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Full Length Article

Heterosis Manifestation for Yield and Yield Components under Two Water Regimes in Cotton

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ABSTRACT

Genetic improvement in seed cotton yield has always been a top priority of cotton breeders. The present study, therefore, was conducted in triplicated trial comprising thirty F_1 and six parents under normal and drought conditions. Different crosses showed heterosis of high exploitable magnitude for different characters. Significant negative heterosis and heterobeltiosis under both water regimes was manifested for initial Nodes by FH-901×FH-634; for Plant height by HR-VO-1×BH-118, FH-634×BH-118, FH-634×CIM-448 and for number of monopodial branches by FH-634×HR-VO-1. Significant positive heterosis and heterobeltiosis under both water regimes was manifested for number of sympodial branches per plant by FH-901×HR-VO-1 and CIM-448×Krishna and their reciprocals; for number of boll per plant by FH-901 X Krishna and CIM-448×Krishna and their reciprocal; for GOT % by CIM-448 × BH-118 and its reciprocal, CIM-448×HR-VO-1 and BH-118×HR-VO-1 and for seed cotton yield by FH-901 × Krishna, CIM-448×Krishna and their reciprocals and Krishna×FH-634. Whereas, for Boll weight, FH-634×CIM-448 and BH-118×CIM-448 under normal and hybrids FH-901×Krishna and it's reciprocal under water stress regime manifested significant positive heterosis and heterobeltiosis.

Key Words: Yield; Manifested; Krishna; Water regimes; Number of monopodial branches; Cotton

INTRODUCTION

Pakistan lies in the semiarid region of the world therefore, supplemental irrigation is necessary for cotton production. Under this situation, the preparation and implementation of strategies are essential for growing cotton successfully under scarce water conditions. Drought tolerant cotton cultivars are required to harvest maximum seed cotton yield per unit of irrigation water. Water deficit causes loss in growth and productivity. Yield is generally reduced because of reduced boll production, boll abortions and fewer flowers when it occurs during reproductive growth (Grimes & Yamada, 1982; McMichael & Hesketh, 1982; Turner *et al.,* 1986; Gerik *et al.,* 1996; Pettigrew, 2004).

Plant breeders include heterosis studies in their breeding programs for the commercial exploitation in the form of hybrid development. The hybrids are better yielding; morpho-physiologically uniform and being heterozygous have wider adaptability. Studies have also shown that hybrids performed better than open pollinated cotton cultivars under drought stress (Patil, 2007).

The manifestation of heterosis requires directional dominance, duplicate genes and gene dispersion (Kearsey & Pooni, 1996). Studies had also shown that magnitude of heterosis decreased with the water supply (Rauf, 2009). Therefore, higher magnitude of heterosis may also be used as criteria for selection of tolerant hybrids.

With the same in mind, studies were carried out to determine the magnitude of heterosis in cotton under normal and water stress condition.

MATERIALS AND METHODS

Six upland cotton types (Table I) were sown in greenhouse during October, 2002 and all possible crosses i.e., thirty (Table II) were successfully attempted at flowering during February, March, 2003. The temperature of the greenhouse was maintained from 60° to 90°F by using steam and electric heaters. Relative humidity ranged from 50 to 75%. Moreover to create optimum desirable agro-climatic condition, plants were given full plant protection umbrella. The homozygosity of the parental material was being maintained by selfing.

The hybrid and parental material was sown in the field in triplicate randomized complete block design in factorial setup under two water regimes e.g., normal and water stress. Plants under normal were well watered throughout the growth period, whereas under water stress the plants had

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alternative irrigations i.e., had half the quantity of water applied to the normal. 10 plants randomly were tagged in each replication of a treatment for recording the data. The average of each character was then computed using data from these ten plants. Two plants on each side of the row were left as non-experimental. Numbers of nodes were counted from the cotyledonary node to the appearance of first monopodial branches. At maturity, the monopodial and sympodial branches developed at each plant were counted and then the average was calculated. The height of the plants was recorded in centimeters by the meter rod, when the apical growth of the main stem was ceased. The height was recorded from the cotyledonary node to the apical bud. The total seed cotton of all the pickings from each plant was weighed on an electronic balance separately. The average seed cotton yield per plant was then computed for every type. The number of effective bolls collected in different pickings from each plant separately were counted and then averaged for the respective genotypes. The weight per boll was worked out by dividing the total yield of seed cotton by the number of effective bolls on the respective plants. The average boll weight per plant for each type was then calculated. The seed cotton from each plant was ginned separately with a single roller electric gin. The lint thus obtained was weighed and ginning outturn percentage was calculated by using the following formula:

Ginning outturn percentage= 100 (Weight of lint/Weight of seed cotton)

Heterosis and heterobeltiosis were calculated in term of percent increase (+) or decrease (-) of a hybrid against its parental mean value and better parent, respectively. The "t" values were calculated by the formula $"t"=(F_{1ij} - MP_{ij})/(3/8\ EMS)^{1/2}$ for heterosis and $"t"=(F_{1ij} - BP_{ij})/(1/2\ EMS)^{1/2}$ for heterobeltiosis (better parent heterosis); Where: F_{ij} = the mean of the ij^{th} cross; MP_{ij} = the mid parent value of the ij^{th} cross; EMS = error mean square.

RESULTS

Significant differences were observed among various cotton types including parents, hybrids and reciprocals under both the water regimes (Table III) for all the characters under study. Generally the hybrids, which showed the highest heterosis under normal condition also showed the best performance for the same character under water stress, but it was not necessary that a hybrid showing significant heterosis under normal would also show significant heterosis under water stress. It was also not necessary that both direct and reciprocal crosses had similar performance under normal or water stress or both water regimes although instances in the present studies are present. Varying degree of heterosis manifestation was observed over the mid and better parents for all the traits. Generally number of hybrid and magnitude of heterosis was greater under normal irrigations compared to water stress regime.

Heterosis for number of nodes under normal and water stress conditions (Table IV) varied both in direction and magnitude and turned up dependent on genotypes of parents. Since the nodes number before the appearance of first monopodia on plant is perceived related with the plant height and late maturity therefore, negative heterosis is likely to be preferred in breeding programs. Hybrid FH-901×FH-634 expressed significant heterosis over the mean of the parents as well as over better parent under both water regimes; another hybrid HR-V0-1×FH-634 expressed heterosis over the mean of the parents as well as over better parent under normal conditions of irrigation.

Heterosis for Plant height under normal and water stress conditions (Table IV) varied both in direction and magnitude and turned up dependent on genotypes of parents. Similar to number of nodes before the appearance of first monopodia negative heterosis is likely to be preferred in breeding programs. Hybrids HR-VO-1×BH-118, FH-634×BH-118, FH-634×CIM-448 had better and exploitable heterosis manifestation under both the water regimes over mean of the parents and over better parent as well.

Table V showed that 47% and 50% of the crosses showed positive heterosis under normal and drought conditions, respectively. The hybrid, FH-634×HR-VO-1 had significant negative heterosis as well as heterobeltiosis under both the water regimes. The magnitude of heterosis was variable depending upon the parents. Besides FH-634×HR-VO-1, the hybrids, CIM-448×HR-VO-1 and HR-V0-1×FH-634 also had significant negative heterosis and heterobeltiosis under normal and hybrids BH-118 x CIM-448 and HR-VO-1 × Krishna under water stress regime.

The data (Table V) indicated that 53.6% crosses showed significant positive heterosis under normal, but none of the crosses showed significant positive heterosis under water stress condition. The level of heterosis manifestation was reduced under water stress conditions. Similarly 30% of the total crosses showed significant heterobeltiosis only under normal condition and none of the crosses showed significant positive heterosis under water stress condition. The hybrids, FH-901×HR-VO-1 and CIM-448 X Krishna and their reciprocals and FH-901 × Krishna showed comparatively better heterosis and heterobeltiosis under normal condition.

Table VI revealed positive heterosis for boll weight ranged from 2.30 to 12.25% under normal condition, while it ranged from 2.49 to 31.11% under water stress condition. Positive heterobeltiosis for this character ranged from 0.38 to 9.07% and 1.47 to 26.64% under normal and water stress conditions, respectively. The hybrids FH-634×CIM-448 and BH-118×CIM-448 under normal and hybrids FH-901×Krishna and it's reciprocal under water stress regime showed significant and comparatively better heterosis and heterobeltiosis.

Table I. List of parental material used in crosses

Types	Main Features
1. FH-634	High yield, low susceptibility to water stress, CLCuV resistant, tall growing
2. FH-901	High yield, high susceptibility to water stress, CLCuV resistant, early maturing, almost single monopodia
3. CIM-448	Low yield, medium susceptibility to water stress, CLCuV resistant, broad leaves
4. BH-118	High yield, low susceptibility to water stress, CLCuV resistant, tall growing
5. HR-VO-1	High yield, medium susceptibility to water stress, CLCuV susceptible, Okra leaves and profusely hairy (velvet type)
6. Karishna	Low yield, high susceptibility to water stress, CLCuV susceptible, early maturing and necariless

Table II. List of crosses in upland cotton (*G. hirsutum* L.)

Crosses		Reciprocals	
1 x 2	FH-634 x FH-901	2 x 1	FH-901 X FH-634
1 x 3	FH-634 x CIM-448	3 x 1	CIM-448 X FH-634
1 x 4	FH-634 x BH-118	4 x 1	BH-118 X FH-634
1 x 5	FH-634 x HR-VO-1	5 x 1	HR-V0-1 X FH-634
1 x 6	FH-634 x Krishna	6 x 1	Krishna X FH-634
2 x 3	FH-901 X CIM-448	3 x 2	CIM-448 X FH-901
2 x 4	FH-901 X BH-118	4 x 2	BH-118 x FH-901
2 x 5	FH-901 X HR-VO-1	5 x 2	HR-VO-1 X FH-901
2 x 6	FH-901 X Krishna	6 x 2	Krishna X FH-901
3 x 4	CIM-448 X BH-118	4 x 3	BH-118 x CIM-448
3 x 5	CIM-448 X HR-VO-1	5 x 3	HR-VO-1 X CIM-448
3 x 6	CIM-448 X Krishna	6 x 3	Krishna X CIM-448
4 x 5	BH-118 x HR-VO-1	5 x 4	HR-VO-1 X BH-118
4 x 6	BH-118 x Krishna	6 x 4	Krishna X BH-118
5 x 6	HR-VO-1 X Krishna	6 x 5	Krishna X HR-VO-1

Table III. Mean squares for analysis of variance of morphological traits under normal and water stress regimes

Traits	Normal			Water stress		
	Replication df=2	Genotype df=35	Error df=70	Replication df=2	Genotype df=35	Error df=70
Nodes/Plant	0.15*	1.25**	0.05	1.05*	1.12**	0.25
Height	37.51	279.16**	42.58	1.11	324.24**	3.51
Monopodial	0.83*	0.41**	0.19	1.04*	0.59**	0.26
Sympodial	10.31**	14.02**	1.93	6.57	5.89**	2.73
Boll weight	0.19**	0.12**	0.03	1.78**	0.19*	0.10
No of bolls	4.65	72.60**	5.72	2.53	38.31**	3.95
GOT (%)	2.87	5.45**	1.17	0.78	5.23**	0.72
Yield	584.81**	733.10**	89.63	331.55**	428.99**	50.51

*Significant (P=0.05) ** Significant

Heterosis studies for number of bolls per plant (Table VI) revealed that 53.3% and 30% of the total crosses showed significantly positive heterosis; ranging from 14.33 to 77.47% and 20.72 to 95.22% under normal and water stress regimes, respectively and 26.6% and 13.3% of the crosses revealed positive heterobeltiosis; ranging from 17.48 to 62.74% and 29.73 to 80.08% under normal and water stress regimes, respectively. The hybrids FH-901 × Krishna and CIM-448 × Krishna and their reciprocal had significant and comparatively better positive heterosis and heterobeltiosis under both the water regimes.

Thirty (30%) and 60% of the total crosses had significant positive heterosis under normal and drought

Table IV. Heterosis manifestations for number of nodes and plant height under water regimes

Crosses	Number of nodes				Plant height			
	Normal		Drought		Normal		Drought	
	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
C 1 x 2	-4.76**	-6.25**	-5.08	-10.78*	12.65**	9.60*	27.06**	11.12**
C 1 x 3	3.85	-12.90**	-9.28	-14.21**	-12.24**	-18.06**	-3.37*	-4.76**
C 1 x 4	6.67**	3.23	8.98	1.39	-15.77**	-26.23**	-6.24**	-17.15**
C 1 x 5	-2.79	-6.45**	20.24**	4.74	2.38	-4.45	-2.55	-5.62**
C 1 x 6	1.62	1.08	3.06	-1.39	18.56**	16.22**	5.96**	1.93
C 2 x 1	-7.94**	-9.38**	-11.34*	-16.67**	6.85	3.96	6.63**	-6.75**
C 2 x 3	9.43**	-9.38**	5.49	-5.88	-0.66	-4.79	-13.39**	-25.19**
C 2 x 4	-3.83	-8.33**	16.04**	1.96	-7.49	-16.99**	-7.20**	-26.94**
C 2 x 5	3.30	-2.08	-1.54	-18.63**	13.51**	3.28	5.36**	-5.21**
C2 x 6	2.13	0.00	1.79	-8.19	19.12**	18.22**	9.83**	-0.56
C3 x 1	-2.56	-18.28**	4.86	-0.84	2.06	-4.72	-14.65**	-15.88**
C3 x 2	28.30**	6.25**	8.79	-2.94	-4.78	-8.74*	-3.73	-16.85**
C3 x 4	-2.67	-16.09**	17.01**	15.00**	0.78	-5.94	-23.19**	-31.26**
C3 x 5	-2.01	-15.12**	5.05	-3.75	0.22	-12.23**	-18.76**	-22.41**
C3 x 6	10.97**	-6.52**	16.48**	15.06**	6.57	1.40	28.33**	21.74**
C4 x 1	5.56*	2.15	6.59	-0.84	-7.95	-19.38**	-29.21**	-37.45**
C4 x 2	21.31**	15.63**	19.39**	4.90	-1.55	-11.66**	8.10**	-14.89**
C4 x 3	14.00**	-1.72	10.52	8.63	-5.14	-11.46**	-12.05**	-21.29**
C4 x 5	7.51**	6.90**	18.18**	10.03	-5.15	-21.68**	-4.61**	-18.02**
C4 x 6	12.85**	9.78**	-2.04	-4.88	1.73	-9.33*	12.20**	-4.15**
C5 x 1	-18.44**	-21.51**	6.17	-7.52	7.14	0.00	1.30	-1.89
C5 x 2	-12.09**	-16.67**	0.83	-16.67**	19.46**	8.69	4.03*	-6.41**
C5 x 3	23.49**	6.98**	24.15**	13.75*	-4.81	-16.63**	-1.38	-5.81**
C5 x 4	9.83**	9.20**	54.33**	43.69**	-9.11*	-24.95**	-31.09**	-40.78**
C5 x 6	5.62*	2.17	23.82**	12.20*	7.84	-1.20	10.52**	9.74**
C6 x 1	-2.70	-3.23	14.12**	9.19	21.87**	19.47**	18.59**	14.07**
C6 x 2	2.13	0.00	6.52	-3.92	25.81**	24.85**	6.04**	-3.99*
C6 x 3	20.00**	1.09	9.88	8.54	18.03**	12.30**	-1.78	-6.82**
C6 x 4	17.32**	14.13**	10.52	7.32	6.01	-5.51	-27.33**	-37.92**
C6 x 5	-4.49	-7.61**	26.38**	14.51**	4.24	-4.49	4.23**	3.49*

* Significant (P=0.05) ** Significant (P=0.01)

Table V. Heterosis manifestations for monopodial and sympodial branches under water regimes

Crosses	Number of Monopodial Branches				Number of Sympodial Branches			
	Normal		Drought		Normal		Drought	
	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
C 1 x 2	25.77	12.96	67.19*	33.75	14.32*	9.08	-7.15	-11.53
C 1 x 3	29.03	20.00	0.00	-4.55	-15.42**	-18.60**	-12.49	-16.98**
C 1 x 4	8.21	-7.44	0.91	-20.88	-20.35**	-25.55**	-8.25	-9.47
C 1 x 5	-41.50**	-51.81**	-50.00**	-59.38**	-3.78	-8.54	-21.55**	-27.24**
C 1 x 6	30.82	20.93	24.53	0.00	14.81*	11.03	3.98	-9.64
C 2 x 1	23.71	11.11	46.87	17.50	23.91**	18.23**	-11.55	-15.72*
C 2 x 3	-3.85	-7.41	-41.18	-54.55*	9.28	8.32	-17.21*	-17.59*
C 2 x 4	-19.65	-23.97	10.17	-26.14	18.98**	16.43**	-3.69	-9.39
C 2 x 5	-36.88**	-42.77**	-6.82	-35.94*	31.79**	31.26**	-16.77**	-26.16**
C2 x 6	12.71	-5.56	13.33	-22.73	34.72**	24.52**	0.51	-8.80
C3 x 1	33.33	24.00	-0.00	-4.55	-2.11	-5.80	-15.58*	-19.92**
C3 x 2	-15.38	-18.52	-35.29	-50.00*	1.54	0.64	-13.49	-13.89
C3 x 4	-5.88	-14.05	-17.83	-33.24*	8.55	5.31	-11.98	-17.55**
C3 x 5	-48.45**	-54.82**	-11.11	-25.00	10.12	8.71	-23.73**	-32.62**
C3 x 6	1.73	-12.00	1.82	-15.15	30.90**	21.99**	9.74	0.00
C4 x 1	8.21	-7.44	12.32	-11.93	-12.45*	-18.16**	-20.58**	-21.63**
C4 x 2	-12.66	-17.36	44.07*	-3.41	11.16*	8.78	2.39	-3.67
C4 x 3	-18.55	-25.62	-36.19*	-48.15**	14.82**	11.39*	-17.21*	-22.45**
C4 x 5	-43.26**	-45.78**	-28.57*	-31.82*	4.28	2.45	-17.18**	-22.22**
C4 x 6	36.08*	9.09	-1.76	-4.83	16.67**	5.71	4.04	-10.61
C5 x 1	-48.81**	-57.83**	-23.08	-37.50*	-2.09	-6.94	-16.52**	-22.58**
C5 x 2	-40.20**	-45.78**	17.05	-19.53	26.14**	25.63**	-9.62	-19.82**
C5 x 3	-43.30**	-50.30**	12.96	-4.69	17.84**	16.33**	-7.51	-18.28**
C5 x 4	-21.20	-24.70*	-38.99**	-41.76**	-11.30*	-12.86*	-22.14**	-26.88**
C5 x 6	-22.25	-39.76**	-44.62**	-45.45**	6.11	-2.28	-13.10	-29.14**
C6 x 1	40.88*	30.23	11.32	-10.61	10.19	6.57	14.35	-0.63
C6 x 2	23.76	3.70	33.33	-9.09	17.76**	8.85	-7.65	-16.20*
C6 x 3	8.67	-6.00	5.45	-12.12	25.31**	16.78**	11.44	1.54
C6 x 4	34.02*	7.44	-35.48**	-37.50	12.61*	2.04	-0.95	-14.90*
C6 x 5	-41.69**	-54.82**	-14.62	-15.91	-14.56*	-21.32**	-15.16*	-30.82**

*Significant (P=0.05) ** Significant (P=0.01)

Table VI. Heterosis manifestations for boll weight and number of bolls under water regimes

Crosses	Boll weight				Number of Bolls			
	Normal		Drought		Normal		Drought	
	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
C 1 x 2	12.13**	5.72	-11.03**	-15.49**	26.86**	18.45	11.48	-16.93*
C 1 x 3	8.90**	7.95**	-9.92**	-19.62**	3.57	2.21	-37.39**	-47.87**
C 1 x 4	3.39	2.03	13.90**	6.11	39.12**	17.48**	-2.10	-12.65*
C 1 x 5	8.58**	0.58	14..57**	9.71**	-21.44**	-40.71**	-35.12**	-44.85**
C 1 x 6	7.22*	6.50*	22.31**	21.34**	30.54**	25.90**	12.50	-5.42
C 2 x 1	5.04	-0.97	18.83**	13.90**	25.08*	16.79	17.38	-12.53
C 2 x 3	9.34**	3.94	7.07**	-7.94**	-13.55	-20.26*	3.17	-10.38
C 2 x 4	-0.36	-4.88	8.34*	-2.95	41.15**	12.76	44.38**	-0.03
C 2 x 5	4.24	2.30	12.86**	3.79	12.64	-18.79**	20.72*	-18.92**
C2 x 6	7.76*	0.96	31.11**	26.64**	77.47**	60.24**	95.22**	67.86**
C3 x 1	-4.89	-5.72	5.63	-5.74	-7.90	-9.10	3.37	-13.93
C3 x 2	9.02**	3.65	13.41**	-2.49	-18.56	-24.88**	-13.28	-24.67*
C3 x 4	3.22	2.76	-3.16	-7.56*	44.45**	23.32**	14.68	-12.74*
C3 x 5	8.98**	1.78	-0.88	-7.94**	-0.83	-24.47**	-3.68	-29.42**
C3 x 6	-5.44	-6.88*	9.83**	-2.68	66.57**	62.74**	82.25**	80.08**
C4 x 1	-7.71*	-8.91**	8.93*	1.47	17.56*	-0.72	-15.63*	-24.73**
C4 x 2	7.14*	2.29	17.51**	5.26	18.88*	-5.04	14.33	-20.84**
C4 x 3	9.56**	9.07**	-2.96	-7.37*	-46.08**	-53.97**	-38.54**	-53.23**
C4 x 5	2.39	-3.98	2.49	-0.42	-24.63**	-34.45**	-26.30**	-30.27**
C4 x 6	-5.61	-7.46*	3.24	-4.53	2.66	-10.60	2.87	-21.07**
C5 x 1	-3.24	-10.37**	16.90**	11.94**	-14.33*	-35.34**	-29.43**	-40.02**
C5 x 2	7.58*	5.58	13.47**	4.35	14.33*	-17.58**	22.85**	-17.49**
C5 x 3	9.71**	2.47	-4.17	-11.00**	16.56*	-11.23*	24.54**	-8.74
C5 x 4	2.81	-3.58	2.38	-0.53	-12.65*	-24.03**	-40.02**	-43.25**
C5 x 6	12.25**	3.35	16.15**	10.38**	-9.84	-30.20**	-15.64*	-37.70**
C6 x 1	-12.51**	-13.10**	18.01**	17.07**	41.96**	36.92**	37.38**	15.50
C6 x 2	7.14*	0.38	29.70**	25.28**	56.51**	41.32**	50.87**	29.73*
C6 x 3	4.27	2.68	3.78	-8.04**	61.94**	58.22**	39.37**	37.71**
C6 x 4	3.36	1.34	5.07	-2.84	22.96**	7.07	4.01	-20.20**
C6 x 5	7.37*	-1.15	13.68**	8.04*	-18.53**	-36.93**	-17.37*	-38.98**

* Significant (P=0.05) ** Significant (P=0.01)

Table VII. Heterosis manifestations for GOT% and seed cotton yield under water regimes

Crosses	GOT %				Yield			
	Normal		Drought		Normal		Drought	
	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %	Ht %	Hbt %
C 1 x 2	8.01**	3.36	0.22	-5.72**	42.28**	25.98*	-3.11	-29.50**
C 1 x 3	3.23	-1.39	2.34*	-0.13	-20.48	-20.65	-14.64**	-46.10**
C 1 x 4	1.55	-1.10	2.06	-2.04	44.48**	23.53**	11.91	-6.35
C 1 x 5	-2.18	-3.73	4.95*	4.32*	-12.53	-30.17**	-27.80**	-40.83**
C 1 x 6	-4.75*	-8.74**	1.29	-1.81	40.27**	34.38**	38.98**	16.23
C 2 x 1	4.86*	0.34	-2.26	-8.05**	28.56*	13.83	38.11*	0.50
C 2 x 3	-0.31	-0.50	2.64	-6.23**	9.74	-3.02	8.40	-16.66
C 2 x 4	3.63	1.78	1.66	-0.45	40.33**	8.57	48.51**	-2.97
C 2 x 5	4.50*	1.55	5.56**	-1.25	18.78*	-13.30	29.79**	-16.22
C2 x 6	-4.53*	-4.65*	-3.98*	-6.91**	88.91**	61.15**	155.32**	114.09**
C3 x 1	2.86	-1.74	7.41**	4.81*	0.24	0.02	12.17	3.58
C3 x 2	0.08	-0.10	-1.86	-5.48**	-11.79	-22.05*	-4.43	-26.52*
C3 x 4	8.74**	6.61**	6.40**	4.61*	50.36**	28.79**	13.85	-10.60
C3 x 5	6.84**	3.65	8.41**	5.17**	10.99	-11.25	-2.37	-24.77**
C3 x 6	-3.07	-3.37	-1.21	-1.88	72.30**	65.42**	103.31**	82.40**
C4 x 1	2.46	-0.21	4.00*	-0.18	11.23	-4.90	-8.31	-23.27**
C4 x 2	5.37**	3.49	2.22	0.10	26.36*	-2.24	27.43*	-16.74*
C4 x 3	5.42**	3.35	8.00**	6.18**	4.11	-10.82	-39.13**	-52.20**
C4 x 5	6.97**	5.82**	10.97**	5.90**	-21.53**	-27.80**	-24.05**	-25.99**
C4 x 6	-0.93	-2.58	3.41	2.35	-2.10	-13.11	4.87	-23.81**
C5 x 1	2.24	0.63	4.91*	4.28*	-6.03	-24.99**	-18.62*	-33.31**
C5 x 2	3.38	0.47	4.59*	-2.16	23.89**	-9.56	34.05**	-13.47
C5 x 3	2.45	-0.61	8.28**	5.04**	31.63**	5.25	20.20*	-7.37
C5 x 4	2.93	1.83	6.66**	1.79	-1.01	-8.91	-38.35**	-39.93**
C5 x 6	-0.07	-2.77	5.30**	1.48	3.62	-14.45*	-3.84	-31.25**
C6 x 1	-0.76	-4.92**	3.86*	0.68	25.38*	20.12*	61.13**	34.76**
C6 x 2	-5.02**	-5.14**	-1.48	-4.48*	67.17**	42.61**	95.49**	63.92**
C6 x 3	-3.21	-3.51	1.56	0.87	68.11**	61.40**	43.22**	28.48*
C6 x 4	-2.40	-4.03*	0.75	-0.27	27.44**	13.10	6.80	-22.40**
C6 x 5	4.29*	1.47	2.52	-1.20	-8.40	-24.37**	-7.29	-33.72**

Significant (P=0.05) ** Significant (P=0.01)

conditions, respectively for GOT percentage. Positive and significant heterobeltiosis was present in 6.6% and 26.8% of the total crosses under the two water regimes, respectively. The detailed study of the table showed that most of the hybrids performed better than their parents under drought conditions (Table VII). Four hybrids (CIM-448×BH-118 & its reciprocal, CIM-448×HR-VO-1 & BH-118×HR-VO-1) showed significant positive heterosis relative to both parental mean and better parent under both the water regimes.

The data (Table VII) revealed 53% and 40% of the total crosses with significant positive heterosis for yield, that ranged from 18.70 to 88.91% and 20.20 to 155.32%, under normal and water stress regimes, respectively. As far as heterobeltiosis is concerned, 30% and 16.6% of the total crosses showed significant positive heterobeltiosis ranging from 20.12 to 65.42% and 28.42 to 114.09% under normal and water stress regimes, respectively. Hybrids, FH-901×Krishna, CIM-448×Krishna and their reciprocals and Krishna×FH-634 manifested significant positive heterosis in relation to parental mean and better parent under both water regimes.

DISCUSSION

In the present study, varying degree of heterotic effects were observed over the mid and better parents for all the traits. Generally the magnitude of heterosis was greater under normal irrigations compared with water stress regime. Sensitivity of the hybrids to the moisture stress was due to repeated parental lines i.e., FH-634, FH-901, CIM-448 and BH-118 selection under normal condition leading to higher yield. This Selection pressure would have increased the frequency of genes expressing under normal conditions increasing the number of hybrids and also the magnitude of the heterosis.

It was noticed that hybrids, which showed the best heterobeltiosis under normal condition also showed the best performance for the same characters under drought conditions, for instance C2 × 6 and C3 × 6 had the highest heterobeltiosis for yield and number of bolls per plant under both conditions. Thaxton *et al.* (1999) (not in the list) also reported that the varieties performing best under normal conditions also perform the best under drought conditions. In other words the breeding under stress conditions might be more useful for wider adaptability.

Some crosses in the present studies showed positive heterosis for plant height. This is not always beneficial as generally taller plants (a) lower harvest index (b) Bear lower number of bolls due to top bearing (c) often tends to lodge and promote the infestation of diseases and insect pests besides hindering the picking process (d) pose problem in hand picking, which is a normal way of crop harvest in Pakistan. On the other hand, several hybrids expressed significant negative heterosis over better parents. Many breeders (Velkov, 1970; Voskoboynik & Gorbachenko, 1977; Rodin, 1978; Fick *et al*., 1985; Miller, 1988) recognized the potential of reduced-height germplasm to increase stem strength. The present studies support the idea of utilising reduced height in breeding cotton hybrids.

Significant positive heterosis was observed in the seed cotton yield in relation to parental mean and better parent (heterobeltiosis). Since the parent material used in the present studies comprise of commercial varieties i.e., FH-634, FH-901, CIM-448 and BH-118, therefore, the observed heterobeltiosis surpassed the commercial varieties. It may be concluded that hybrid also exhibited some commercial (useful) heterosis (Xian *et al.,* 1995; Gutierrez *et al.,* 1998; Meredith & Brown, 1998; Zhang *et al.,* 2003).

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