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Research Article

HETEROSIS ANALYSIS FOR YIELD CONTRIBUTING TRAITS AND FIBER QUALITY IN UPLAND COTTON (*Gossypium hirsutum* L.)

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Abstract: Amongst the fibres, Cotton is under cultivation from ancient period as a source of a fibre in India. Development of superior varieties and exploitation of phenomenon of heterosis are the main breeding approaches followed for developing high yielding varieties in respect to cotton. The field trials with fifty five genotypes (10 parents and 45 crosses) along with local released hybrid as a check PKV Hy–2 in two sets of environmental conditions were conducted using Completely Randomized Block Design (CRBD) on farm of University Department of Agricultural Botany, Dr PDKV, Akola (MS) as per procedure for Diallel analysis given by Griffings, 1956. The heterosis is the genetic expression of the beneficial effects of hybridization and specifically in cotton, the hybrid vigour is a target for all most all cotton breeders. The data were recorded for all the fourteen morphological including fibre quality characters *viz*., days to 50 per cent flowering, plant height (cm), number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight (g), number of seeds per boll, ginning outturn (%), seed index (g), lint index (%), 2.5 per cent span length (mm), fibre strength (g/tex), micronaire value (µg/inch) and seed cotton yield per plant (g). The maximum estimates of heterosis and heterobeltiosis for seed cotton yield per plant was observed in JLH–1594 x AKH–24 (74.21 and 58.67 per cent) followed by KH–118 x AKH–62 (73.06 and 54.03 per cent) over environments, whereas KH–118 x AKH–62 surpassed among all the forty five crosses for useful heterosis (22.84 per cent) over the locally adapted upland cotton hybrid PKV Hy–2.

Keywords: *Cotton, Diallel, Heterosis, Heterobeltiosis and Upland Cotton*

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Introduction

Cotton is a major fibre crop of global importance with immense trade value; it's commercially in the temperate and tropical regions of more than seventy countries. India occupies 37.56% of world cotton area and produces 24.26% of world cotton production and stands tall. The second largest producer of cotton-China occupies 9.97% of world cotton area and produces 22.41% of world cotton production. India, China, United States and Brail together take the share of 74% of world cotton production. Cotton production in India during 2019-20 was around 360 lakh bales of 170 kg from 125.84 lakh hectares with a productivity of 486 kg lint/ha., Maharashtra, Gujarat and Telangana were the major cotton growing states covering around 69.60% (87.59 lakh hectare) in area under cotton cultivation and 63.88% (230 lakh bales) of cotton production in India [4].

Globally, the Gossypium genus comprises about 50 species [9]. Place of origin of the genus Gossypium is not known, however the primary centers of diversity are west-central and southern Mexico (eighteen species), north-east Africa and Arabia (fourteen species) and Australia (seventeen species). DNA sequence data from the existing Gossypium spp. suggests that the genus arose about 10-20 million years ago [33]. The antiquity of cotton in the Indian subcontinent has been traced to the 4th millennium BC [22]. The first reference to cotton is found in rig Veda hymn [12]. The fabrics dated approximately 3000 BC recovered from Mohenjodaro excavated in Sind were identified to have originated from cotton plants, closely link to *Gossyppium arboreum* species [10], thereby confirming that cotton lint was spun and woven into cloth even before 3000 B.C.[3]. In Breeding the need of diverse lines always thrust area for defect correction at genetic level of commercial varieties and development of novel cultivars to fulfil the specific objectives of crops [32]. Heterosis evolved being a basic tool for the improvement of crops in the form of F1 generation. In Indian context, heterosis has been exploited extensively to improve the yield. Several factors like geographical and genetic diversity, agronomic performance, adaptability and genetic base of parental lines are reported to play an important role in the manifestation of heterosis in cotton [3]. Though, hetorosis in cotton was known by the end of nineteenth century, the first commercial hybrid of the world "Hybrid 4 (HXH)" was developed in India in 1971 by using hand emasculation method [17]. In the same year first inter-specific hybrid HXB was also developed [11]. The two events transformed the entire cotton scenario of India. Therefore, an experiment with objective to estimate the extent of heterosis for desired attributes in cotton lines was conducted.

Material and Methods

The experimental material comprises of the ten cotton parents developed from various cotton research stations of three major cotton growing states of India [Table-1]. Forty-five hybrids were developed in 10x10 diallel excluding reciprocals were evaluated in two sets of environments along with local check *i.e*., PKV HY-2 on experimental farm of the Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MS) in Randomized Block Design (RBD) fashion with three replications. The data were collected from each plot to for important morphological and fibre quality traits *viz*., days to 50 per cent flowering, plant height (cm), number of monopodia per plant, number of sympodia per plant, number of bolls per plant, boll weight (g), number of seeds per boll, ginning outturn (%), seed index (g), lint index (%), 2.5% span length, fibre strength (g/tex), micronaire value (µg/inch) and seed cotton yield per plant (g).

Table-1 *Details of Parents/Genotypes used in crossing program*

State	Research Station	No parents/ genotypes	Details of parents/ genotypes
Maharashtra	Akola	6	AKH-84635, AKH-91, AKH-62, AH-107, AKH-44 and AKH-24
	Jalgaon (Kh)	1	JLH-1594
	Nanded	1	NH-545
Madhya Pradesh	Khandwa	1	KH-118
Tamil Nadu	Coimbatore	1	LRA-5166

Table-2 *Pooled combined Analysis of variance for fourteen morphological characters of cotton*

Source of variation	d.f.	Mean sum of squares [MSS]													
		DF	PH	MONO	SYMP	BOLLS	BW	SPP	GOT	SI	LI	2.5% SP	FS	MV	SCY
Environments	1	2272.5**	20447.3**	0.7 ^{NS}	3050.1**	3869.7**	7.5**	10.7*	2019.9**	17.9**	95.2**	117.6**	4412.4**	220.7**	31784.0**
Replication	2	18.2 ^{NS}	689.9**	4.1**	757.1**	1594.9**	3.0**	18.4**	1027.1**	5.1**	40.5**	90.1**	725.3**	34.4**	4865.7**
Genotypes	54	37.4 ^{NS}	433.4 ^{NS}	1.1**	28.9**	93.2**	1.1**	87.07**	58.3**	2.04**	2.5**	12.1**	24.7**	0.5**	253.5**
Parents	9	20.6*	174.8 ^{NS}	0.7**	4.6**	50.2**	0.2 ^{NS}	19.6**	13.5**	0.4**	0.7**	1.6**	20.3**	0.6**	63.3**
Crosses	44	20.5**	251.4**	0.8**	13.5**	48.8**	0.7**	48.03**	31.6**	1.3**	1.4**	6.8**	14.1**	0.3**	169.7**
Crosses x Par	1	19.9 ^{NS}	116.2 ^{NS}	0.4 ^{NS}	1.2 ^{NS}	74.7**	0.1 ^{NS}	95.5**	58.9**	2.3**	0.2 ^{NS}	3.1**	1.5 ^{NS}	12.17**	194.01**
Env x Repl	2	27.6**	109.8**	6.3**	367.0**	75.8**	3.1**	39.03**	130.9**	10.8**	19.2**	388.4**	456.0**	33.80**	2630.7**
Env x Genoty	54	6.7 ^{NS}	67.8 ^{NS}	0.3*	2.0**	5.8 ^{NS}	0.2**	1.6 ^{NS}	0.8**	0.05 ^{NS}	0.09**	0.13**	5.6**	0.22**	49.6**
Env x Parents	9	6.3 ^{NS}	141.1 ^{NS}	0.12 ^{NS}	8.6**	19.3**	0.03 ^{NS}	0.3 ^{NS}	1.5**	1.6**	1.5**	3.2**	2.1**	0.09 ^{NS}	130.1**
Env x Crosses	44	7.3 ^{NS}	147.7*	0.03 ^{NS}	6.5**	33.7**	0.05 ^{NS}	1.8 ^{NS}	0.1 ^{NS}	0.9**	0.5**	1.9**	2.4**	0.19**	363.6**
Env x Cross x Parnt	1	20.8 ^{NS}	0.008 ^{NS}	0.11 ^{NS}	1.3 ^{NS}	161.2**	0.2 ^{NS}	2.5 ^{NS}	9.6**	0.7*	0.04 ^{NS}	0.6**	9.04*	0.01 ^{NS}	301.9**
Pooled Error	216	9.4883	105.3974	0.2549	0.4908	6.2462	0.1693	2.7082	0.18	0.16	0.25	0.07	1.8	0.06	12.4

Analysis of Variance (ANOVA)

The analysis of variance was performed to test the significance of difference between the progenies for all the traits under investigation, which was carried out as per standard method [16, 25] for all the fourteen characters under study. The statistical model for completely randomized block design is:

$Y_{ijk} = \mu + g_{ij} + b_k + e_{ijk}$

Where,

Y_{ijk} =Phenotypic performance of ijth genotype in kth block

μ=General mean

g_{ij}=Effect of ijth genotype

b_k=Effect of kth block

e_{ijk}=Error effect

The analysis of variance based on this model is as under:

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	
			Observed	Expected
Replication	(r-1)	SS_r	M_1	
Genotypes	(g-1)	SS_g	M_2	$\sigma^2\varepsilon + \rho\sigma^2\gamma$
Parents	(p-1)	SS_p	M_3	
Crosses	(c-1)	SS_c	M_4	
Parents vs Crosses	1	SS_p/SS_c	M_5	
Error	(r-1)(g-1)	SS_e	M_e	$\sigma^2\varepsilon$
Total	(rg-1)	S.S.		

Where, R=number of replications, p=number of parents

G=number of genotypes, c=number of crosses

The mean squares were tested against error variance (Me) by using 'F' test. The standard error of difference for comparing any two-progeny means was estimated by the formula.

S.E.(d)=√2Me/r

The critical difference was computed by multiplying the standard error of difference with 't' value for (r-1)(g-1) error degree of freedom at 5 and 1 per cent level of significance.

C.D. = S.E.(d) x 't' table value at 5% and 1% level of significance at error d.f.

Estimation of Heterosis and mean performance

Heterosis (expressed over mid parent value), heterobeltiosis (expressed over better parent value) and useful heterosis (expressed over standard check *i.e.*, "PKV Hy 2") were estimated by the following formulae.

Heterosis (H_1)=[F_1-MP/MP] x 100

Where MP= (P_1 +P_2) /2

Heterobeltiosis (H_2)= [(F_1-BP)/BP] x 100

Useful heterosis was calculated as the deviation of F_1 over check variety "PKV Hy-2" and was expressed as per cent increase over it.

Useful Heterosis(Hs)= [(F_1-Check) / Check] x 100

Where,

F_1=Mean performance of F_1

MP= Mid parental value

BP=Mean performance of better parent for the respective cross

Check= Mean performance of check variety

Standard error of difference for heterotic effect and critical difference were calculated by the following formulae.

S.E.(d) H_1=√3Me/2r

C.D. = S.E.(d) H_1 x 't' table value at 5% and 1% level of error degrees of freedom

S.E.(d) H_2 & H_3=√2Me/r

C.D. = S.E.(d) H_2 x 't' table value at 5% and 1% level of error degrees of freedom

C.D. = S.E.(d) H_3 x 't' table value at 5% and 1% level of error degrees of freedom

Experimental Findings and Discussion

Analysis of Variance over Environments

The analysis of variance for the experimental design showed significant differences for the genotypes for all the fourteen traits comprising yield contributing traits and fibre quality traits over the set of two environments [Table-2]. ANOVA revealed that the parents' vs crosses were significant for plant height, number of bolls per plant, number of seeds per boll, ginning outturn, seed index, lint index, 2.5 per cent span length, fibre strength and micronaire value. This indicated significant differences among the parents and crosses. Pooled analysis of variance showed significant differences among the parents and crosses for all the traits except plant height and boll weight in respect of parents. This indicated that substantial genetic variability exists among the parents for most of the characters, which is a pre-requisite in any breeding programme.

Heterosis Analysis: The common approach for selection of parents on the basis of per se performance is not a good indication of their superior combining ability pointed out by many workers [1]. The choice of parents in breeding programme for rainfed areas has to be based on the complex genetic information and knowledge of combining ability of parents and not merely on the field performance of different genotypes. Similarly, the combining ability estimates are greatly influenced by the environment, so that studies in single environment may not provide reliable information. Hence knowledge about combining ability of parents must be judged on set of environments and use of basic biometrical techniques.

The term heterosis was first used by Shull (1914) [24]. Heterosis referred as the superiority or inferiority of F1offsprings, which derived from crossing two dissimilar genotypes over either of parents or both for one or more characters. However, in plant breeding programme, heterosis is estimated in term of heterosis over check (useful heterosis).

Exploitation of heterosis on commercial basis has revolutionized the production in many crops including cotton. Therefore, exploitation of hybrid vigour has become the important aspect in cotton improvement programme. The presence of heterosis in cotton has been pointed out by several workers [6,5,8,19,13,36,21,30 and 26].

In the present investigation substantial magnitude of heterosis, heterobeltiosis and useful heterosis has been observed for most of the characters.

Table-3 *Estimates Heterosis (H_1), Heterobeltiosis (H_2) and Useful Heterosis (H_3) in percentage for morphological and fibre quality traits*

SN	Crosses	Days to 50 % flowering			Plant Height (cm)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	-1.36	1.87	2.35	8.34	6.73	6.08
2	AKH-84635 x KH-118	-2.71	0.94	1.41	-3.97	-13.50	-16.61
3	AKH-84635 x NH-545	-1.00	4.45	4.94	-0.97	-3.81	-1.60
4	AKH-84635 x AKH-91	-4.69	-2.34	-1.88	-5.20	-8.79	-12.05
5	AKH-84635 x AKH-62	1.37	3.98	4.47	7.42	5.52	1.76
6	AKH-84635 x AH –107	-3.57	1.17	1.65	14.32	8.47	4.60
7	AKH-84635 x AKH-44	-2.77	2.81	3.29	-8.89	-8.96	-12.20
8	AKH-84635 x AKH-24	-1.90	2.81	3.29	0.80	-0.86	-4.39
9	AKH-84635 xLRA-5166	-2.26	1.17	1.65	18.23*	9.81	5.90
10	JLH-1594 x KH-118	-4.81*	-4.40	2.35	21.22**	7.72	7.06
11	JLH-1594 x NH-545	-1.61	0.44	7.53**	7.91	6.37	8.81
12	JLH-1594 x AKH-91	-3.21	-2.46	2.82	-4.04	-8.99	-9.55
13	JLH-1594 x AKH-62	-4.20	-3.56	1.88	-11.62	-14.45	-14.98
14	JLH-1594 x AH-107	-3.90	-2.42	4.47	2.71	-3.91	-4.50
15	JLH-1594 x AKH- 44	-4.62*	-2.42	4.47	-4.02	-5.51	-6.09
16	JLH-1594 x AKH-24	-5.74*	-4.40	2.35	8.77	5.42	4.78
17	JLH-1594 x LRA-5166	1.32	1.54	8.71**	-2.64	-10.81	-11.36
18	KH-118 x NH-545	-3.11	-1.53	6.35*	-9.52	-20.60*	-18.77*
19	KH-118 x AKH-91	-1.87	-0.67	4.71	6.49	-0.61	-11.41
20	KH-118 x AKH-62	-0.22	0.89	6.59*	15.45*	5.66	-1.72
21	KH-118 x AH –107	-8.19**	-7.19**	0.24	22.41**	15.82	0.26
22	KH-118 x AKH –44	-0.53	1.31	9.41**	7.64	-3.01	-6.60
23	KH-118 x AKH-24	1.40	2.40	10.59**	12.10	2.47	-4.42
24	KH-118 x LRA –5166	-6.99**	-6.78**	0.24	32.83**	28.44**	6.23
25	NH –545 x AKH –91	0.22	3.12	8.71**	5.50	-1.29	0.98
26	NH –545 x AKH –62	-0.98	1.78	7.53**	4.16	-0.57	1.72
27	NH –545 x AH-107	-4.14	-3.62	6.35*	9.58	1.15	3.48
28	NH –545 x AKH –44	-4.42*	-4.22	6.82**	-28.33**	-30.43**	-28.83**
29	NH –545 x AKH –24	-7.01**	-6.41*	3.06	-3.45	-7.71	-5.58
30	NH –545 x LRA-5166	3.11	5.03	12.94**	4.63	-5.39	-3.21
31	AKH –91 x AKH –62	3.01	3.12	8.71**	26.17**	23.54**	14.91
32	AKH –91 x AH –107	1.20	3.57	9.18**	8.43	6.88	-4.74
33	AKH –91 x AKH – 44	-1.52	1.56	7.06**	-0.76	-4.45	-7.99
34	AKH –91 x AKH –24	-3.71	-1.56	3.76	-6.41	-8.49	-14.64
35	AKH –91 x LRA– 5166	-6.52**	-5.58*	-0.47	6.23	2.40	-8.73
36	AKH –62 x AH – 107	-2.83	-0.67	4.94	19.33*	15.20	7.15
37	AKH –62 x AKH – 44	-3.14	-0.22	5.41*	2.51	0.77	-2.97
38	AKH –62 x AKH –24	-0.33	1.78	7.53**	5.16	5.01	-2.05
39	AKH –62 x LRA –5166	0.44	1.34	7.06**	16.52*	10.06	2.37
40	AH –107 x AKH – 44	-1.16	-0.43	9.88**	8.45	2.97	-0.84
41	AH – 107 x AKH – 24	-5.44*	-5.34*	4.24	16.52*	12.33	4.78
42	AH – 107 x LRA –5166	3.67	5.03	12.94**	36.01**	32.98**	15.12
43	AKH – 44 x AKH – 24	-5.30*	-4.49	5.18*	2.02	0.42	-3.30
44	AKH – 44 x LRA–5166	-4.61*	-2.63	4.71	10.32	2.53	-1.26
45	AKH – 24 x LRA–5166	-5.51*	-4.38	2.82	-4.33	-9.75	-15.82
	S.E.(d) ±	2.17	2.51		7.2594	8.3024	
	C.D. (5%)	4.3867	5.05		14.6204	16.8821	
	C.D. (1%)	5.8373	6.75		19.5271	22.5487	

SN	Crosses	No. of bolls per plant			Boll Weight (g)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	17.13**	-1.83	-24.35**	7.48**	3.31**	22.69**
2	AKH-84635 x KH-118	16.73**	11.58**	-5.69**	10.32**	3.88**	23.35**
3	AKH-84635 x NH-545	12.73**	9.59**	-10.56**	-11.08**	-14.48**	1.55**
4	AKH-84635 x AKH-91	23.40**	19.87**	-7.63**	10.71**	8.57**	28.92**
5	AKH-84635 x AKH-62	0.32	-6.56**	-16.55**	-0.77*	-8.21**	9.00**
6	AKH-84635 x AH –107	2.76	-8.52**	-9.67**	28.56**	28.56**	52.60
7	AKH-84635 x AKH-44	-6.12**	-9.36**	-30.15**	35.13**	20.14**	42.67**
8	AKH-84635 x AKH-24	47.30**	25.28**	-3.46	-0.05	-3.88**	14.15**
9	AKH-84635 xLRA-5166	33.29**	27.75**	7.36**	-4.80**	-5.70**	14.15**
10	JLH-1594 x KH-118	18.84**	-3.94	-18.81**	5.90**	3.65**	13.54**
11	JLH-1594 x NH-545	38.81**	13.72**	-7.18**	4.14**	4.09**	14.15**
12	JLH-1594 x AKH-91	5.99**	-8.99**	-33.88**	-6.12**	-8.01**	5.00**
13	JLH-1594 x AKH-62	3.30	-18.21**	-26.95**	2.30**	-1.71**	7.67**
14	JLH-1594 x AH-107	-18.88**	-38.03**	-38.81**	14.64**	10.20**	30.86**
15	JLH-1594 x AKH- 44	27.21**	9.80**	-21.22**	4.59**	-3.59**	5.61**
16	JLH-1594 x AKH-24	39.45**	36.99**	-26.00**	-7.13**	-7.18**	1.79**
17	JLH-1594 x LRA-5166	-7.32**	-24.92**	-36.91**	10.35**	5.10**	27.23**
18	KH-118 x NH-545	-6.80**	-8.40**	-22.58**	-13.86**	-15.74**	-7.59**
19	KH-118 x AKH-91	5.43**	-1.97	-17.14**	19.49**	14.64**	30.86**
20	KH-118 x AKH-62	7.30**	4.43*	-6.73**	2.21**	0.29	5.19**
21	KH-118 x AH –107	10.22**	2.29	1.00	-17.36**	-22.18**	-7.59**
22	KH-118 x AKH –44	14.76**	6.08**	-10.33**	6.63**	0.29	5.19**
23	KH-118 x AKH-24	34.32**	10.08**	-6.95**	-13.86**	-15.74**	-7.59**
24	KH-118 x LRA –5166	10.97**	10.65**	-6.48**	1.05**	-5.70**	14.15**
25	NH –545 x AKH –91	2.78	-2.86	-20.71**	2.00**	0.00	14.15**
26	NH –545 x AKH –62	-16.68**	-20.27**	-28.79**	17.14**	12.48**	23.35**
27	NH –545 x AH-107	-25.33**	-31.81**	-32.66**	-19.09**	-22.18**	-7.59**
28	NH –545 x AKH –44	1.22	-4.90*	-22.38**	28.26**	18.17**	29.59**
29	NH –545 x AKH –24	41.64**	17.70**	-3.94	0.00	0.00	9.67**
30	NH –545 x LRA-5166	-18.62**	-19.79**	-32.60**	-17.90**	-21.76**	-5.29**
31	AKH –91 x AKH –62	-21.42**	-28.74**	-36.36**	-6.14**	-11.56**	0.95**
32	AKH –91 x AH –107	-4.82**	-17.39**	-18.43**	5.93**	3.88**	23.35**
33	AKH –91 x AKH – 44	-19.32**	-19.83**	-41.75**	-2.26**	-11.56**	0.95**
34	AKH –91 x AKH –24	9.63**	-4.43*	-30.56**	-17.42**	-19.05**	-7.59**
35	AKH –91 x LRA– 5166	6.72**	-0.51	-16.39**	6.44**	3.40**	25.17**
36	AKH –62 x AH – 107	-31.88**	-35.13**	-35.95**	-17.92**	-24.07**	-9.83**
37	AKH –62 x AKH – 44	29.44**	16.71**	4.24*	39.24**	33.35**	34.62**
38	AKH –62 x AKH –24	-4.31*	-23.22**	-31.42**	-16.22**	-19.55**	-11.77**
39	AKH –62 x LRA –5166	7.68**	4.50*	-6.67**	-12.93**	-20.16**	-3.35**
40	AH –107 x AKH – 44	-4.78**	-17.80**	-18.83**	18.21**	5.10**	24.81**
41	AH – 107 x AKH – 24	49.00**	15.26**	13.81**	-19.09**	-22.18**	-7.59**
42	AH – 107 x LRA –5166	-25.98**	-31.49**	-32.35**	-23.18**	-23.91**	-7.89**
43	AKH – 44 x AKH – 24	62.51**	42.44**	2.19	-4.35**	-11.87**	-3.35**
44	AKH – 44 x LRA–5166	22.32**	13.38**	-4.72*	43.04**	26.11**	52.66**
45	AKH – 24 x LRA–5166	55.02**	27.34**	7.01**	-8.82**	-13.11**	5.19**
	S.E.(d) ±	1.76	2.0406		0.29	0.33	
	C.D. (5%)	3.5591	4.1098		0.5859	0.6766	
	C.D. (1%)	4.7557	5.4893		0.7825	0.9037	

SN	Crosses	No. of monopodia per plant			No. of sympodia per plant		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	-6.00**	-4.08**	-19.83**	3.57**	2.06**	-26.75**
2	AKH-84635 x KH-118	10.50**	15.81**	-11.68**	-11.52**	-17.89**	-31.15**
3	AKH-84635 x NH-545	-6.76**	-4.72**	-23.69**	15.98**	14.08**	-15.36**
4	AKH-84635 x AKH-91	-13.17**	-4.14**	-19.87**	17.22**	16.80**	-15.57**
5	AKH-84635 x AKH-62	-7.19**	-0.25	-27.47**	-11.87**	-17.05**	-32.54**
6	AKH-84635 x AH –107	-1.36**	7.74**	-23.97**	-2.78**	-12.56**	-21.45**
7	AKH-84635 x AKH-44	12.98**	17.75**	-1.58**	9.28**	7.83**	-20.50**
8	AKH-84635 x AKH-24	8.96**	17.51**	-15.10**	17.57**	11.73**	-19.81**
9	AKH-84635 xLRA-5166	6.00**	18.13**	-19.65**	-1.11*	-1.55**	-28.71**
10	JLH-1594 x KH-118	6.35**	13.84**	-13.18**	27.69**	16.90**	-1.99**
11	JLH-1594 x NH-545	-6.81**	-2.78**	-22.15**	41.99**	37.67**	2.14**
12	JLH-1594 x AKH-91	-25.25**	-19.25**	-29.75**	5.87**	3.96**	-24.85**
13	JLH-1594 x AKH-62	-13.16**	-4.63**	-30.66**	-1.68**	-8.73**	-25.76**
14	JLH-1594 x AH-107	1.07**	12.83**	-20.37**	15.86**	2.86**	-7.60**
15	JLH-1594 x AKH- 44	19.11**	21.60**	5.79**	29.92**	26.35**	-6.85**
16	JLH-1594 x AKH-24	27.77**	40.81**	1.74**	22.36**	17.94**	-17.82**
17	JLH-1594 x LRA-5166	35.90**	54.85**	5.33**	27.22**	24.82**	-9.61**
18	KH-118 x NH-545	11.58**	14.38**	-12.77**	8.16**	1.94**	-14.54**
19	KH-118 x AKH-91	5.42**	22.49**	-6.59**	-10.49**	-16.66**	-30.12**
20	KH-118 x AKH-62	24.31**	27.35**	-7.41**	-28.23**	-29.30**	-40.73**
21	KH-118 x AH –107	-10.32**	-6.71**	-34.16**	-22.59**	-25.17**	-32.78**
22	KH-118 x AKH –44	-14.45**	-6.38**	-28.61**	-24.79**	-29.33**	-40.75**
23	KH-118 x AKH-24	50.06**	54.22**	11.43**	10.53**	-2.12**	-17.94**
24	KH-118 x LRA –5166	12.20**	19.00**	-19.05**	-9.51**	-15.68**	-29.30**
25	NH –545 x AKH –91	6.01**	19.83**	-4.04**	-22.94**	-23.93**	-43.56**
26	NH –545 x AKH –62	-32.76**	-29.35**	-48.63**	-45.79**	-48.17**	-57.85**
27	NH –545 x AH-107	-0.63	6.06**	-25.15**	-21.18**	-28.04**	-35.36**
28	NH –545 x AKH –44	-9.54**	-3.58**	-22.78**	-15.30**	-15.57**	-37.36**
29	NH –545 x AKH –24	-0.42**	4.97**	-24.15**	4.80**	-1.95**	-27.25**
30	NH –545 x LRA-5166	6.30**	15.72**	-21.28**	-28.41**	-29.27**	-47.52**
31	AKH –91 x AKH –62	-9.88**	7.63**	-21.74**	-38.51**	-41.93**	-52.77**
32	AKH –91 x AH –107	22.49**	48.87**	5.06**	7.48**	-3.01**	-12.87**
33	AKH –91 x AKH – 44	-4.25**	1.20**	-8.27**	-32.03**	-32.69**	-50.37**
34	AKH –91 x AKH –24	-22.14**	-6.68**	-32.57**	-25.45**	-29.39**	-48.96**
35	AKH –91 x LRA– 5166	11.74**	38.80**	-5.59**	-1.42**	-1.51*	-28.68**
36	AKH –62 x AH – 107	-5.11**	-3.68**	-32.02**	-31.50**	-34.74**	-41.37**
37	AKH –62 x AKH – 44	4.01**	16.83**	-15.05**	32.41**	26.22**	2.65**
38	AKH –62 x AKH –24	-7.28**	-6.99**	-32.79**	-14.40**	-23.18**	-37.52**
39	AKH –62 x LRA –5166	-6.37**	-3.14	-34.11**	14.03**	7.78**	-12.34**
40	AH –107 x AKH – 44	7.20**	22.44	-13.59**	-0.61	-9.52**	-18.72**
41	AH – 107 x AKH – 24	4.36**	5.61	-25.47**	17.16**	0.73	-9.51**
42	AH – 107 x LRA –5166	18.71**	20.94	-17.73**	-19.23**	-27.06**	-34.47**
43	AKH – 44 x AKH – 24	-4.36**	7.81	-22.10**	7.89**	1.24*	-25.36**
44	AKH – 44 x LRA–5166	6.97**	24.75	-15.14**	2.21**	1.30*	-25.32**
45	AKH – 24 x LRA–5166	15.54**	19.13	-18.96**	35.46**	28.19**	-7.17**
	S.E.(d) ±	0.35	0.4122		0.4954	0.5720	
	C.D. (5%)	0.7189	0.8302		0.9977	1.1520	
	C.D. (1%)	0.9603	0.1089		1.3326	1.5387	

SN	Crosses	No. of seeds per boll			Ginning outturn (%)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	10.08**	4.13**	18.89**	20.14**	10.30**	21.94**
2	AKH-84635 x KH-118	-28.05**	-34.76**	-18.34**	1.81**	1.28**	11.97**
3	AKH-84635 x NH-545	31.36**	25.93**	28.25**	20.13**	17.07**	29.41**
4	AKH-84635 x AKH-91	-0.14	-8.98**	12.63**	-19.17**	-19.59**	-11.11**
5	AKH-84635 x AKH-62	-35.42**	-38.09**	-36.95**	-15.61**	-18.65**	-10.07**
6	AKH-84635 x AH –107	-15.25**	-17.88**	-10.84**	-15.06**	-19.33**	-10.82**
7	AKH-84635 x AKH-44	6.73**	5.23**	7.17**	6.80**	6.40**	18.52**
8	AKH-84635 x AKH-24	-20.38**	-27.42**	-10.19**	-0.39	-2.49**	12.54**
9	AKH-84635 xLRA-5166	-12.15**	-19.39**	-17.90**	2.00**	-0.52	9.97**
10	JLH-1594 x KH-118	5.46**	0.83	26.21**	-8.15**	-15.26**	-7.30**
11	JLH-1594 x NH-545	24.04**	12.77**	28.75**	11.73**	5.10**	10.25**
12	JLH-1594 x AKH-91	-5.12**	-8.78**	12.87**	-10.16**	-17.12**	-9.33**
13	JLH-1594 x AKH-62	50.23**	36.58**	55.94**	-5.04**	-9.73**	-7.41**
14	JLH-1594 x AH-107	14.73**	11.92**	27.78**	8.10**	4.31**	3.71**
15	JLH-1594 x AKH- 44	34.97**	25.99**	43.85**	-10.55**	-18.16**	-8.84**
16	JLH-1594 x AKH-24	-7.02**	-10.61**	10.60**	-2.95**	-12.60**	0.87*
17	JLH-1594 x LRA-5166	36.56**	19.14**	36.03**	-0.19	-6.19**	-1.42**
18	KH-118 x NH-545	-2.34**	-14.72**	6.74**	-18.37**	-20.05**	-12.53**
19	KH-118 x AKH-91	0.81	0.24	25.46**	-7.56**	-7.56**	1.13**
20	KH-118 x AKH-62	-15.86**	-26.53**	-8.04**	2.37**	-0.83*	8.50**
21	KH-118 x AH –107	6.44**	-0.61	24.41**	-6.41**	-10.67**	-2.28**
22	KH-118 x AKH –44	-9.59**	-19.05**	1.33	-14.32**	-15.09**	-5.41**
23	KH-118 x AKH-24	-12.13**	-12.63**	9.36**	-10.28**	-12.62**	0.85*
24	KH-118 x LRA –5166	-8.48**	-23.15**	-3.81**	-8.87**	-10.67**	-2.28**
25	NH –545 x AKH –91	-16.03**	-26.32**	-8.83**	-10.66**	-12.50**	-4.27**
26	NH –545 x AKH –62	41.39**	41.39**	32.09**	18.37**	17.06**	22.79**
27	NH –545 x AH-107	-17.26**	-23.03**	-16.43**	-2.39**	-4.94**	-0.28
28	NH –545 x AKH –44	3.27**	0.37	-0.65	-9.90**	-12.53**	-2.56**
29	NH –545 x AKH –24	5.03**	-7.83**	14.05**	-8.96**	-13.11**	0.29
30	NH –545 x LRA-5166	40.64**	34.33**	25.50**	-9.97**	-10.05**	-5.48**
31	AKH –91 x AKH –62	46.47**	28.53**	59.03**	-7.51**	-10.40**	-1.97**
32	AKH –91 x AH –107	0.34	-5.81**	16.55**	-3.41**	-7.81**	0.85*
33	AKH –91 x AKH – 44	22.00**	9.80**	35.86**	-17.42**	-18.16**	-8.84**
34	AKH –91 x AKH –24	15.82**	15.82**	43.31**	-2.67**	-5.21**	9.40**
35	AKH –91 x LRA– 5166	41.01**	18.97**	47.21**	-1.71**	-3.65**	5.41**
36	AKH –62 x AH – 107	47.01**	36.75**	48.49**	-3.52**	-5.00**	-2.56**
37	AKH –62 x AKH – 44	34.73**	30.95**	29.61**	-5.19**	-8.95**	1.42**
38	AKH –62 x AKH –24	0.39	-11.91**	9.00**	-10.60**	-15.58**	-2.56**
39	AKH –62 x LRA –5166	30.45**	24.60**	16.41**	-24.54**	-25.44**	-21.65**
40	AH –107 x AKH – 44	13.63**	8.61**	17.93**	0.41	-4.98**	5.84**
41	AH – 107 x AKH – 24	6.00**	-0.49	23.13**	9.27**	1.71**	17.38**
42	AH – 107 x LRA –5166	37.33**	22.45**	32.95**	-9.45**	-11.89**	-7.41**
43	AKH – 44 x AKH – 24	20.17**	8.15**	33.82**	-9.05**	-10.64**	3.14**
44	AKH – 44 x LRA–5166	22.51**	13.89**	12.73**	-12.08**	-14.57**	-4.84**
45	AKH – 24 x LRA–5166	47.72**	24.63**	54.21**	-5.16**	-9.41**	4.56**
	S.E.(d) ±	1.16	1.34		0.30	0.34	
	C.D. (5%)	2.3437	2.7061		0.6070	0.7009	
	C.D. (1%)	3.1303	3.6144		0.8107	0.9362	

The heterosis, heterobeltiosis and useful heterosis in desirable direction [Table-3]. In the present study the highest magnitude of heterosis was estimated for seed cotton yield per plant (74.21 per cent) followed by fibre strength (73.21 per cent) and number of bolls per plant (62.51 per cent). The maximum heterosis over better parent was recorded for fibre strength (69.29 per cent) followed by seed cotton yield per plant (58.67 per cent) and number of bolls per plant (42.44%). Similar kinds of results were reported by many cotton workers [7,14,27,21 and 26].

The useful heterosis was estimated in comparison of check PKV Hy-2. The maximum magnitude was estimated for trait lint index (57.51 per cent) followed by number of seeds per boll (55.94 per cent) and boll weight (52.66 per cent). The cross AKH-84635 x LRA-5166 ranked second in per se performance for cotton yield also showed significant heterosis, heterobeltiosis and useful heterosis over environments for plant height, number of bolls per plant, ginning outturn, lint index, 2.5 per cent span length and micronaire value.

Table-3 *Estimates Heterosis (H_1), Heterobeltiosis (H_2) and Useful Heterosis (H_3) in percentage for morphological and fibre quality traits*

SN	Crosses	Seed Index (g)			Lint Index (%)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	12.23**	8.73**	6.08**	48.26**	27.25**	44.55**
2	AKH-84635 x KH-118	0.61*	0.00	-1.24**	3.49**	3.28**	17.32**
3	AKH-84635 x NH-545	11.24**	10.77**	9.00**	42.56**	38.66**	57.51**
4	AKH-84635 x AKH-91	-0.81**	-4.53**	-6.86**	-30.74**	-33.85**	-24.86**
5	AKH-84635 x AKH-62	5.44**	5.44**	2.87**	-21.14**	-25.41**	-15.27**
6	AKH-84635 x AH –107	8.18**	7.51**	4.88**	-14.97**	-21.74**	-11.10**
7	AKH-84635 x AKH-44	-0.11	-1.56**	-3.96**	11.02**	8.87**	23.67**
8	AKH-84635 x AKH-24	-8.80**	-10.46**	-9.35**	-9.74**	-14.12**	8.04**
9	AKH-84635 xLRA-5166	5.08**	-1.24**	-3.65**	10.52**	-2.03**	11.28**
10	JLH-1594 x KH-118	-10.66**	-13.96**	-15.03**	-23.62**	-34.34**	-25.71**
11	JLH-1594 x NH-545	-2.78**	-6.21**	-7.70**	10.89**	-2.52**	4.67**
12	JLH-1594 x AKH-91	-4.71**	-5.35**	-13.42**	-19.35**	-27.92**	-25.48**
13	JLH-1594 x AKH-62	-3.22**	-6.24**	-8.53**	-10.45**	-19.25**	-18.20**
14	JLH-1594 x AH-107	10.39**	7.60**	3.67**	23.69**	14.55**	9.42**
15	JLH-1594 x AKH- 44	13.94**	11.99**	6.08**	-2.61**	-15.01**	-7.19**
16	JLH-1594 x AKH-24	2.49**	-2.46**	-1.24**	-3.90**	-20.86**	-0.44
17	JLH-1594 x LRA-5166	0.43	-2.68**	-10.97**	3.04**	-0.71	-12.83**
18	KH-118 x NH-545	1.43**	1.25**	-0.01	-25.21**	-27.12**	-17.54**
19	KH-118 x AKH-91	0.65*	-3.69**	-4.89**	-10.62**	-14.48**	-3.24**
20	KH-118 x AKH-62	9.35**	8.69**	7.33**	12.90**	6.99**	21.05**
21	KH-118 x AH –107	3.78**	2.52**	1.24**	-6.24**	-13.54**	-2.17**
22	KH-118 x AKH –44	-0.40	-2.44**	-3.65**	-20.11**	-21.51**	-11.19**
23	KH-118 x AKH-24	-9.76**	-10.87**	-9.76**	-23.58**	-27.43**	-8.70**
24	KH-118 x LRA –5166	4.40**	-2.44**	-3.65**	-7.31**	-17.70**	-6.88**
25	NH –545 x AKH –91	-12.09**	-15.74**	-17.08**	-26.17**	-27.54**	-22.20**
26	NH –545 x AKH –62	-6.64**	-7.04**	-8.53**	20.79**	17.37**	26.03**
27	NH –545 x AH-107	1.42**	0.36	-1.24**	-3.00**	-8.35**	-1.59**
28	NH –545 x AKH –44	2.27**	0.36	-1.24**	-12.20**	-12.93**	-4.92**
29	NH –545 x AKH –24	12.40**	10.83**	12.21**	-3.37**	-10.45**	12.66**
30	NH –545 x LRA-5166	15.16**	7.80**	6.08**	-0.02	-9.14**	-2.44**
31	AKH –91 x AKH –62	6.48**	2.49**	-0.01	-5.27**	-6.23**	-3.06**
32	AKH –91 x AH –107	12.42**	8.86**	4.88**	6.81**	2.75**	6.22**
33	AKH –91 x AKH – 44	4.18**	1.72**	-3.65**	-20.66**	-22.77**	-15.67**
34	AKH –91 x AKH –24	4.44**	-1.24**	-0.01	-0.10	-9.00**	14.48**
35	AKH –91 x LRA– 5166	31.60**	28.38**	15.85**	31.15**	21.26**	25.36**
36	AKH –62 x AH – 107	14.48**	13.77**	10.99**	8.48**	5.39**	6.75**
37	AKH –62 x AKH – 44	5.31**	3.77**	1.24**	-1.77**	-5.33**	3.38**
38	AKH –62 x AKH –24	0.59*	-1.24**	-0.01	-15.21**	-23.47**	-3.73**
39	AKH –62 x LRA –5166	17.06**	10.01**	7.33**	-19.35**	-24.73**	-23.75**
40	AH –107 x AKH – 44	-4.25**	-5.06**	-8.53**	-2.69**	-8.78**	-0.39
41	AH – 107 x AKH – 24	-2.48**	-4.84**	-3.65**	11.44**	-1.98**	23.32**
42	AH – 107 x LRA –5166	8.42**	2.50**	-1.24**	-3.63**	-7.53**	-11.67**
43	AKH – 44 x AKH – 24	4.52**	1.16**	2.42**	-8.69**	-14.72**	7.29**
44	AKH – 44 x LRA–5166	1.33**	-3.43**	-8.53**	-13.66**	-22.12**	-14.96**
45	AKH – 24 x LRA–5166	18.67**	9.63**	10.99**	11.06**	-5.72**	18.61**
	S.E.(d) ±	0.2848	0.3288		0.3601	0.4158	
	C.D. (5%)	0.5735	0.6623		0.7252	0.8374	
	C.D. (1%)	0.7661	0.8845		0.9687	1.1184	

SN	Crosses	Micronaire value (μg/inch)			Seed Cotton Yield per plant (g)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	1.59**	-9.21**	-11.34**	51.16**	25.54**	4.24
2	AKH-84635 x KH-118	-5.77**	-12.78**	-14.82**	3.98	-9.05**	-24.48**
3	AKH-84635 x NH-545	-2.46**	-6.60**	-8.79**	19.41**	9.98**	-8.68**
4	AKH-84635 x AKH-91	-0.61**	-6.96**	-9.14**	-40.94**	-41.41**	-50.57**
5	AKH-84635 x AKH-62	-6.20**	-8.20**	-10.35**	-29.26**	-30.66**	-42.42**
6	AKH-84635 x AH –107	-3.21**	-3.21**	-5.48**	-25.05**	-25.48**	-37.40**
7	AKH-84635 x AKH-44	-16.43**	-21.52**	-12.72**	0.51	-5.20	-21.29**
8	AKH-84635 x AKH-24	1.11**	-4.26**	-6.50**	-2.83	-12.08**	-26.99**
9	AKH-84635 xLRA-5166	1.22**	-10.63**	-12.72**	35.60**	34.71**	13.34**
10	JLH-1594 x KH-118	3.89**	0.00	-16.88**	39.85**	31.61**	-18.12**
11	JLH-1594 x NH-545	-10.03**	-16.32**	-25.20**	66.74**	48.80**	4.05
12	JLH-1594 x AKH-91	16.42**	10.77**	-5.65**	25.89**	3.89	-12.34**
13	JLH-1594 x AKH-62	-7.38**	-15.60**	-21.09**	-0.13	-15.71**	-32.77**
14	JLH-1594 x AH-107	0.00	-10.63**	-12.72**	-3.74	-20.43**	-33.16**
15	JLH-1594 x AKH- 44	-16.10**	-29.04**	-21.09**	66.49**	45.33**	6.95**
16	JLH-1594 x AKH-24	3.76**	-2.41**	-14.82**	74.21**	58.67**	6.67**
17	JLH-1594 x LRA-5166	-1.39**	-2.73**	-25.20**	56.83**	29.56**	9.01**
18	KH-118 x NH-545	-3.63**	-7.01**	-16.88**	-14.52**	-19.24**	-43.53**
19	KH-118 x AKH-91	-8.61**	-9.72**	-23.10**	16.44**	1.15	18.58**
20	KH-118 x AKH-62	-1.17**	-6.65**	-12.72**	73.06**	54.03**	22.84**
21	KH-118 x AH –107	-19.52**	-25.52**	-27.26**	18.84**	3.43	-13.12**
22	KH-118 x AKH –44	-25.14**	-34.59**	-27.26**	44.72**	33.53**	-1.74
23	KH-118 x AKH-24	-9.74**	-11.89**	-23.10**	4.17	0.28	-32.59**
24	KH-118 x LRA –5166	13.20**	7.53**	-10.62**	25.33**	9.00**	-8.29**
25	NH –545 x AKH –91	14.25**	11.56**	-0.29	21.70**	11.28**	-6.10**
26	NH –545 x AKH –62	-9.10**	-11.10**	-16.88**	16.99**	9.79**	-12.44**
27	NH –545 x AH-107	-6.67**	-10.63**	-12.72**	1.13	-7.34**	-22.17**
28	NH –545 x AKH –44	-23.33**	-30.85**	-23.10**	32.65**	29.35**	-4.82
29	NH –545 x AKH –24	-10.66**	-11.71**	-21.09**	10.68**	8.55**	-24.10**
30	NH –545 x LRA-5166	23.98**	13.86**	1.77**	14.81**	5.11	-11.56**
31	AKH –91 x AKH –62	-16.27**	-20.00**	-25.20**	-24.42**	-26.50**	-37.98**
32	AKH –91 x AH –107	-4.53**	-10.63**	-12.72**	-32.28**	-32.44**	-42.99**
33	AKH –91 x AKH – 44	-25.79**	-34.47**	-27.13**	24.41**	16.45**	-1.74
34	AKH –91 x AKH –24	-13.26**	-14.30**	-25.20**	27.34**	14.40**	-3.47
35	AKH –91 x LRA– 5166	9.12**	2.47**	-12.72**	-21.14**	-21.25**	-33.55**
36	AKH –62 x AH – 107	-19.54**	-21.26**	-23.10**	-24.02**	-25.93**	-37.79**
37	AKH –62 x AKH – 44	-28.93**	-34.58**	-27.27**	-1.85	-5.64	-24.75**
38	AKH –62 x AKH –24	-5.77**	-8.90**	-14.82**	-5.11*	-12.56**	-30.27**
39	AKH –62 x LRA –5166	6.22**	-4.40**	-10.62**	-26.43**	-28.35**	-39.72**
40	AH –107 x AKH – 44	-16.43**	-21.52**	-12.72**	-28.63**	-33.05**	-43.77**
41	AH – 107 x AKH – 24	-10.11**	-14.89**	-16.88**	-33.28**	-39.94**	-49.55**
42	AH – 107 x LRA –5166	-5.99**	-16.99**	-18.94**	-30.35**	-30.41**	-41.45**
43	AKH – 44 x AKH – 24	-14.18**	-23.41**	-14.82**	20.66**	15.45**	-15.04**
44	AKH – 44 x LRA–5166	-6.16**	-21.52**	-12.72**	-19.40**	-24.46**	-36.44**
45	AKH – 24 x LRA–5166	5.11**	-2.41**	-14.82**	9.46**	-1.54	-17.16**
	S.E.(d) ±	0.18	0.21		2.49	2.88	
	C.D. (5%)	0.3676	0.4243		5.0318	5.8102	
	C.D. (1%)	0.4909	0.5668		6.7206	7.7605	

SN	Crosses	2.5 % span length (mm)			Fibre Strength (g/tex)		
		H_1	H_2	H_3	H_1	H_2	H_3
1	AKH-84635 xJLH-1594	8.82**	6.58**	8.37**	-7.88**	-15.98**	-29.81**
2	AKH-84635 x KH-118	0.38*	-2.66**	1.00**	-2.95**	-3.73**	-19.58**
3	AKH-84635 x NH-545	0.20	-5.35**	3.77**	-0.86	-8.25**	-23.36**
4	AKH-84635 x AKH-91	-3.26**	-4.72**	-7.11**	-12.81**	-20.33**	-19.58**
5	AKH-84635 x AKH-62	12.69**	9.28**	13.39**	6.08**	-2.25	-3.12**
6	AKH-84635 x AH –107	-12.81**	-15.94**	-11.71**	-4.93**	-11.48**	-14.24**
7	AKH-84635 x AKH-44	14.84**	11.05**	15.90**	26.83**	13.32**	-5.34**
8	AKH-84635 x AKH-24	2.10**	0.00	1.68**	6.18**	-3.73**	-19.58**
9	AKH-84635 xLRA-5166	3.81**	3.43**	0.83**	-5.20**	-7.14**	-19.12**
10	JLH-1594 x KH-118	-5.09**	-6.05**	-2.51**	5.29**	-3.26**	-20.47**
11	JLH-1594 x NH-545	8.12**	4.20**	14.23**	32.41**	30.34**	-7.37**
12	JLH-1594 x AKH-91	7.46**	3.69**	5.43**	12.01**	-5.79**	-4.90**
13	JLH-1594 x AKH-62	0.20	-0.81**	2.93**	20.66**	2.24	1.34
14	JLH-1594 x AH-107	-9.45**	-10.89**	-6.42**	20.68**	3.22**	0.00
15	JLH-1594 x AKH- 44	-5.76**	-6.97**	-2.92**	73.21**	69.29**	16.56**
16	JLH-1594 x AKH-24	4.94**	4.94**	6.71**	16.26**	15.49**	-20.47**
17	JLH-1594 x LRA-5166	-8.91**	-11.11**	-9.62**	-4.86**	-14.82**	-25.82**
18	KH-118 x NH-545	-2.75**	-5.35**	3.77**	-9.57**	-15.69**	-30.70**
19	KH-118 x AKH-91	4.64**	0.00	3.77**	-20.94**	-28.28**	-27.60**
20	KH-118 x AKH-62	6.86**	6.86**	10.88**	9.82**	0.45	-0.44
21	KH-118 x AH –107	4.61**	3.98**	9.20**	-5.51**	-12.67**	-15.40**
22	KH-118 x AKH –44	-7.93**	-8.19**	-4.19**	5.71**	-4.88**	-21.81**
23	KH-118 x AKH-24	-4.69**	-5.65**	-2.09**	12.63**	2.87*	-15.44**
24	KH-118 x LRA –5166	0.56*	-2.83**	0.83**	10.78**	7.67**	-6.23**
25	NH –545 x AKH –91	5.35**	-1.90**	7.55**	-9.59**	-22.97**	-22.24**
26	NH –545 x AKH –62	10.97**	8.00**	18.40**	-3.50**	-17.15**	-17.88**
27	NH –545 x AH-107	-8.39**	-10.31**	-1.67**	15.37**	0.00	-3.12**
28	NH –545 x AKH –44	-1.85**	-4.20**	5.02**	45.09**	39.65**	-0.75
29	NH –545 x AKH –24	3.81**	0.04	9.68**	46.41**	43.20**	1.77
30	NH –545 x LRA-5166	-5.13**	-10.69**	-2.09**	-2.25*	-11.24**	-22.70**
31	AKH –91 x AKH –62	5.91**	1.21**	5.02**	-14.71**	-15.49**	-14.69**
32	AKH –91 x AH –107	-2.71**	-7.56**	-2.92**	-11.04**	-12.84**	-12.01**
33	AKH –91 x AKH – 44	3.07**	-1.78**	2.51**	17.86**	-2.70*	-1.78
34	AKH –91 x AKH –24	7.04**	3.29**	5.02**	0.50	-15.93**	-15.13**
35	AKH –91 x LRA– 5166	12.85**	11.56**	7.95**	-15.42**	-21.22**	-20.47**
36	AKH –62 x AH – 107	3.93**	3.31**	8.50**	-24.76**	-25.60**	-26.26**
37	AKH –62 x AKH – 44	-1.90**	-2.18**	2.09**	-10.54**	-25.60**	-26.26**
38	AKH –62 x AKH –24	-7.13**	-8.06**	-4.60**	-4.25**	-19.31**	-20.02**
39	AKH –62 x LRA –5166	2.65**	-0.81**	2.93**	-4.07**	-9.89**	-10.69**
40	AH –107 x AKH – 44	1.92**	1.60**	6.71**	-11.15**	-25.43**	-27.76**
41	AH – 107 x AKH – 24	-1.62**	-3.18**	1.68**	5.68**	-10.10**	-12.91**
42	AH – 107 x LRA –5166	7.00**	2.79**	7.95**	6.78**	1.39**	-1.78
43	AKH – 44 x AKH – 24	10.07**	8.65**	13.39**	21.00**	19.03**	-19.12**
44	AKH – 44 x LRA–5166	8.59**	4.64**	9.20**	37.60**	20.73**	5.15**
45	AKH – 24 x LRA–5166	-1.75**	-4.12**	-2.51**	32.45**	17.90**	2.68*
	S.E.(d) ±	0.18	0.41		0.97	1.12	
	C.D. (5%)	0.3786	0.8374		1.9582	2.2611	
	C.D. (1%)	0.5057	1.1184		2.6154	3.0200	

Whereas, the cross JLH-1594 x LRA-5166 ranked third in per se performance for yield showed significant heterosis in desirable direction for yield and most of the yield contributing traits. This was closely followed by the crosses *viz*., JLH-1594 x AKH-44, JLH-1594 x AKH-24, AKH-84635 x JLH-1594 and JLH-1594 x NH-545 exhibiting significant heterosis, heterobeltiosis and useful heterosis in desirable direction for most of the characters including seed cotton yield.

Similar results have been reported by several workers using different parents which supports the present findings [6-9, 13-26, 34-37]. The highest estimates of useful heterosis over PKV Hy-2 was recorded in cross KH-118 x AKH-62 for seed cotton yield per plant 22.84 per cent. It is revealed from present investigation that most of the high yielding crosses are generally associated with high heterosis. However, perfect co-linearity between yielding ability and heterosis could not be established. Similar results have been reported by many scientists working in cotton [28,29,8,34,31,35,2]

Conclusion

The considerable magnitudes were estimated for all three kinds of heterosis in desirable direction. The maximum estimates of heterosis and heterobeltiosis for seed cotton yield per plant were observed in JLH-1594 x AKH-24 (74.21 and 58.67 per cent) followed by KH-118 x AKH-62 (73.06 and 54.03 per cent) over environments, whereas KH-118 x AKH-62 surpassed all the forty-five crosses for useful heterosis (22.84 per cent) over local released hybrid *i.e.*, PKV Hy-2.

Implication

On average basis, the crosses *viz*., JLH-1594 x AKH-24, KH-118 x AKH-62 and KH-118 x AKH-62 may be identified for the exploitation of heterosis for seed cotton yield and for improvement of contributing traits.

Application of research

Development of Hybrids in cotton

Research Category: Genetics and Plant breeding, Cotton hybrid breeding

Abbreviations: ANOVA-Analysis of Variance,
SE-Standard Error, CD-Critical Difference

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Research project name or number: Molecular analysis of polymorphism, heterosis and combining ability in cotton (*Gossypium hirsutum* L.)

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Study area / Sample Collection: Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 444 104, Maharashtra

Cultivar / Variety / Breed name: Cotton (*Gossypium hirsutum* L.)

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