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Research Article

HETEROTIC EFFECT FOR SEED COTTON YIELD AND ITS CONTRIBUTING TRAITS IN CHANGING ENVIRONMENT

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ABSTRACT. The present research was carried out to assess the heterotic performance of F_1 hybrids at two locations. Analysis of variance exhibited that hybrids and environment was significant for all the characters. However, their interaction was also significant which indicated sufficient genetic variability is available in the material. Hybrids expressed high significant mid and better parent heterosis for seed cotton yield, also possess higher heterosis values for yield contributing traits at both locations, their mean performance was also noted high. In both the environments hybrids given 50% heterosis effect for yield and its contributing traits need to special attention for further exploitation for boos up cotton production and per acre yield. The heterotic effect of hybrids were diverse in environments, therefore suggested that formulation of effective breeding program high heterotic crosses could be selected which performed best in individual locations. It is further suggested that parents which were involved in hybrid combinations performed best must pick for utilization in heterosis breeding program.

Keywords: *Heterosis, Heterobeltiosis, seed cotton yield, Cotton, Environment.*

INTRODUCTION

Cotton placed an important position in national economy of Pakistan; the crop has significant consideration nationally. Since many years cotton yield is stagnant due to various factors. The most important factor in the process of crop production has always been a good variety in any crop. Cotton crop is generally grown for commercial purpose in more than 70 countries at tropical and sub-tropical zones. The particular areas for the production of cotton are India, China, USA, Pakistan, Brazil, Australia, Turkey, Egypt, Uzbekistan etc. However it depends upon the climatic conditions which suit the cotton crop according to the requirement for growth and development. Continuous improvement in genetic architecture of cotton for increasing yield per hectare is the prime principles of cotton breeder. Therefore, cotton breeders are managing to evolve new varieties with high yielding and require fiber characteristics through manipulations of different genetic material and breeding practice. Heterosis is the phenomenon in which the two genetically distinct parents express increase in size and vigor for various traits over mid parent (Heterosis) and over better parent (Heterobeltiosis). The study of heterosis helpful to achieve high degree of heterotic response [1]. Parents can be used for heterosis breeding followed by proper evaluation through multi locations trial [2]. Considerable amount of heterosis for seed cotton yield and its related characters with suggestions of commercial exploitation reported by [3]. Cotton breeders are trying to create genetic variability though conventional breeding method by crossing two genotypes to produce superior hybrid. The high heterotic performance hybrid could be developed by utilizing all available germplasm and it is necessary that would evaluate in multiple environments for adoptability and proper evaluation.

MATERIALS AND METHODS

The present research was conducted to develop F_1 hybrids for study of heterosis and heterobeltiosis by attempting 10x10 half diallel crosses, those well-adjusted in multiple environmental conditions and produced higher seed cotton yield. The experiment was conducted to assess the heterosis and heterobeltiosis at environmental conditions of Sakrand and Mirpurkhas during the crop season 2017-18. The material was comprised on 10 parents (1-CRIS-129, 2-MNH-886, 3-FH-142, 4-NIA-Noori, 5-Baghdadi, 6-CIM-602, 7-NIAB-824, 8-CEMB-33, 9-Mac-7 and 10-USD16-3058 and 45 F_1 hybrids developed by using half diallel Method-2, Model-1 suggested by [4]. The characters were studied, plant height (cm), sympodial branches plant^{-1}, bolls plant^{-1}, boll weight (g), seed index (g) and seed cotton yield plant^{-1}.

The data was statistically analyzed through methods given by [5] and the heterosis and heterobeltiosis was calculated according to [6]. However, the standard error, critical difference and t-test value was applied according to procedure given by [7, 8]. The data was statistically analyzed by using statistically software statistix-8.1.

MidParent Heterosis (%) = $\frac{F1-MP}{MP} X\ 100$

Better Parent Heterosis (heterobeltiosis)% = $\frac{F1-BP}{BP} X\ 100$

Whereas,

Mid Parent Value = $\frac{P1+P2}{2}$

F1 = Mean of the crosses

MP = Mid Parent

BP = Better Parent

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) was carried out for testing of significant difference between the genotypes which were studied. The data exhibited that hybrids were significant for all the characters viz. plant height, sympodial branches plant^{-1}, bolls plant^{-1}, boll weight, seed index and seed cotton yield plant^{-1}. Whereas, environment was also found significant for all the traits studied. However, interaction of hybrids with environment was also observed significant for all traits which indicated that sufficient genetic variability is present in the material (Table 1). [9, 10, 11, 12, 13] reported highly significant difference in their studies among cotton genotypes for the yield and its contributing traits and they were emphasized that significant suggests the genetic diversity in material.

Heterosis is natural phenomenon happening in practically all the traits but its extent varied in different characters. The result of heterosis and heterobeltiosis was diverse at both the locations. As regards the trait plan height 30 crosses shown significant positive heterosis with range of-18.2 to 51.9 and 20 hybrids given significant positive heterobeltiosis with range of -32 to 47.2 at the environmental condition of Sakrand (Table 2 & 3).

Table 1. *Analysis of variance for yield and yield contributing traits in combined environment.*

Source of Variation	DF	PH	SB	BPP	BW	SI	SCY
Replication	02	286.31	0.273	0.553	0.015	0.278	27.78
Hybrids	44	2821.47**	158.513**	741.849**	2.461**	14.776**	5832.43**
Error Replication*Hybrids	88	49.87	1.718	16.553	0.114	0.445	149.31
Environment	01	1911.48**	175.208**	143.3**	0.001**	7.905**	2616.45**
Hybrids*Environment	44	415.16**	13.015**	99.437**	0.136**	1.078**	530.68**
Error Replication*Hybrids*Environment	90	74.60	1.618	17.401	0.089	0.368	148.32
C.V Replication*Hybrids		7.36	6.69	8.80	10.59	10.83	15.84
C.V Replication*Hybrids*Environment		7.11	6.50	9.02	9.37	9.85	15.78

DF=Degree of Freedom, PH=Plant Height, SB=Sympodial Branches, BPP=Bolls Plant^{-1}, BW=Boll Weight, SI=Seed Index, SCY=Seed Cotton Yield Plant^{-1}

Table 2. *Heterosis (H) and Heterobeltiosis (HB) assessment for seed cotton yield and its contributing traits at environmental conditions of Sakrand.*

F_1	Plant Height		Sympodial Branches		Bolls Plant^{-1}		Boll Weight		Seed Index		Seed Cotton Yield Plant^{-1}	
	H	HB	H	HB	H	HB	H	HB	H	HB	H	HB
1x2	32.1**	30.4**	8.5*	7.7	43.0**	26.2**	23.4**	13.2	21.6**	9.4	7.9	-2.5
1x3	37.9**	27.6**	31.3**	24.7**	2.8	-6.8	12.6*	0.0	25.9**	12.2	36.0**	32.6**
1x4	-6.6	-10.6*	-7.5	-14.1**	22.8**	4.1	4.1	0.0	0.2	-10.5	-8.1	-30.3**
1x5	48.7**	42.3**	3.5	1.0	32.9**	6.1	15.4**	-0.9	11.5	-2.6	4.6	-1.5
1x6	13.8**	10.6	18.1**	17.3**	47.1**	25.5**	25.2**	22.8**	11.2	7.7	56.0**	34.8**
1x7	9.7*	5.6	11.2**	6.5	23.3**	1.0	22.7**	14.9*	0.4	-3.7	45.5**	16.8*
1x8	28.6**	21.6**	18.1**	9.9**	16.3**	-6.6	25.7**	11.1	34.9**	24.0**	24.7**	-0.9
1x9	13.0*	-1.5	-8.9	-37.0**	7.9	-26.3**	6.3	-10.5	-30.7**	-39.8**	-33.7**	-58.1**
1x10	-2.1	-17.6**	-1.2	-25.9**	3.3	-32.6**	-7.9	-19.6**	11.8	7.9	-36.9**	-55.0**
2x3	31.1**	19.8**	25.2**	19.8**	26.0**	22.2**	17.5**	13.3*	11.1	10.0	49.4**	38.2**
2x4	20.2**	13.6**	-13.7**	-19.3**	14.1*	8.9	25.5**	11.0	-20.1*	-35.0**	-3.5	-20.9*
2x5	51.9**	47.2**	32.7**	30.6**	32.8**	18.3*	32.0**	22.6**	25.0**	20.9**	28.5**	23.0*
2x6	33.8**	31.8**	22.0**	20.2**	70.5**	64.0**	11.8	4.4	0.8	-11.8	55.3**	47.7**
2x7	37.4**	30.7**	2.7	-2.4	53.4**	40.8**	-4.5	-6.6	-4.2	-10.4	32.6**	15.9
2x8	33.0**	24.2**	17.2**	8.2*	48.0**	32.7**	21.1**	16.2*	8.0	5.5	35.6**	17.3
2x9	3.1	-9.1	-4.1	-33.4**	15.5	-14.6*	-6.3	-26.4**	-40.1**	-52.4**	-36.4**	-57.8**
2x10	20.2**	2.3	-18.4**	-38.5**	10.4	-22.8**	11.9*	5.9	3.2	-10.0	-20.4	-39.2**
3x4	8.3	4.5	1.8	-0.6	24.2**	15.2*	-3.6	-17.3**	-0.9	-20.0**	24.1*	-4.3
3x5	34.7**	19.6**	25.8**	22.3**	38.4**	20.0**	34.3**	29.2**	27.9**	25.0**	23.6**	19.2*
3x6	18.0**	6.3	8.9*	2.7	56.7**	46.4**	23.2**	11.2	-2.7	-15.7*	46.1**	29.1**
3x7	20.0**	15.1**	23.0**	12.1**	30.7**	16.7*	2.7	-3.1	15.2*	6.7	3.4	-15.4
3x8	29.4**	26.4**	33.0**	18.0**	48.8**	29.9**	24.9**	24.2**	11.8*	8.1	28.7**	4.3
3x9	-2.2	-20.2**	25.9**	-10.3*	-5.0	-31.1**	-16.0*	-35.7**	-19.7**	-36.7**	-36.4**	-59.4**
3x10	2.8	-18.8**	-5.5	-26.5**	-4.0	-34.0**	14.0**	11.8	18.3**	2.2	-38.1**	-55.2**
4x5	2.2	-6.3	18.0**	12.0**	60.5**	49.2**	20.5**	0.0	0.3	-20.5**	40.3**	11.2
4x6	18.9**	10.7*	5.0	-3.1	28.8**	27.8**	4.7	-1.3	6.7	-1.9	9.1	-6.8
4x7	24.8**	24.0**	31.3**	17.2**	39.9**	34.2**	-0.6	-10.3	9.1	-6.1	54.1**	42.8**
4x8	30.0**	28.4**	42.5**	23.8**	56.7**	46.7**	14.8*	-2.0	24.9**	3.6	39.0**	30.4*
4x9	-1.8	-17.6**	18.4**	-14.4**	18.3*	-9.7	-5.9	-18.0*	-4.2	-1.2	8.5	-18.0
4x10	12.8*	-8.4	-10.0	-28.8**	20.1*	-13.6	16.3*	-2.0	-14.9	-21.6*	-6.6	-14.6
5x6	23.2**	21.2**	25.6**	21.8**	55.4**	43.4**	22.2**	6.6	3.5	-12.0	50.0**	36.9**
5x7	49.0**	37.5**	12.4**	5.3	50.2**	45.3**	18.1**	7.5	-2.8	-11.8	36.3**	14.8
5x8	26.1**	14.4**	37.3**	25.0**	46.9**	45.7**	22.9**	18.9**	32.7**	25.5**	20.0*	0.0

5x9	20.3**	9.0	19.0**	-16.6**	41.9**	14.5	-5.1	-29.2**	-5.7	-26.8**	-4.3	-37.8**
5x10	12.9*	-1.3	-1.1	-24.6**	21.8*	-8.0	14.4**	12.3*	-25.5**	-36.8**	-43.0**	-57.7**
6x7	26.0**	18.1**	-3.6	-7.0	50.8**	43.6**	15.7*	10.3	18.3*	10.1	35.1**	23.6*
6x8	18.2**	8.8	16.2**	8.8*	72.7**	60.5**	24.7**	12.1	9.1	-2.6	45.8**	31.9**
6x9	10.2	-1.5	-3.6	-33.6**	39.3**	5.8	0.8	-16.5	-8.0	-17.7*	-16.0	-42.8**
6x10	3.8	-10.5	-15.6**	-37.0**	4.7	-25.0**	11.6	-1.0	-2.9	-3.2	-35.2**	-48.6**
7x8	11.8**	9.7	5.2	2.1	65.2**	61.1**	10.8	4.0	12.0	7.1	60.9**	58.9**
7x9	-8.6	-22.9**	0.2	-32.3**	15.6	-9.0	-9.4	-27.6**	-11.4	-25.7**	-11.7	-36.6**
7x10	-5.8	-23.1**	-9.1	-33.8**	30.4**	-3.7	-3.7	-10.8	3.6	-3.9	-15.9	-28.3*
8x9	-18.2**	-32.0**	-6.1	-37.6**	24.4*	-0.2	-8.6	-30.3**	-26.9**	-40.8**	-5.7	-31.7*
8x10	1.8	-18.1**	-16.0**	-40.0**	20.8*	-9.2	-4.5	-5.9	-15.4*	-24.7**	-22.3	-33.0*
9x10	-8.2	-11.9	19.9*	5.9	6.7	-2.2	7.8	-18.6**	-0.4	-10.7	-27.8	-41.5*
SE	5.86	6.77	0.85	0.98	2.89	3.34	0.21	0.24	0.15	0.17	8.15	9.41
CD 5%	11.60	13.40	1.69	1.95	5.72	6.61	0.42	0.48	0.29	0.33	16.14	18.62
CD 1%	15.12	17.47	2.20	2.54	7.46	8.61	0.54	0.62	0.38	0.44	21.03	24.27

Table 3. *Range of Heterosis (H), Heterobeltiosis (HB) percent and number of significant crosses for different yield and its contributing traits at Sakrand environment.*

Traits	**Heterosis**		**Heterobeltiosis**		**No. of significant positive hybrids**	
	Minimum	**Maximum**	**Minimum**	**Maximum**	**H**	**HB**
Plant Height (cm)	-18.2	51.9	-32.0	47.2	31	20
Sympodial Branches Plant^{-1}	-18.4	42.5	-38.5	30.6	24	15
Bolls Plant^{-1}	-5.0	72.7	-34.0	64.0	35	22
Boll Weight (g)	-16.0	34.3	-35.7	29.2	24	09
Seed index (g)	-40.1	34.0	-52.4	25.5	10	04
Seed Cotton Yield Plant^{-1}	-43.0	60.9	-59.4	58.9	22	14

While at Mirpurkhas location 35 hybrids found with significant positive heterosis ranging from -16.7 to 52.8 and 24 hybrids exhibited significant positive heterobeltiosis with range of -23.6 to 46.3 (Table 5 & 6). The top most superior hybrids were identified on the basis of higher per se (mean) performance for plant height. The hybrids MNH-886 x Baghdadi (51.9 and 47.2), Baghdadi x NIAB-824 (49.0 and 34.5) and CRIS-129 x Baghdadi (48.7 and 42.3) were found with highest significant positive heterosis and heterobeltiosis for Sakrand environment (Table 4). Whereas, at Mirpurkhas environments, hybrids Baghdadi x CEMB-33 (52.8 and 46.3), NIA-Noori x Baghdadi (38.0 and 31.8) and MNH-886 x Baghdadi (37.0 and 21.7) unveiled highest mid and better parent heterosis and found as superior crosses (Table 7).

Table 4. *Superior crosses on the basis of heterosis and heterobeltiosis percent for yield and its contributing traits at Sakrand environment.*

Traits	Superior Crosses	Per se Performance	Heterosis (H)	Heterobeltiosis (HB)
Plant Height (cm)	MNH-886 x Baghdadi	148.6	51.9**	47.2**
	Baghdadi x NIAB-824	153.9	49.0**	37.5**
	CRIS-129 x Baghdadi	147.4	48.7**	42.3**
Sympodial Branches Plant^{-1}	NIA-Noori x CEMB-33	27.6	42.5**	23.8**
	Baghdadi x CEMB-33	27.8	37.3**	25.0**
	FH-142 x CEMB-33	26.3	33.0**	18.0**
Bolls Plant^{-1}	CIM-602 x CEMB-33	59.7	72.7**	60.5**
	MNH-886 x CIM-602	66.0	70.5**	64.0**
	NIAB-824 x CEMB-33	54.2	65.2**	61.1**
	NIA-Noori x Baghdadi	54.6	60.5**	49.2**
	NIA-Noori x CEMB-33	53.7	56.7**	46.7**
	FH-142 x CIM-602	62.7	56.7**	46.4**
Boll Weight (g)	FH-142 x Baghdadi	4.6	34.3**	29.2**
	MNH-886 x Baghdadi	4.3	32.0**	22.6**
	CRIS-129 x CEMB-33	3.7	25.7**	11.1
Seed index (g)	CRIS-129 x CEMB-33	8.1	34.9**	24.0**
	Baghdadi x CEMB-33	9.2	32.7**	25.5**
	FH-142 x Baghdadi	9.2	27.9**	25.0**
Seed Cotton Yield Plant^{-1}	NIAB-824 x CEMB-33	91.9	60.9**	58.9**
	CRIS-129 x CIM-602	128.9	56.0**	34.8**
	MNH-886 x CIM-602	114.1	55.3**	47.7**
	NIA-Noori x NIAB-824	82.6	54.1**	42.8**
	Baghdadi x CIM-602	115.6	50.0**	36.9**
	MNH-886 x FH-142	108.2	49.4**	38.2**

Table 5. *Heterosis (H) and Heterobeltiosis (HB) assessment for seed cotton yield and its contributing traits at environmental conditions of Mirpurkhas.*

F_1	Plant Height		Sympodial Branches		Bolls Plant^{-1}		Boll Weight		Seed Index		Seed Cotton Yield Plant^{-1}	
	H	HB	H	HB	H	HB	H	HB	H	HB	H	HB
1x2	28.5**	23.0**	6.8	0.4	21.8**	12.6*	10.9	2.1	5.6	-1.5	19.6**	8.2
1x3	23.8**	21.0**	25.7**	22.5**	63.1**	43.4**	23.9**	9.6	21.2**	9.1	42.6**	25.0*
1x4	17.4**	13.4**	-6.2	-6.2	11.8*	7.7	11.0	7.5	-35.6**	-43.2**	3.7	2.7
1x5	23.7**	14.3**	29.1**	24.6**	15.9**	18.8**	31.4**	22.8**	39.4**	30.8**	38.1**	29.6**
1x6	23.5**	17.3**	15.5**	11.3**	28.2**	18.1**	-2.4	-7.8	0.5	-1.6	20.0*	11.1
1x7	21.8**	14.6**	41.2**	32.6**	43.2**	23.2**	14.0*	6.5	5.2	1.7	35.8**	14.2*
1x8	-5.1	-8.6	29.7**	26.4**	49.2**	46.6**	23.2**	6.4	26.0**	14.6**	44.8**	43.0**
1x9	30.5**	4.7	3.5	-24.3**	3.0	-17.2*	-1.5	-18.8*	-42.5**	-52.4**	-42.7**	-62.0**
1x10	20.3**	3.6	16.2**	-10.9*	20.3**	-9.3	-1.1	-9.4	5.3	2.2	-6.3	-27.2*
2x3	29.6**	21.4**	8.3*	4.4	52.5**	25.4**	14.6*	9.6	-2.8	-6.5	33.9**	7.8
2x4	17.5**	8.9*	12.5**	5.8*	14.7**	9.8	15.3*	3.2	-9.2	-24.6**	-3.1	-13.0
2x5	37.0**	21.7**	29.2**	17.6**	20.9**	14.3*	29.4**	27.4**	31.9**	31.0**	41.1**	35.8**
2x6	17.7**	7.3	-0.9	-3.3	23.2**	22.7**	-7.0	-9.5	-2.3	-10.6	-15.1*	-17.2*
2x7	13.8**	11.8*	4.7	-7.1	16.7**	8.0	-13.4*	-14.7*	-15.0**	-18.1**	19.4**	9.9
2x8	32.4**	22.3**	20.2**	10.4**	14.0**	3.7	6.3	-0.9	-1.9	-4.6	-13.2	-20.6*
2x9	-6.0	-27.0**	-28.9**	-50.0**	-2.9	-26.4**	-14.3*	-33.7**	-39.7**	-52.7**	-39.0**	-61.4**
2x10	1.6	-15.6**	-28.0**	-47.0**	-6.9	-33.4**	4.7	4.2	-12.3*	-20.4**	-21.8*	-43.3**

3x4	32.1**	30.6**	16.5**	13.5**	61.8**	37.8**	0.6	-13.5*	-0.2	-19.6**	43.6**	26.9*
3x5	22.6**	15.8**	29.9**	22.3**	56.0**	34.4**	29.6**	22.1**	9.0*	4.3	62.8**	35.1**
3x6	36.0**	32.1**	-14.7**	-15.8**	36.7**	12.0*	-4.1	-10.6	-2.5	-13.9	15.0	-5.6
3x7	4.4	-3.8	8.4	-0.6	41.4**	9.4*	11.2*	4.8	18.5**	10.1*	-4.0	-27.4**
3x8	27.3**	25.4**	17.8**	12.0**	44.7**	29.3**	27.1**	23.6**	16.0**	14.7**	47.5**	27.9*
3x9	-1.6	-19.7**	-19.6**	-42.2**	11.0	-0.1	-15.4*	-36.5**	-20.5**	-39.4**	-37.6*	-55.3**
3x10	-12.7*	-23.2**	-7.8	-30.5**	22.3**	2.1	11.0*	6.7	0.5	-11.9	-6.6	-18.9
4x5	38.0**	31.8**	21.6**	17.3**	8.3	6.8	43.7**	30.4**	10.8*	-7.6	-5.0	-11.7
4x6	33.3**	31.0**	2.9	-0.9	33.9**	27.7**	5.5	-3.3	15.0*	3.2	11.2	2.1
4x7	10.1*	0.3	16.7**	9.6*	20.2**	6.9	0.6	-8.7	7.3	-8.2	13.2	-5.6
4x8	30.5**	30.1**	17.0**	14.1**	1.1	-4.2	8.1	-9.1	8.1	-12.2*	-13.9	-15.7
4x9	-2.4	-19.6**	-15.7**	-38.4**	10.4	-13.7*	-0.8	-16.0*	1.4	-5.7	-32.8*	-55.2**
4x10	2.9	-8.7	-20.6**	-39.1**	15.5*	-15.1*	22.8**	9.4	-7.9	-16.7*	-28.5*	-44.1**
5x6	34.8**	31.0**	28.5**	19.7**	35.1**	27.3**	-4.0	5.4	9.7*	0.9	35.0**	33.1**
5x7	25.7**	9.9*	51.8**	47.6**	15.8**	1.8	10.9	10.9	14.0**	10.6*	-18.8**	-27.8**
5x8	52.8**	46.3**	28.6**	27.3**	38.6**	33.0**	38.6**	27.3**	35.5**	31.0**	39.5**	32.4**
5x9	31.9**	12.9*	15.7**	-13.4**	-7.4	-26.9**	-9.7	-29.3**	-17.2**	-34.8**	-30.3*	-55.2**
5x10	11.8*	3.6	-15.5**	-33.4**	14.0*	-15.4*	18.1**	15.6*	15.3**	5.2	-1.8	-27.0**
6x7	24.5**	11.7*	27.6**	15.8**	27.9**	18.8**	0.0	-1.1	-7.4	-12.3	4.8	-5.7
6x8	32.3**	30.4**	9.6*	3.0	0.2	-9.2	-5.0	-13.6	7.3	-4.3	41.7**	32.8**
6x9	27.3**	6.4	-13.6**	-38.3**	-7.7	-30.2**	-11.3	-30.0**	-10.9	-25.0**	-51.3**	-68.9**
6x10	11.9*	0.9	-26.3**	-44.9**	-9.0	-35.0**	6.5	3.1	11.4*	10.3	-37.8**	-54.2**
7x8	18.0**	7.3	38.8**	33.6**	-7.5	-21.6**	10.9*	1.8	14.5**	7.5	29.2**	9.8
7x9	15.9**	-11.2*	22.9**	-6.3	-13.7*	-37.9**	-8.3	-28.3**	-43.1**	-54.1**	-34.2**	-59.8**
7x10	-1.1	-19.0**	-12.6*	-29.7**	-6.4	-36.1**	3.2	1.0	5.3	-1.2	-35.0**	-55.2**
8x9	30.1**	7.5	4.5	-22.4**	4.8	-14.6*	-14.8*	-37.3**	-37.8**	-52.2**	-40.3**	-60.7**
8x10	13.6*	1.1	-15.3*	-33.8**	28.1**	-2.2	3.9	-2.7	-16.2**	-25.8**	-13.9	-33.7**
9x10	-16.7*	-23.6**	18.0*	10.0	-0.5	-1.9	2.7	-20.8**	-16.0*	-28.7**	-9.5	-28.2
SE	6.49	7.49	0.97	1.13	2.96	3.42	0.24	0.28	0.44	0.51	9.17	10.59
CD 5%	12.85	14.85	1.92	2.23	5.85	6.76	0.48	0.56	0.87	1.01	18.16	20.96
CD 1%	16.74	19.34	2.50	2.91	7.62	8.81	0.62	0.72	1.14	1.32	23.66	27.32

Table 6. *Range of Heterosis (H), Heterobeltiosis (HB) and number of significant crosses for different yield and its contributing traits at Mirpurkhas environment.*

Traits	**Heterosis**		**Heterobeltiosis**		**No. of significant positive hybrids**	
	Minimum	**Maximum**	**Minimum**	**Maximum**	**H**	**HB**
Plant Height (cm)	-16.7	52.8	-23.6	46.3	35	24
Sympodial Branches Plant^{-1}	-28.9	51.8	-50.0	47.6	25	19
Bolls Plant^{-1}	-13.7	63.1	-37.9	46.6	29	18
Boll Weight (g)	-15.4	43.4	-37.3	30.7	16	07
Seed index (g)	-43.1	39.4	-54.1	31.0	15	07
Seed Cotton Yield Plant^{-1}	-51.3	62.8	-68.9	43.0	16	11

Similar results were obtained by [2, 11, 14, 15, 16]. Sympodial branches plant^{-1} is considered as fruiting branches and yield contributing trait because boll setting occurs on these fruiting branches. In Sakrand environment 24 hybrids expressed significant positive heterosis. The minimum hybrid found with -18.4 and highest was 42.5. The 15 hybrids produced significant positive heterobeltiosis with range of -38.5 to 30.6. The superior hybrids which expressed highest heterosis and heterobeltiosis with high value of mean performance for sympodial branches plant^{-1} NIA-Noori x CEMB-33 (42.5 and 23.8), Baghdadi x CEMB-33 (37.3 and 25.0) and FH-142 x CEMB-33 (33.0 and 18.0). It was noted that the top three hybrids which given maximum heterosis and heterobeltiosis at Sakrand environment have same male parent (CEMB-33) with higher sympodial branches as compared with other. At the Mirpurkhas environmental condition the heterosis range was observed from -28.9 to 51.8 and -50 to 47.6 for heterobeltiosis. Among the 45 hybrids, 25 were given significant positive heterosis and 19 heterobeltiosis for sympodial branches plant^{-1}. The top most superior hybrids were recorded which manifested maximum significant positive heterosis and heterobeltiosis Baghdadi x NIAB-824 (51.8 and 47.6), CRIS-129 x NIAB-824 (41.2 and 32.6) and NIAB-824 x CEMB-33 (38.8 and 33.6). [2, 16, 17, 18] also reported similar findings with high heterosis and heterobeltiosis for sympodial branches plant^{-1}.

Table 7. *Superior crosses on the basis of heterosis and heterobeltiosis percent for yield and its contributing traits at the environmental condition of Mirpurkhas.*

Traits	**Superior Crosses**	**Per se Performance**	**Heterosis (H)**	**Heterobeltiosis (HB)**
Plant Height (cm)	Baghdadi x CEMB-33	154.4	52.8**	46.3**
	NIA-Noori x Baghdadi	139.9	38.0**	31.8**
	MNH-886 x Baghdadi	151.5	37.0**	21.7**
Sympodial Branches Plant^{-1}	Baghdadi x NIAB-824	28.2	51.8**	47.6**
	CRIS-129 x NIAB-824	27.3	41.2**	32.6**
	NIAB-824 x CEMB-33	26.1	38.8**	33.6**
Bolls Plant^{-1}	CRIS-129 x FH-142	57.7	63.1**	43.4**
	FH-142 x NIA-Noori	59.8	61.8**	37.8**
	FH-142 x Baghdadi	56.8	56.0**	34.4**
	MNH-886 x FH-142	59.4	52.5**	25.4**
	CRIS-129 x CEMB-33	58.9	49.2**	46.6**
Boll Weight (g)	NIA-Noori x Baghdadi	4.0	43.7**	30.4**
	Baghdadi x CEMB-33	4.7	38.6**	27.3**
	CRIS-129 x Baghdadi	3.8	31.4**	22.8**
Seed index (g)	CRIS-129 x Baghdadi	9.2	39.4**	30.8**
	Baghdadi x CEMB-33	9.9	35.5**	31.0**
	MNH-886 x Baghdadi	9.3	31.9**	31.0**
Seed Cotton Yield Plant^{-1}	FH-142 x Baghdadi	121.5	62.8**	35.1**
	FH-142 x CEMB-33	103.4	47.5**	27.9**
	CRIS-129 x CEMB-33	115.6	44.8**	43.0**
	FH-142 x NIA-Noori	98.1	43.6**	26.9**
	CRIS-129 x FH-142	98.5	42.6**	25.0**
	MNH-886 x Baghdadi	100.2	41.1**	35.8**

The trait bolls plant^{-1} have a special attention in cotton breeding program, it is an important yield contributing character, because if the number of bolls plant^{-1} will be increased simultaneously amplified in seed cotton yield. The superior hybrids for heterosis and heterobeltiosis for the environmental conditions of Sakrand (Table 4) indicated that hybrids which attained high mean phenotypic value also possessed high heterosis and heterobeltiosis. The hybrids CIM-602 x CEMB-33, MNH-886 x CIM-602, NIAB-824 x CEMB-33, NIA-Noori x Baghdadi, NIA-Noori x CEMB-33, FH-142 x CIM-602 given highest significant heterosis and heterobeltiosis. Out of 45 cross combinations, 35 hybrids noted with significant heterosis and 22 for heterobeltiosis, the minimum -5.0 and maximum 72.7 heterosis was observed. While, heterobeltiosis value lowest was -34 percent and highest value was 64 percent given by hybrids at Sakrand location (Table 2 and 3). As regards the Mirpurkhas location (Table 5) results indicated that 29 hybrids noted with significant positive heterosis and 18 for heterobeltiosis. The range of heterosis was observed from -13.7% to 63.1% and for heterobeltiosis -37.9% to 46.6% (Table 6). The superior hybrids which exhibited high significant positive heterosis and heterobeltiosis at the Mirpurkhas locations are CRIS-129 x FH-142, FH-142 x NIA-Noori, FH-142 x Baghdadi, MNH-886 x FH-142 and CRIS-129 x CEMB-33 (Table 7). The concise results of these findings are according with [15, 19, 20, 21, 22] reported significant positive heterosis and heterobeltiosis for bolls plant^{-1}. The character boll weight is also key factor which increase yield. The 24 hybrids were found with significant positive heterosis and 09 for heterobeltiosis with range from -16% to 34.3% and -35.7% to 29.2% respectively (Table 2 and 3). It was noted that hybrids with high mean value also exhibited maximum heterosis and heterobeltiosis for boll weight (Table 4). The crosses FH-142 x Baghdadi, MNH-886 x Baghdadi and CRIS-129 x CEMB-33 are superior for Sakrand locations with highest significant positive heterosis and heterobeltiosis. Table 5 and 6 represent the results of Mirpurkhas environment which indicated that 16 hybrids produced significant positive heterosis and 07 for heterobeltiosis. The range of heterosis was calculated from -15.4% to 43.4% and from -37.3% to 30.7% for heterobeltiosis. Among the 45 hybrids, the superior cross combinations were noted NIA-Noori x Baghdadi, Baghdadi x CEMB-33 and CRIS-129 x Baghdadi with significant positive heterosis and heterobeltiosis (Table 7). These results are confirmed with [15, 16, 23, 24].

For the trait seed index 10 hybrids found with significant positive heterosis with range from -40.1% to 34.0%, whereas, only 04 hybrids exhibited heterobeltiosis ranging with -52.4% to 25.5% (Table 2 and 3). As regards the superior cross combinations (Table 4), hybrids CRIS-129 x CEMB-33, Baghdadi x CEMB-33 and FH-142 x Baghdadi found best for the environmental conditions of Sakrand. While results of Mirpurkhas locations, 15 hybrids shown significant positive heterosis and 07 for heterobeltiosis with ranging from -43.1% to 39.4% and -54.1% to 31% respectively (Table 5 and 6). The superior hybrids were identified CRIS-129 x Baghdadi, Baghdadi x CEMB-33 and MNH-886 x Baghdadi according the higher mean value and maximum significant positive heterosis and heterobeltiosis. Similar results were obtained by [6, 11, 17, 22]. Seed cotton yield is compound trait which depend on supporting traits bolls plant^{-1} and boll weight, in both characters increasing results encourage the improvement in seed cotton yield. The data presented in (Table 2 and 3) expressed those 22 hybrids given significant positive heterosis and 14 heterobeltiosis. The heterosis range was observed from -43% to 60.9% and from -59.4% to 58.9% for heterobeltiosis. Among the superior cross combinations (Table 4) revealed that hybrids NIAB-824 x CEMB-33, CRIS-129 x CIM-602, MNH-886 x CIM-602, NIA-Noori x NIAB-824, Baghdadi x CIM-602 and MNH-886 x FH-142 excelled highest significant positive heterosis and heterobeltiosis in Sakrand environment and which suggested that special consideration should be given to these hybrids. However, at Mirpurkhas location the hybrids range was noted from -51.3% to 62.8% for mid parent and -68.9% to 43% for better parent heterosis. The 16 hybrids manifested significant positive mid and 11 shown better parent heterosis (Table 5 and 6). The superior cross was identified which shown higher heterotic performance for both mid and better parent are NIAB-824 x CEMB-33, CRIS-129 x CIM-602, MNH-886 x CIM-602, NIA-Noori x NIAB-824, Baghdadi x CIM-602 and MNH-886 x FH-142. These hybrids exhibited higher mean value and heterotic effect which need to special attention

(Table 7). [9] suggested that good cross combinations could be utilized for heterosis. The earlier worker [1, 12, 25] also reported similar results of significant mid and better parent heterosis.

CONCLUSION

In this study, 45 F1 hybrids developed through half diallel were assessed for heterosis and heterobeltiosis at two environments of Sindh. Positive influence of environment was observed for the results of heterosis and heterobeltiosis; therefore, hybrids produced more than 50% heterosis for the traits could be selected to boost up seed cotton yield. However, parents combinations performed best must pick for utilization in breeding program to develop hybrids.

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