan (3.5) and lowest height node ratio was exhibited in VH-367 (3.2), while in F1 hybrid crosses FH-215× CIM-602 and Kehkshan×CIM-602 reported the maximum (3.72) and lowest (3.19) for height node ratio respectively. According to the Table 3 and 4, parent CIM-602 and VH-367 have the highest mean value (8.5) and CIM-622 and Kehkashan have the lowest mean value (6.5) for seed index. While in F1 crosses, the maximum value (9) shown by the FH-215×kahkshan and kahkshan×CIM-602. Therefore, in parents, highest values of mean were 78.9 exhibited by VH-367 and the lowest value was 30.7 by MNH-998, While F1 crosses, 75.19 was highest was highest value of seed cotton yield revealed by CIM-622×CIM-602 and 50.6 was lowest value showed by FH-215×kehkshan for seed cotton yield per plant. In parents, highest values of ginning out turn were (46.5) showed by CIM-622and the lowest value was (39.6) revealed by CIM-602. In F1 crosses, (48.08) was highest ginning out turn exhibited by CIM-622×CIM-602 and the lowest ginning out turn was (36.42) presented by VH-367×CIM-622. For fiber length.in parents, highest values of mean were (29.35) showed by MNH-998 the lowest value was (24.65) by FH-215.in F1 crosses, (27.45) was highest mean by Kehkshan×CIM-602 and 23.75 was lowest mean by VH-367×CIM-622. However, in parents, highest values of mean were (27.4) showed by MNH-998 the lowest value was (26.2) exhibited by CIM-602 In F1 crosses, (30.75) was highest mean by FH-215×MNH-998 and (24.15) was lowest mean by FH-215×CIM-602 for fiber strength.

According to our findings for micronaire highest mean value from all parents were (5.25) showed by CIM-622 and the lowest value was (4.3) presented by FH-215.in F1 crosses, (5.5) was highest mean by FH-215×kehkshan and 4.00 was lowest mean by CIM-622×Kehkshan. Mean comparison values are given in Table 2 and 3 for uniformity ratio. In parents, highest values of mean were (84.3) showed by CIM-622 the lowest value was (81.9) by Kehkashan.in F1 crosses, (85.2) was highest mean by VH-367×FH-215 and (81.5) was lowest mean by VH-367×CIM-622. It revealed that in parents, highest values of lint index were (316.7) showed by VH-367and the lowest value was (223.4) revealed by Kehkashan. In F1 crosses, (371.6) was highest lint index exhibited by Kehkshan×CIM-602 and the lowest lint index was (210.47) presented by CIM-622×CIM-602. While It depicted that mean comparison values are given in Table 2 and 3 for earliness index. In parents, highest values of mean were 78.58 showed by CIM-622 and the lowest value was 42.62 revealed by VH-367. In F1 crosses, 75.65 was highest mean exhibited by FH-215xkehkshan and 25.14 was lowest mean by KehkshanxCIM-602.

3.1. Better Parent and Mid Parent Heterosis

3.1.1. In this Experiment for Plant Height

FH-215×kehkshan showed the lowest heterosis (-4.206) while two crosses VH-367×FH-215 and FH-215×CIM-602 exhibited the maximum heterosis (16.14) and (16.64). Four crosses VH-367×FH-215, FH-215×CIM-602, CIM-622×Kehkshan and Kehkshan×CIM-602 revealed positive significant heterosis (16.14, 16.64, 11.43 and 23.39) while four crosses MNH-998×CIM-602, FH-215×kehkshan, CIM-622×CIM-602, VH-367×CIM-622 and FH-215×MNH-998 revealed non-significant positive and negative heterosis. VH-367×CIM-622 showed the lowest heterobeltiosis (-11.08) and Kehkshan×CIM-602 displayed the highest heterobeltiosis (18.38). Five crosses showed significant positive and negative heterobeltiosis. While remaining four crosses revealed non-significant heterobeltiosis. The estimates of heterosis and heterobeltiosis are shown in Table 5 and 6. VH-367×CIM-622 revealed the lowest value of heterosis (21.41) while two crosses Kehkshan×CIM-602 and MNH-998×CIM-602 showed the maximum value of heterosis (45.8) and (43.8). Four crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602 and Kehkshan×CIM-602 revealed positive significant heterosis (43.8, 30.16, 29.20and 45.8) while five crosses FH--215×kehkshan, VH-367×FH-215, CIM-622×Kehkshan, VH-367×CIM-622 and FH-215×MNH-998 revealed non-significant positive and negative heterosis. VH-367×CIM-622 exhibited the lowest value for heterobeltiosis (-25.29) and MNH-998×CIM-602 showed the highest value of heterobeltiosis (42.04). Four crosses showed significant positive and negative heterobeltiosis. While remaining five crosses revealed non-significant heterobeltiosis. Formation of more sympodial branches increases the opportunity for more number of bolls produced by the individual plant. For node number of effective boll bearing branches, the estimates of heterosis and heterobeltiosis are shown in table 4.3.2. VH-367×CIM-622 displayed the lowest heterosis (28.31) while cross MNH-998×CIM-602 showed the maximum heterosis (5.97). Three crosses MNH-998×CIM-602, FH-215×CIM-602 and Kehkshan×CIM-602 revealed positive significant heterosis (5.97, 4.26 and 1.92) while six crosses revealed non-significant negative heterosis FH-215×kehkshan, CIM-622×CIM-602, VH-367×FH-215, CIM-622×Kehkshan, VH-367×CIM-622, FH-215×MNH-998 (-15.7, -6.1, -12, -26.1, -28.3 and -12.8) respectively. VH-367×CIM-622 exhibited the lowest value for heterobeltiosis (-31.9) and FH-215×CIM-602 showed the highest value of heterobeltiosis (3.77). Three crosses presented significant positive heterobeltiosis. While remaining six crosses revealed non-significant negative heterobeltiosis. According to our findings for earliness index, the estimates of heterosis and heterobeltiosis are shown in table 4.4.2. Kehkshan×CIM-602 exhibited the lowest heterosis (-56.77) while crosses FH-215 ×Kehkashan showed the maximum heterosis (13.12). Three crosses FH-215×kehkshan, CIM-622×Kehkshan and VH-367×CIM-622 revealed positive significant heterosis (13.12, 7.15 and 17.8) while six crosses MNH-998×CIM-602, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, FH-215×MNH-998 and Kehkshan×CIM-602 revealed significant negative heterosis.

Kehkshan×CIM-602 showed the lowest heterobeltiosis (-57.08) and FH-215×kehkshan exhibited the highest heterobeltiosis (1.002). One cross showed significant and positive heterobeltiosis. While remaining eight crosses revealed negative non-significant heterobeltiosis. The estimates of heterosis and heterobeltiosis for number of

Table 5: Estimated Mid parent heterosis effects of F1 hybrids for different traits in upland cotton

F1 hybrids	MNH-998 X CIM-602	FH-215 X Kehkshan	CIM-622 X CIM-602	VH-367 X FH-215	FH-215 X CIM-602	CIM-622 X Kehkshan	VH-367 X CIM-622	FH-215 X MNH-998	Kehkshan X CIM-602
Plant Height	9.51ns	-4.20ns	2.83ns	16.14*	16.64*	11.43*	-2.43ns	-2.27ns	22.39*
Number of monopodial branches	22.44*	-25.77	22.48*	26.88*	48.88*	36.76	-40.90*	16.32*	73.19*
No of Sympodial branches	43.86*	43.86*	30.16*	-6.46	29.20*	15.39	-21.41	-5.62	45.85*
Number of fruiting nodes per plant	43.86	-15.88	30.16*	-6.46	29.207	15.39	-21.41	-5.62	45.85
Node number for 1st fruiting branch	-9.22	-14.66	-24.705	-14.28	-13.04*	-14.46	-15.33	0.66	-13.77
Node for first boll bearing branch	5.97*	-15.78	-6.603	-12	4.26	-26.19	-28.31	-12.87	1.92
Number of bolls per plant	57.46*	-7.2	9.6	4.78	17.52	21.48*	-15.13	32.404*	9.2
Boll weight	-4.36	-7.74	48.8*	-15.0	-0.0	32.9*	14.2*	3.45	-6.9
Height node ratio	-18.0	-0.39	-2.2	14.44*	10.6*	-3.33	-0.84	4.62*	-9.32
Seed index	-6.25	33.33*	-13.3	9.6	9.67	0	0	-3.4	38.46*
Seed cotton yield per plant	56.31*	-13.91	68.28*	-9.611	17.18	63.14*	-2.4	40.4*	3.30
Ginning Out Turn	4.37	9.18	-9.1	6.6	-2.9	-10.99	-30.14	29.96*	16.61*
Fiber Length	-10.53	2.64	0.09	1.17	3.5	-1.3	-8.03	-1.2	3.48
Fiber Strength	0.27	2.57	4.4	-4.66	-7.7	-1.34	12.09	14.7	4.1
Micronaire value	3.51*	16.84*	8.45*	7.02*	2.19	-23.44	-10.78	10.05*	8*
Uniformity Ratio	-1.02	0.63	0.05	1.85*	3.06*	1.35	-3.20	2.47*	2.81*
Lint index	-6.44	51.08*	-23.22	17.24*	7.46	-11.15	-30.59	43.75*	41.90*
Earliness index	-8.34	13.12*	-23.65	-29.63	-3.88	7.15*	17.806	-7.23	-56.77

Table 6: Estimated Better parent heterosis effects of F1 hybrids for different traits in upland cotton

F1 hybrids	MNH-998 X CIM-602	FH-215 X Kehkshan	CIM-622 X CIM-602	VH-367 X FH-215	FH-215 X CIM-602	CIM-622 X Kehkshan	VH-367 X CIM-622	FH-215 X MNH-998	Kehkshan X CIM-602
Plant Height	7.30ns	-4.85ns	-3.32ns	15.36*	12.09*	1.55*	-11.08*	-4.19ns	18.38*
Number of monopodial branches	22.44*	-30.76	-5.95	22.91*	48.88*	10.71*	-53.57	7.54	61.53*
No of Sympodial branches	42.04*	-17.05	20.17*	-14.22	23.69*	12.60	-25.29	-8.53	37.78*
Number of fruiting nodes per plant	42.04	-17.05	20.17	-14.22	23.69	12.60	-25.29	8.53	37.78
Node number for 1st fruiting branch	-14.32	-17.94	-28.08	-19.51	-21.34	-16.04	-15.85	-3.79*	-19.10
Node for first boll bearing branch	1.42	-16.98	-7.47	-16.806	3.77*	-27.57	-31.93	-16.98	0.95
Number of bolls per plant	19.23	-9.9	3.84	4.78	9.61	19.89	-15.13	32.404*	4.807
Boll weight	-9.58	-15.8	-6.9	-17.5	-13.4	15.0	-10.7	-5.8	-11.9
Height node ratio	-19.27	-4.69	-2.76	14.38*	6.67*	-4.60	-3.95	2.35	-10.04
Seed index	-11.76	28.57*	-23.52	0	0	0	-11.76	-6.66	38.46*
Seed cotton yield per plant	24.67	-19.21	45.37*	-18.92	6.92	37.40*	-27.9	4.65	0.23
Ginning Out Turn	-1.17	3.2	-18.7	1.41	-4.88	-18.19	-35.71	20.72*	10.31
Fiber Length	-14.65	-0.75	-2.81	-2.44	-0.37	-3.7	-19.0	-9.19	3.01
Fiber Strength	-2.03	2.48	3.43	-5.11	-7.82	-2.29	10.60	12.02	4.19
Micronaire value	0	6.73*	10.10*	-1.79	-3.12	-23.80	-13.33	0.97	3.84*
Uniformity Ratio	-1.56	-0.1	-0.59	1.3	3.06	-0.11*	-3.3	1.92*	1.98*
Lint index	-7.46	50.47*	-25.43	0.69	-4.92	-19.60	-34.79	28.41*	25.10*
Earliness index	-12.84	1.002*	-32.004	-32.004	-13.62	-5.17	-7.49	12.605	-57.08

fruiting nodes per plant the F1 hybrids VH-367×CIM-622 showed the lowest heterosis (-21.41) while crosses Kehkshan×CIM-602 showed the maximum heterosis (45.85). Five crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602, CIM-622×Kehkshan and Kehkshan×CIM-602 revealed positive significant heterosis (43.86, 30.16, 29.2, 15.39 and 45.85) while four crosses FH-215×kehkshan, VH-367×FH-215, VH-367×CIM-622 and FH-215×MNH-998 revealed significant negative heterosis (-15.88, -6.46, -21.41 and -5.62). VH-367×CIM-622 showed the lowest heterobeltiosis (-25.29) and MNH-998×CIM-602 exhibited maximum heterobeltiosis (42.04). Six crosses showed significant and positive heterobeltiosis. While remaining three crosses revealed negative and non-significant heterobeltiosis. While for node number for 1st fruiting branch, the estimates of heterosis and heterobeltiosis are shown in Table 5 and 6. CIM-622×CIM-602showed the lowest heterosis (-24.7) while two crosses FH-215xMNH-998showed the maximum heterosis (0.66). One crosses FH-215xMNH-998 revealed positive significant heterosis (0.66) while eight crosses revealed significant positive and negative heterosis. CIM-622×CIM-602 showed the lowest heterobeltiosis (-28.08) and FH-215×MNH-998 showed the highest heterobeltiosis (-3.79). For heterobeltiosis all the crosses revealed negative significant and non-significant heterobeltiosis. The heterosis and heterobeltiosis in VH-367×CIM-622 showed the lowest heterosis (-15.13) while the cross MNH-998×CIM-602 exhibited the maximum heterosis (57.46). Seven crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602, CIM-622×Kehkshan, VH-367× FH-215, FH-215×MNH-998 and

Kehkshan×CIM-602 revealed positive significant heterosis (57.46, 9.64, 4.78, 17.52, 21.48, 32.4 and 9.27) while two crosses VH-367×CIM-622 and FH-215×kehkshan revealed significant negative heterosis (-15.13 and - 7.27). VH-367×CIM-622 displayed the lowest value for heterobeltiosis (-15.13) and FH-215×MNH-998 showed the maximum value of heterobeltiosis (32.4). Seven crosses showed significant and positive heterobeltiosis. While remaining two crosses revealed negative non-significant heterobeltiosis for number of bolls per plant. For seed cotton yield per plant, the estimates of heterosis and heterobeltiosis in FH-215×kehkshan showed the lowest heterosis (-13.91) while the cross CIM-622×Kehkshan displayed the maximum heterosis (63.14).Six crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602, CIM-622×Kehkshan, FH-215×MNH-998 and Kehkshan×CIM-602 revealed positive significant heterosis (56.31, 68.28, 17.18,63.14, 40.4 and 3.30) while three crosses FH-215×kehkshan, VH-367×FH-215 and VH-367×CIM-622 revealed significant negative heterosis (-13.91, -9.61, -2.46). VH-367xCIM-622 showed the lowest heterobeltiosis (-27.9) and CIM-622×CIM-602 showed the highest heterobeltiosis (45.37). Six crosses showed significant and positive heterobeltiosis. While remaining three crosses revealed negative non-significant heterobeltiosis. According to our results for seed index, the estimates of heterosis and heterobeltiosis in CIM-622×CIM-602showed the lowest heterosis (-13.3) while the cross Kehkshan×CIM-602 showed the maximum heterosis (38.46). Four crosses FH-215×kehkshan, VH-367×FH-215, FH-215×CIM-602 and Kehkshan×CIM-602 revealed positive significant heterosis (33.3, 9.6, 9.6, 38.4) while three crosses MNH-998×CIM-602, CIM-622×CIM-602 and FH-215×MNH-998 revealed significant negative heterosis (-6.25, -13.33 and-3.44). CIM-622×CIM-602 showed the lowest heterobeltiosis (-23.52) and Kehkshan×CIM-602 exhibited the highest heterobeltiosis 38.42. Two crosses revealed significant positive heterobeltiosis while four crosses displayed negative heterobeltiosis.

The estimation of heterosis and heterobeltiosis for height node ratio among the F1 hybrids MNH-998× CIM-602 showed the lowest heterosis (-18.06) while the cross VH-367×FH-215 exposed the maximum heterosis (14.44).Three crosses VH-367×FH-215, FH-215×CIM-602 and FH-215× MNH-998 revealed positive significant heterosis (14.4, 10.6 and 4.6) while six crosses MNH-998×CIM-602, FH-215×Kehkshan, CIM-622×CIM-602, CIM-622×Kehkshan, VH-367×CIM-622, Kehkshan×CIM-602 revealed significant negative heterosis (-18.06, -0.39, -2.25, -3.33, -0.84, -9.23). MNH-998×CIM-602 showed the lowest heterobeltiosis (-19.27) and VH-367×FH-215 showed the highest heterobeltiosis (14.38). For heterobeltiosis three crosses revealed significant positive heterobeltiosis while six crosses showed negative heterobeltiosis.

Therefore, VH-367×FH-215 showed the lowest heterosis (-15.02) while the cross CIM-622×CIM-602 showed the maximum heterosis (48.87).Four crosses CIM-622× CIM-602, CIM-622× Kehkashan, VH-367×CIM-622, FH-215×MNH-998 revealed positive significant heterosis (48.87, 32.92, 14.24, 3.45) while five crosses MNH-998×CIM-602, FH-215×Kehkshan, VH-365×FH-215, FH-215×CIM-602, Kehkshan×CIM-602 revealed significant negative heterosis (-4.36, -7.74, -15.02, -0.01, -6.95).VH-367×FH-215 showed the lowest heterobeltiosis (-17.55) and CIM -622×Kehkshan showed the highest heterobeltiosis 15.03. For heterobeltiosis one cross revealed significant positive heterobeltiosis while eight crosses exhibited negative heterobeltiosis for boll weight. It is estimated that VH-367×CIM-622 revealed the lowest value of heterosis (-30.14) while one cross FH-215×MNH-998 showed the maximum value of heterosis (29.92). two crosses Kehkshan×CIM-602 andFH215×MNH-998 revealed positive significant heterosis (16.61, 29.92) while seven crosses revealed non-significant positive and negative heterosis. VH-367×CIM-622 exhibited the lowest value for heterobeltiosis (-35.71) and FH-215×MNH-998 showed the highest value of heterobeltiosis (20.72). One cross showed non-significant positive heterobeltiosis. While remaining eight crosses revealed non-significant heterobeltiosis for ginning out turn%. Moreover, for lint index the estimates of heterosis and heterobeltiosis in CIM-622×Kehkshan revealed the lowest value of heterosis (-11.15) while one cross FH-215×kehkshan showed the maximum value of heterosis (51.08). Four crosses FH-215×kehkshan, VH-367×FH-215, FH-215×MNH-998 and Kehkshan×CIM-602 revealed positive significant heterosis (51.08, 17.24, 43.75, 41.9) while five crosses revealed non-significant positive and negative heterosis. VH-367×CIM-622 exhibited the lowest value for heterobeltiosis (-34.79) and FH-215×kehkshan showed the highest value of heterobeltiosis (50.47). Three crosses showed significant positive heterobeltiosis. While remaining six crosses revealed non-significant heterobeltiosis.

Therefore, the assessments of heterosis and heterobeltiosis in VH-367×FH-215 showed the lowest heterosis (-4.66) while two crosses FH-215×MNH-998 showed the maximum heterosis (14.73). Six crosses MNH-998×CIM-602, FH-215×kehkshan, CIM-622×CIM-602, VH-367×CIM-622, FH-215×MNH-998 and Kehkshan×CIM-602 revealed positive significant heterosis (0.27, 2.57, 4.43, 12.09, 14.7, 4.1) while three crosses VH-367×FH-215, FH-215×CIM-602 and CIM-622×Kehkshan revealed significant negative heterosis (-4.66, -7.73 and 1.34). FH215×CIM602 exhibited the lowest heterobeltiosis (-7.82) and FH 215×MNH-998 displayed the highest heterobeltiosis (12.02). For heterobeltiosis five crosses revealed significant positive heterobeltiosis while four crosses showed negative heterobeltiosis for fibre strength. According to our findings for fiber length, the estimates of heterosis and heterobeltiosis are shown Table 5. MNH-998×CIM-602 showed the lowest heterosis (-10.53) while the cross FH-215×CIM-602 showed the maximum heterosis (3.51).Five crosses FH-215×kehkshan,CIM-622×CIM-602,VH-367×FH-215,FH-215×CIM-602,Kehkshan×CIM-602 revealed positive significant heterosis(2.64, 0.09, 1.17, 3.51, 3.48) while four crosses MNH-998×CIM-602, CIM-622×Kehkshan, VH-367×CIM-622, FH-215×MNH-998 revealed significant negative heterosis (-10.53, -1.35, -8.03, -1.29) .VH-367×CIM-622 showed the lowest heterobeltiosis (-19.08) and Kehkshan×CIM-602 showed the highest heterobeltiosis (3.001). For heterobeltiosis one cross Kehkshan×CIM-602 revealed significant positive heterobeltiosis while eight crosses exhibited negative heterobeltiosis. The approximations of heterosis and heterobeltiosis in VH-367×CIM-622 showed the lowest heterosis (-3.206) while two crosses FH-215×CIM-602 exhibited the maximum heterosis (3.06). Seven crosses FH-215×kehkshan, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, CIM-622×Kehkshan, FH-215×MNH-998, Kehkshan×CIM-602 revealed positive significant heterosis (0.63, 0.05, 1.85, 3.06, 1.35, 2.47, 2.81) while two crosses MNH-998×CIM-602, VH-367×CIM-622 revealed significant negative heterosis (-1.02, -3.206). MNH-998×CIM-602 showed the lowest heterobeltiosis (-1.56) and FH-215×CIM-602 showed the highest heterobeltiosis (3.06). For heterobeltiosis four crosses revealed significant positive heterobeltiosis while five crosses showed negative heterobeltiosis for uniformity ratio. Therefore, the estimates of heterosis and heterobeltiosis for uniformity ratio shown that CIM-622×Kehkshan has the lowest heterosis (-23.44) while the cross FH-215×kehkshan showed the maximum heterosis (16.84).

Seven crosses FH-215×kehkshan, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, FH-215MNH-998, Kehkshan×CIM-602, MNH -998×CIM-602 revealed positive significant heterosis (3.51,16.84,8.45,7.02,2.19,10.05,8) while two crosses CIM-622×Kehkshan and VH-367×CIM-622revealed significant negative heterosis (-23.44 and -10.78). CIM-622×Kehkashan showed the lowest heterobeltiosis (-23.8) and CIM-622×CIM-602 showed the highest heterobeltiosis (10.10). For heterobeltiosis four crosses revealed significant positive heterobeltiosis while four crosses showed negative heterobeltiosis. It is revealed that the estimates of heterosis and heterobeltiosis for monopodial branches in VH-367×CIM-622 showed the lowest heterosis (-40.9) while two crosses Kehkshan×CIM-602 showed the maximum heterosis (73.19).Seven crosses, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, FH-215×MNH-998, CIM-622×Kehkshan, Kehkshan×CIM-602, MNH-998×CIM-602 revealed positive significant heterosis (22.44, 22.48, 26.88, 48.88, 36.76, 16.32, 73.19) while two crosses FH-215×kehkshan, VH-367×CIM-622 revealed significant negative heterosis (-25.77 and -40.9).VH-367×CIM-622 showed the lowest heterobeltiosis (-53.57) and Kehkshan×CIM-602 showed the highest heterobeltiosis (61.53). For heterobeltiosis six crosses revealed significant positive heterobeltiosis while three crosses showed negative heterobeltiosis.

4. DISCUSSION

The success of breeding program for crop improvement is generally dependent on the avaibillity of genetic material that transfer the favorable character into its progenies (Razzaq et al. 2022). The genetic material that utilized in breeding program, which dependent on the critical selection procedure to evaluate their potential. To study the genetic material six cotton parents were crossed into line and tester mating design and 9 F1 hybrids were developed to estimates heterosis and heterobeltiosis. Heterosis breeding is an important genetic tool for agricultural research which has a great influence on the plant yield (Herath et al. 2021). The development of superior F1 hybrids using stable and high yielding new lines will increase the yield maximum of this crop. While to select a high yielding cross combination, it is necessary to assess hybrid combinations for seed cotton yield and its related components from the available advance lines. In this study, per cent increase or decrease over midparent (heterosis) and better parent (heterobeltiosis) was used for the estimation of heterosis. Therefor magnitude and direction is an important step in the assessment of heterosis. In segregating generations, the nature and magnitude of heterosis both help in recognizing high yielding cross combinations to get better transgressive segregants (Kanasagra et al. 2022).

In the current study, certain crosses have maximum heterosis while some crosses have low heterosis according to the genetic makeup of the parents and their nature of gene action (Begna, 2021). The significant and non-significant level of positive and negative relative heterosis and heterobeltiosis in maximum crosses for almost all the traits also indicated the genetic diversity of parents utilized in this study. The range of heterosis as well as the number of crosses exhibiting significant positive or negative heterosis is presented in Table 5 and 6. According to our findings four crosses VH-367×FH-215, FH-215×CIM-602, CIM-622×Kehkshan and Kehkshan×CIM-602 revealed positive significant heterosis and five crosses MNH-998×CIM-602, FH-215×kehkshan, CIM-622×CIM-602, VH-367×CIM-622 and FH-215×MNH-998 revealed non-significant positive and negative heterosis, while Five crosses showed significant positive and negative heterobeltiosis, remaining four crosses revealed non-significant heterobeltiosis for plant height. Medium taller plants are considered as desirable in cotton breeding because medium taller plants may produce greater number of sympodia, as a result they bear additional fruiting branches. Secondly, medium taller plants are reasonably tolerant to lodging. Similar findings were reported by (Pavitra et al. 2019; Ankit et al. 2018). Therefore, seven crosses, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, FH-215×MNH-998, CIM-622×Kehkshan, Kehkshan×CIM-602, MNH-998×CIM-602 revealed positive significant heterosis over mid parent and two crosses FH-215×kehkshan, VH-367×CIM-622 revealed significant negative heterosis over better parent. While six crosses revealed significant positive heterobeltiosis while three crosses showed negative heterobeltiosis over better parents for monopodial branches, Chivikant et al. (2017), Islam et al. (2021) also reported similar results. For sympodial branches four crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602 and Kehkshan×CIM-602 revealed positive significant heterosis and five crosses FH--215×kehkshan, VH-367×FH-215, CIM-622×Kehkshan, VH-367×CIM-622 and FH-215×MNH-998 revealed non-significant positive and negative heterosis. While Four crosses showed significant positive and negative heterobeltiosis. While remaining five crosses revealed non-significant heterobeltiosis. Formation of more sympodial branches increases the opportunity for more number of bolls produced by the individual plant. Same results were described by (Aman et al. 2017; Islam et al. 2021; Pavitra et al. 2019). For boll per plant Seven crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602, CIM-622×Kehkshan, VH-367× FH-215, FH-215×MNH-

998 and Kehkshan×CIM-602 revealed positive significant heterosis and two crosses VH-367×CIM-622 and FH-215×kehkshan revealed significant negative heterosis, while Seven crosses showed significant and positive heterobeltiosis. While remaining two crosses revealed negative non-significant heterobeltiosis. As bolls plant-1 increase, the yield is also expected to increase simultaneously. Therefore, high affirmative relationship between bolls and yield is usually observed between these two traits. Same findings also reported by earlier workers Shinde et al. (2018), Solongi et al. (2019), Vaid et al. (2022), Komala et al. (2018) and Islam et al. (2021).

The data present in a given Table 5 and 6 for seed cotton yield Six crosses MNH-998×CIM-602, CIM-622×CIM-602, FH-215×CIM-602, CIM-622×Kehkshan, FH-215×MNH-998 and Kehkshan×CIM-602 revealed positive significant heterosis and three crosses FH-215×kehkshan, VH-367×FH-215 and VH-367×CIM-622 revealed significant negative heterosis, while six crosses showed significant and positive heterobeltiosis. While remaining three crosses revealed negative non-significant heterobeltiosis over better parent heterosis. Similar findings of useful heterosis have also been reported by Adsare et al. (2017), Bilwal et al. (2018), Patel et al. (2021), Islam et al. (2021), Thiyagu et al. (2019). For ginning out turn two crosses Kehkshan×CIM-602 and FH-215×MNH-998 revealed positive significant heterosis while seven crosses revealed non-significant positive and negative heterosis. Moreover, one cross showed non-significant positive heterobeltiosis. While remaining eight crosses revealed non-significant heterobeltiosis. Similar answers were stated by Islam et al. (2021), Naik et al. (2020), Chakloma et al. (2021), Ahuja et al. (2018), Ahmad et al. (2019), Shiva et al. (2017), Ankit et al. (2018), Chivikant et al. (2017) and Adhare et al. (2017).

Fibre fineness or micronaire and fibre strength are very important characteristic of the fiber quality of cotton and are extremely useful for textile industry. According to our findings for fiber strength Six crosses MNH-998×CIM-602, FH 215×kehkshan, CIM-622×CIM-602, VH-367×CIM-622, FH-215×MNH-998 and Kehkshan×CIM-602 revealed positive significant heterosis, while three crosses VH-367×FH-215, FH-215×CIM-602 and CIM-622×Kehkshan revealed significant negative heterosis. For heterobeltiosis five crosses revealed significant positive heterobeltiosis while four crosses showed negative heterobeltiosis. These results have also correlate by Chupare et al. (2021), Thiguya et al. (2019), Chakloma et al. (2021), Pavitra et al. (2019) and Ushrani et al. (2015). For fiber length Five crosses FH-215×kehkshan, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, Kehkshan×CIM-602 revealed positive significant heterosis while four crosses MNH-998×CIM-602, CIM-622×Kehkshan, VH-367×CIM-622, FH-215×MNH-998 revealed significant negative heterosis. Therefore, heterobeltiosis one cross Kehkshan×CIM-602 revealed significant positive heterobeltiosis while eight crosses exhibited negative heterobeltiosis. Because of genetic variations, cotton fibre length, which is crucial for the production of fabrics, varies substantially among cotton varieties. Since cotton fibres with long staple lengths are finer, stronger, and more flexible than those with short staple lengths, they generate fabrics that are smoother and stronger. Amongst the fibre properties, staple length is one of the most important fibre properties being considered from economic point of view, however, fibre length is more useful in yarn manufacturing. These results generally correspond with the findings of Chupare et al. (2021), Thiguya et al. (2019), Chakloma et al. (2021), Pavitra et al. (2019) and Ushrani et al. (2015).

Micronaire value is an important fibre quality trait in judging lint quality of cotton. Our results for micronaire value shown that Seven crosses FH-215×kehkshan, CIM-622×CIM-602, VH-367×FH-215, FH-215×CIM-602, FH-215MNH-998, Kehkshan×CIM-602, MNH -998×CIM-602 revealed positive significant heterosis, while two crosses CIM-622×Kehkshan and VH-367×CIM-622 revealed significant negative heterosis. For heterobeltiosis four crosses revealed significant positive heterobeltiosis while four crosses showed negative heterobeltiosis. The findings of Chupare et al. (2021), Thiguya et al. (2019), Chakloma et al. (2021), Pavitra et al. (2019), and Ushrani et al. (2015) are supported by these results. Hybrid vigour or heterosis was also studied by Jyotiba et al. (2010), Babu et al. (2011) and Abro et al. (2014). Heterosis occurs due to multiple reasons; 1) Dominant hypothesis states that the accumulation of favorable genes in the population can produce heterosis. 2) The heterozygotic condition of a character can be superior to the homozygotic state. 3) The interaction of favorable alleles at different loci can improve the character more than without this interaction (Abro et al. 2009). The presence of variation in the performance of the parents compared to hybrid development programmes can be attributed to differences in the genetic constitution of the plants and their specific interaction with the prevailing environment (Wang et al. 2016). Previously, several initiatives have been utilized to study the molecular basis of heterosis and to reveal the number and types of QTLs associated with the phenomenon of heterosis. The existence of non-additive gene action for most of the deliberate parameters further suggests that some of the lines are good options for hybrid development. Bordering countries of Pakistan, including China and India, have achieved higher cotton production than Pakistan by developing hybrids of cotton (Blaise et al. 2014). The hybrid development of cotton in Pakistan is at an early stage and needs to be strengthened to boost the cotton production to support economy of country.

Conclusion

Climate change severely decrease the cotton production. The ability of a cotton plant to show flexibility against climate change is governed by non-additive gene action. According to the analysis of variance in the current study, all attributes exhibited substantial differences between parents and hybrids. Based on the results two crosses FH215×MNH998 and Kehkashan×CIM602 shown maximum heterosis and heterobeltiosis for ginning outturn and yield related traits that can be used in future breeding programmes for the development of synthetic verities or commercial hybrids. Among the crosses, CIM622×CIM602 and CIM622×Kehkshan expressed maximum positive and significant heterosis for majority of the traits specially for seed cotton yield hence they are suitable crosses for selection programmes to select desirable plants from segregating populations. The hybrids CIM 622xCIM602 shown high heterotic effects for bolls per plant, seed cotton yield and fibre quality attributes. The cross CIM 622×CIM602 proved to be the best for cross combination for the traits like plant height, boll weight, height node ratio, seed cotton yield/plant, node number for first fruiting branch and micronaire, fiber length, fiber strength, Got% and number of sympodial branches. This cross can be utilized in hybrid cotton development program. It is suggested that the superior cross combination can be utilized in future breeding programme to improve cotton crop yield and productivity that withstand climate change.

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