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BREEDING FOR ENHANCED FIBRE QUALITY TRAITS IN UPLAND COTTON (*Gossypium hirustum* L.) THROUGH LINE × TESTER ANALYSIS

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ABSTRACT

The experiment was conducted using a randomized complete block design with three replications at Shah Abdul Latif Experimental Farm, Sindh Agriculture University, Tandojam. Following a line × tester mating design in upland cotton (*Gossypium hirsutum* L.), twenty-one cross combinations were obtained from seven females and three males. F_1 and F_2 generations, along with their parents, were sown in a randomized complete block design with three replications during 2012-13 and 2013-14. Studied traits included lint yield (g) per plant, G.O.T (%), staple length (mm), fiber fineness (mic.value), and fiber strength (g/tex). Throughout the growing period, recommended cultural practices were followed. Analysis of variance revealed high significance for genotypes, parents, crosses, and their interactions (P×C) for all traits. In the F_1 generation, lint yield and staple length under line × tester (L×T) were highly significant. For the F_2 generation, genotypes, parents, crosses, and P×C were highly significant for all traits except G.O.T%, where lines, testers, and L×T were highly significant for all traits except G.O.T%. Cross VH-292 × VH-291 excelled in lint yield per plant, while CRIS-342 × IR-3701 demonstrated superior fiber fineness and strength. VH-292 × VH-291 also displayed higher lint yield per plant, while CRIS-342 × FH-113 exhibited longer staple length with increased fiber fineness. Significant mean squares for genotypes (parents, crosses, and parents × crosses) indicate the data's utility for assessing parental performance, hybrid evaluation, heterotic effects, and inbreeding depression.

Key words: Heterosis, fibre traits, line x tester analysis, upland cotton

INTRODUCTION

Cotton is a cash crop of Pakistan and is mainly grown for fiber, food and feed, and cotton fibers play a significant role in uplifting country's economy. Pakistan ranks fourth in area (3.11 million hectares) and production (7.06 million bales) but in Pakistan yield/unit area is very low as compared to ten major cotton growing countries of the world (33.0 million hectares) (Mangi et al., 2019). Cotton accounts for about 11% cropped area and produces 55 percent of the domestic edible oil production in the country (Pakistan Bureau of Statistics, 2023). As the lint is a major product of cotton but the byproducts are also very important like seed oil which is being to partial fulfill the needs of cooking oil. Seed hull are also being used to improve the soil fertility as mulching.

Hybrid cotton seed displayed many advantages with respect to the conventional variety seed such as tolerance to abiotic stresses (drought, heat, cold), responsive to inputs and higher productivity (Falconer, 1989), therefore the aim of cotton breeders is to develop varieties those well adapted to environmental conditions and produce higher yields, higher ginning outturn, better fiber quality, fertilizer responsive with increased tolerance to complex diseases and insect pests. For breeding programmers, parents must be genetically superior, physiologically efficient with better general and specific combining abilities so that they could be utilized for both variety development as well as exploitation of heterosis for hybrid crop development. In quantitative genetics, additive genes play progeny performance, while dominant genes are specific to only genotypic value of an individual (Falconer, 1989), thus do not contribute to the progeny from one generation to another. In cotton breeding programs the improvement in lint yield is not the only objective but fiber quality characters like length, strength and fineness etc. are also important in textile industry. The science of plant breeding has a documented history of cotton improvement to meet the producer and processor requirements (Chao-Zhu *et al.*, 2007; Soomro *et al.*, 2008; Batool *et al.*, 2010; Khan *et al.*, 2010).

Objectives

1. To create genetic variability for higher fiber quality traits.
2. To study heterosis in the F_1 generation and inbreeding depression in the F_2 generations

MATERIAL AND METHODS

The experimental material consisted of seven parental lines/ females Viz, VH-292, VH-259, Bt-802, Sadori, Shahbaz, CRIS-342, Bt.ZZ.NL-370 and three testers/ pollinators like VH-291, FH-113 and IR-3701 of upland cotton (*Gossypoium hirsutum* L.) were grown at Shah Abdul Latif experimental farm of Sindh Agriculture University, Tandojam. All female lines were crossed with each tester parent respectively under line × tester mating design. Thus, obtained F_0 seed of 21 cross combination. The next consecutive years the 21 F_1 and F_2 hybrids were grown along with parental lines and testers in a randomized complete bock design (RCBD) with three replications. Space between rows 75 cm and plant to plant 30 cm was maintained. Plot size/ entry were 7.5ft × 24ft (i.e. three rows 24ft long). Five plants from each population per replication were tagged and the data regarding fibre quality tests were collected, seed cotton samples from central row per entry/ replications was collected and reserve the seed. Data was collected from the parameters like:

Lint yield (g) plant^{-1}: Fuzz consisting especially of fine raveling and short fibres of yarn and fabric a fibrous coat of thick convoluted hairs borne by cotton seeds that yields the cotton staples, this lint is removed and used to make cotton thread and fabric cotton seed is the seed of the cotton plant.

G.O.T (%): Seed cotton of selected samples were weighed and then ginned separately with a single roller electric gin. The lint obtained from each sample was weighed and lint percentage was calculated by the following formula:

$$\text{Lint\%} = \frac{\text{weight of lint (g)}}{\text{seed cotton yield per plant (g)}} \times 100$$

Staple length (mm): Staple length was measured from the representative sample from every plant by USTER Hvi-1000 electronic machine and computerized value of staple length each sample were showed in tabulation

Fibre fineness (mic. value): Fineness or micronaire value measure weight of fibre in a micro gram per inch and it was determined with the help of USTER Hvi-1000 on electronical machine and computerized value of fibre fineness for each sample were showed in tabulation.

Fibre Strength (g/tex): Toughness of cotton fibre has effect on yarn and fabric strength with reflects the ultimate physical behavior of the fibre. Higher of fibre strength, higher the yarn and fabric strength through USTER Hvi-1000 on electronical machine and results showed in computerized tabulation

1 .

Lint yield (g) plant^{-1}, G.O.T (%), Staple length (mm), Fibre fineness (mic. value) and Fibre Strength (g/tex):

Statistical analysis: The analysis variance was carried out according to Gomez and Gomez (1984) for determining differences among the genotypes whereas combining ability variances and effects were determine according to statistical methods developed by Kempthrone, (1957) heterosis by Fehr (1987). The inbreeding depression in F_2 hybrid was calculated as percent decrease of F_2 hybrids as compared with F_1 hybrid means as outlined by Soomro *et al*. (2012).

RESULTS

The present research was conducted to find out the heterotic effects of different characters viz. lint yield plant^{-1}, G.O.T (%), staple length, fibre fineness, fibre strength from line x tester mating design. The data regarding variance of twenty-one F_1 and F_2 hybrids along with their parental lines for five quantitative traits are presented in (Table-1). Whereas, the mean performance of parental lines(females), testers (males) and F_1 and F_2 hybrids is summarized (Table-2) for different characters studied. The heterotic effects of F_1 hybrids for fibre traits are presented in (Table-3). The inbreeding depression in F_2 generation of twenty-one crosses is present (Table-4).

Analysis of Variance: The analysis of variance of genotypes and their F_1 and F_2 hybrids showed that they were significantly different for all the traits studied, while in F_2 generation non-significant for GOT% (Table-1).

Mean performance: The data regarding average performance of twenty-one F_1 hybrids along with their seven parental lines indicated that the F_1 hybrids gave lower and some hybrids showed higher mean values against their parents (lines and testers) for all the traits studied. Among the F_1 hybirds the cross maximum values were recorded the cross VH-292×VH-291, Lint yield plant^{-1} (57.70), VH-292×FH-113, fibre fineness (5.40), VH-259×FH-113 staple length (30.3), Sadori×VH-291 G.O.T (%) (37.77), CRIS-342×IR-3701 Fibre strength (33.70). While VH-292 maximum set staple length (28.25), Bt-802 gave lint yield plant^{-1}(46.86), G.O.T (%) (37.99), Sadori set most fibre fineness (4.82), Bt-ZZ-NL-370 set maximum fibre strength (30.65). Whereas in F_2 generation cross VH-292 x VH-291 produced higher lint yield plant-1 (45.03 g), whereas cross CRIS-342 x FH-113 and Sadori x VH-291 showed higher staple length (31.27 mm) and fibre strength (34.80) respectively, while VH-292 xFH-113 displayed higher fibre fineness (5.24)

Table-1 Mean square values (ANOVA) for characters studied of F_1 and F_2 hybrids and parents involved in L×T mating design during 2012-13 and 2013-14

Source of variation	Degree of Freedom	Lint yield g plant^{-1}		G.O.T (%)		Staple length (mm)		Fibre fineness (mic.value)		Fibre Strength (g/tex)	
		F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Replications	2	14.59	24.56	17.19	11.28	15.51	19.35	16.12	13.68	??-^{1}	3.04
Genotypes	30	129.81**	67.32**	1.02**	0.75 ns	4.29**	4.60**	0.54**	0.53**	12.81**	19.71**
Parents(P)	9	98.08**	86.75**	2.00**	1.55 ns	4.98**	2.76**	0.48*	0.47*	4.90**	1.80 ns
P vs C	1	882.734**	6.54 ns	17.962**	0.14 ns	44.857**	29.26**	4.288**	2.13**	44.101**	104.74**
Crosses (C)	20	122.61**	61.62**	0.63 ns	0.43 ns	3.51**	4.19**	0.46**	0.47*	16.26**	23.53**
Lines (female parents)	6	98.95**	59.42 **	1.70**	1.26 ns	4.84 **	5.12 **	0.95 **	0.34 ns	21.86**	47.08 **
Testers (Male parents)	2	808.835**	386.09 **	502 ns	0.25 ns	0.318 ns	3.28 **	0.167 ns	1.02 *	9.720 **	38.09 **
Line x Tester	12	20.075**	8.64 ns	0.11 ns	0.04 ns	3.384**	3.88**	0.257 ns	0.45*	14.557**	9.32**
Error	60	0.678	10.55	0.321	2.4	0.222	0.31	0.192	0.23	0.397	1.59

**, * = Significant at 1% and 5% probability Level

Table-2 Mean values for Characters studied of F_1 hybrids, Lines (L) and Testers (T) involved in F_1 L×T mating design during 2012-13

F_1 hybrids/Lines (L) and Testers (T)	Lint yield g Plant^{-1}		G.O. T (%)		Staple length (mm)		Fibre fineness (mic.value)		Fibre Strength (g/tex)	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
VH-292 × VH-291	57.70 a	45.03 a	37.15 a-e	36.94 ab	27.08 i-n	27.81 e-i	4.86 a-e	4.62 a-d	28.50 hi	28.60 g-j
VH-292 × FH-113	51.65 d	35.50 f-k	36.31 ef	36.67 ab	26.49 l-o	28.75 de	5.40 a	5.24 a	25.70 l	29.60 f-i
VH-292 × IR-3701	43.41 u	35.36 f-k	36.90 c-e	36.52 ab	29.59 ab	27.33 h-k	4.85 a-e	4.52 a-e	30.80 de	30.10 e-g
VH-259 × VH-291	52.03d	43.42 a-d	36.45 d-f	36.15 ab	27.66 f-j	29.59 cd	4.93 a-d	3.85 c-e	30.60 ef	32.50 a-d
VH-259 × FH-113	47.88 e	40.56 a-g	36.47 d-f	36.29 ab	30.3 a	30.63 ab	5.30 ab	4.38 a-e	31.30 c-e	31.20 c-f
VH-259 × IR-3701	41.54 k	36.09 f-j	36.46 d-f	36.15 ab	29.18 bc	27.89 e-i	4.98 a-d	4.80 a-c	31.90 cd	30.00 e-g
Bt.802 × VH-291	56.25 b	43.92 a-c	37.55 a-d	36.87 ab	27.71 f-j	30.00 bc	4.49 b-h	4.10 b-e	30.60 ef	29.60 f-i
Bt.802 × FH-113	47.36 e-g	37.89 c-h	36.80 c-e	36.89 ab	29.01 b-d	27.48 g-k	4.72 a-f	3.97 b-e	32.00 c	30.20 e-g
Bt.802 × IR-3701	42.10 jk	35.32 g-k	36.97 b-e	36.67 ab	26.92 l-n	26.65 j-m	4.71 a-f	4.88 ab	28.00 u	24.40 l
Sadori × VH-291	56.78 ab	44.25 ab	37.77 a-c	37.07 ab	29.13 bc	28.55 e-g	4.61 a-g	4.59 a-e	33.10 ab	34.80 a
Sadori × FH-113	47.56 ef	38.54 b-h	37.39 a-e	37.17 ab	27.94 f-i	27.94 e-h	4.20 d-h	4.49 a-e	31.20 c-e	33.40 a-c
Sadori × IR-3701	44.19 i	35.88 f-j	37.64 a-c	36.96 ab	28.14 e-h	27.66 f-j	4.23 c-h	5.12 a	32.20 bc	29.00 f-j
Shahbaz × VH-291	54.58 c	41.49 a-g	37.31 a-e	37.18 ab	27.48 f-k	27.10 h-l	4.42 c-h	4.37 a-e	26.90 jk	29.70 f-h
Shahbaz × FH-113	44.36 i	37.14 d-i	37.27 a-e	37.15 ab	26.87 j-n	27.20 h-l	4.65 a-g	4.68 a-d	28.70 hi	27.30 h-j
Shahbaz × IR-3701	36.75 m	31.07 i-m	37.19 a-e	36.69 ab	28.35 c-f	28.85 de	5.09 a-c	5.11 a	29.00 hi	24.89 kl
CRIS-342 × VH-291	47.40 e-g	37.89 c-h	37.41 ef	36.08 ab	27.69 f-j	28.70 d-f	4.37 c-h	5.06 a	30.20 e-g	34.00 ab
CRIS-342 × FH-113	45.75 h	36.89 e-i	36.30 ef	36.12 ab	27.36 g-l	31.27 a	4.17 d-h	3.91 c-e	27.10 jk	30.40 d-g
CRIS-342 × IR-3701	37.32 lm	29.49 k-m	36.44 d-f	36.12 ab	27.29 h-m	28.88 de	4.03 e-h	4.74 a-c	33.70 a	33.30 a-c
Bt.ZZ.NL. -370 × VH-291	43.16 u	36.12 f-j	36.91 c-e	36.67 ab	27.58 f-j	27.86 e-i	5.08 a-c	4.34 a-e	25.7 l	33.30 a-c
Bt.ZZ.NL. -370 × FH-113	46.21 f-h	35.12 g-l	36.82 c-e	36.54 ab	26.24 no	27.92 e-i	4.90 a-e	4.48 a-e	31.20 c-f	33.30 a-c
Bt.ZZ.NL. -370 × IR-3701	36.00 m	28.89 m	36.98 b-e	36.49 ab	26.42 m-o	28.55 e-g	4.20 d-h	5.53 a-e	28.80 hi	32.10 b-e
VH-292 (L)	46.82 e-h	41.80 a-f	37.08 a-e	36.92 ab	28.85 b-e	28.50 e-g	4.72 a-f	4.65 a-d	29.25 f-h	29.00 f-j
VH-259 (L)	43.68 ij	41.77 a-f	35.68 g	35.70 b	28.25 d-g	28.50 e-g	4.35 c-h	4.30 a-e	29.15 g-i	29.13 f-j
Bt-802 (L)	46.86 e-h	43.04 a-e	37.99 ab	37.33 ab	26.30 mo	26.85 i-m	3.81 gh	3.75 de	20.25 e-g	28.85 f-j
Sadori (L)	43.96 j	40.48 a-g	37.99 ab	37.91 a	26.55 l-o	27.00 h-m	4.82 a-f	4.65 a-d	26.85 k	26.85 jk
Shahbaz (L)	38.19 l	36.03 f-g	37.53 a-c	37.41 ab	25.25 p	26.50 k-m	4.31 c-h	4.31 a-e	27.25 jk	27.15 ij
CRIS-342 (L)	35.86 m	33.57 h-m	35.62 fg	35.67 b	25.85 op	26.00 m	3.97 f-h	3.85 c-e	30.45 ef	28.45 g-j
Bt.ZZ.NL-370 (L)	33.26 n	30.46 j-m	36.68 d-f	36.52 ab	26.65 k-o	26.85 i-m	4.60 a-g	4.60 a-e	30.65 ef	28.85 f-j
VH-291 (T)	46.54 e-h	44.28 ab	36.82 c-f	36.67 ab	26.25 no	26.20 lm	3.70 h	3.65 e	29.15 g-i	28.45 g-j
FH-113 (T)	45.94 gh	39.32 a-h	36.89 c-f	36.75 ab	29.06 b-d	28.50 e-g	4.15 d-h	4.01 b-e	28.05 hi	27.95 g-j
IR-3701 (T)	33.09 n	29.14 lm	36.99 a-e	36.33 ab	27.05 i-n	27.20 h-l	4.70 a-f	4.60 a-e	28.45 hi	28.15 g-j

Dendogram of fibre traits in F_1 and F_2 generation: The diagram of lines, tester and their crosses for the fibre traits (Fig. 1) for F_1generation which further revealed that four groups are formed. The largest groups contain 17 genotypes while Bt-802 remain single in a group, while for the fibre traits in F_2 generation, similar trend of groups is formed. The largest group contains 15 genotypes while smallest group contain 5 genotypes (Fig 2).

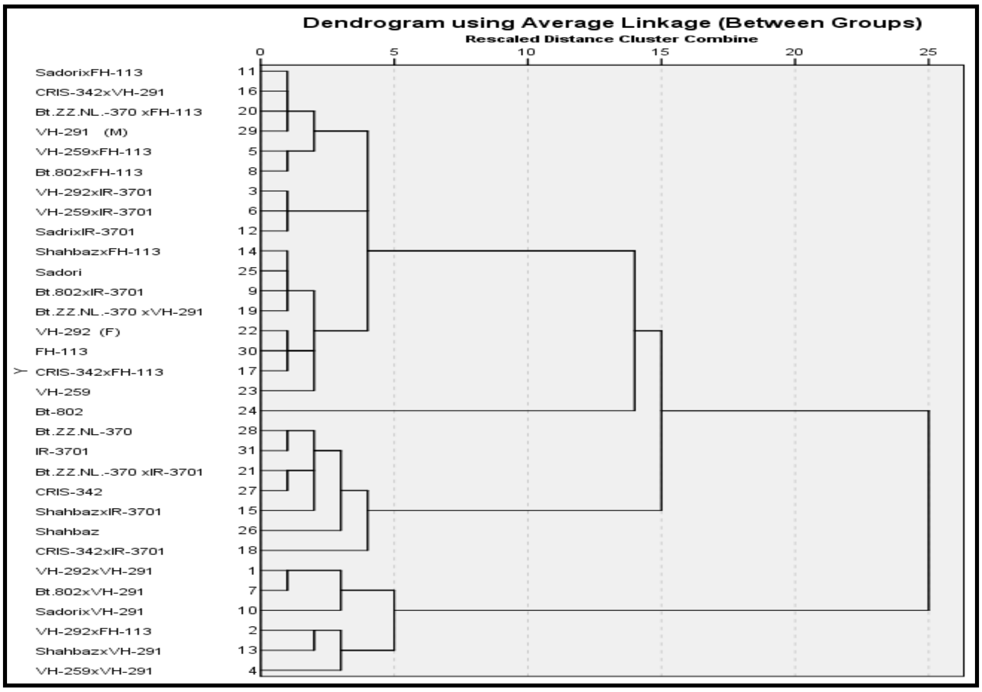

Figure 1 Diagram for Parents and their crosses for fibres traits in F_1 generation

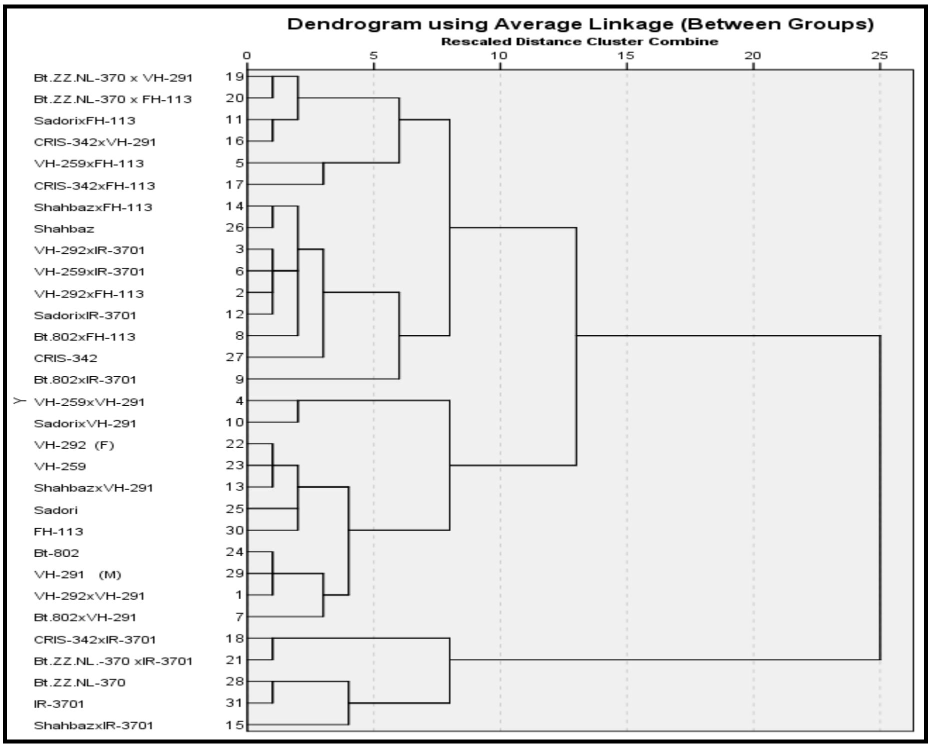

Figure No. 2. Diagram for Parents and their crosses for fibre traits in F_2 generation

Table-3 Hetertic effect (%) (Heterosis over mid parent, heterobeltiosis over better parent) in F_1 generation of L×T mating design during 2012-13

F_1 Crosses	Lint Yield plant^{-1}		G.O. T (%)		Staple Length		Fibre fineness		Fibre Strength	
	Ht (%)	Htb (%)	Ht (%)	Htb (%)	Ht (%)	Htb (%)	Ht (%)	Htb (%)	Ht (%)	Htb (%)
VH-292 × VH-291	23.60	23.24	0.54	0.19	-1.70	-6.13	15.44	2.97	-2.39	-2.56
VH-292 × FH-113	11.36	10.32	-1.84	-2.08	-8.49	-8.81	21.62	14.40	-10.29	-12.14
VH-292 × IR-3701	8.63	-7.28	-0.38	-0.48	5.40	2.11	2.97	2.75	6.76	5.29
VH-259 × VH-291	15.34	11.82	0.55	-1.00	1.50	-2.09	22.33	13.33	4.97	4.1
VH-259 × FH-113	6.85	4.22	0.49	-1.16	5.75	4.30	24.70	21.84	9.44	7.37
VH-259 × IR-3701	8.21	-4.89	0.33	-1.43	5.53	2.40	9.93	14.48	10.76	9.43
Bt-802 × VH-291	20.47	20.04	0.37	-1.16	5.44	5.36	19.41	17.85	3.03	1.16
Bt-802 × FH-113	2.09	1.09	-1.74	-3.13	4.80	-0.14	18.59	13.73	9.78	5.78
Bt-802 × IR-3701	5.30	-10.16	-1.39	-2.68	0.89	-0.48	10.82	0.21	-4.59	-7.44
Sadori × VH-291	25.48	22.03	0.96	-0.58	10.34	9.72	8.21	-0.20	18.21	13.55
Sadori × FH-113	5.80	3.53	-0.16	-1.58	0.50	-3.82	-6.46	-12.86	13.66	11.23
Sadori × IR-3701	14.69	0.52	0.40	-0.92	5.00	4.03	-11.13	-12.24	16.45	13.18
Shahbaz × VH-291	28.85	17.30	3.35	-0.59	6.72	4.68	10.5	2.55	-4.60	-7.72
Shahbaz× FH-113	5.44	-3.44	0.21	-0.61	-1.03	-7.50	9.93	7.89	3.79	2.32
Shahbaz × IR-3701	3.11	-3.77	-0.19	-0.90	8.41	4.80	12.86	18.09	4.13	1.93
CRIS-342 × VH-291	15.05	1.87	0.52	-1.11	6.29	5.48	13.80	10.07	4.08	-0.82
CRIS-342 × FH-113	11.86	-0.41	0.11	-1.63	-0.33	-5.82	2.70	0.48	-7.35	-11.00
CRIS-342 × IR-3701	8.20	4.04	0.36	-1.49	3.17	0.89	-7.14	-14.25	14.43	10.67
Bt.ZZ.NL370× VH-291	8.20	-7.24	0.43	0.24	4.27	3.49	22.40	10.43	-14.05	-16.15
Bt.ZZ.NL.370× FH-113	16.41	0.59	0.08	-0.22	-5.78	-9.67	11.87	18.07	6.30	1.79
Bt.ZZ.NL .370×IR-3701	8.50	8.79	0.38	-0.03	-1.60	-2.33	-9.68	-10.64	-2.54	-6.03

Table-4 Heterotic effect (%) (heterosis over mid parent (Ht%), heterobeltosis (Htb %) over better parent and inbreeding depression (%) in F_2 generation of L × T for fibre mating design in cotton *(G. hirsutum* L.) during 2013-14

F_2 Crosses	Seed Cotton Yield plant^{-1}			Lint Yield plant^{-1}			G .O .T(%)			Staple Length			Fibre Fineness			Fibre Strength		
	Ht (%)	Htb (%)	Ibd (%)	Ht (%)	Htb (%)	Ibd (%)	Ht (%)	Htb (%)	Ibd (%)	Ht (%)	Htb (%)	Ibd (%)	Ht(%)	Htb(%)	Ibd(%)	Ht(%)	Htb(%)	Ibd(%)
VH-292×VH-291	4.19	0.36	21.51	4.62	1.69	21.96	0.38	0.05	0.56	1.68	-2.42	-2.69	11.35	-0.64	4.94	-0.45	-1.38	-0.35
VH-292×FH-113	3.70	0.85	19.72	-12.47	-15.07	31.27	-0.46	-0.68	-0.99	0.87	0.88	-8.53	21.02	12.69	2.96	3.93	2.07	-15.17
VH-292×IR-3701	0.09	-14.50	17.72	-0.31	-15.40	18.54	-0.30	-1.08	1.03	-1.87	-4.10	7.23	-2.37	-2.79	6.80	5.32	3.79	2.27
VH-259×VH-291	1.04	-0.53	15.85	0.90	-1.94	16.55	-0.11	-1.42	0.82	8.19	3.82	-6.52	-3.27	-10.46	21.90	15.25	11.57	-6.20
VH-259×FH-113	-0.16	-4.45	14.87	0.02	-2.89	15.29	-0.08	-1.25	0.49	7.47	7.48	-1.09	5.54	1.86	17.36	11.63	7.11	0.32
VH-259×IR-3701	1.26	-14.66	12.36	1.78	-13.59	13.12	0.36	-0.49	0.86	0.14	-2.14	4.42	7.86	4.35	3.61	6.95	2.99	5.96
Bt-802×VH-291	0.93	-1.35	20.47	0.59	-0.81	21.92	-0.35	-1.23	1.81	13.08	11.73	-8.26	10.81	9.33	8.68	3.31	2.59	3.27
Bt-802×FH-113	-7.60	-10.93	20.21	-7.98	-11.96	20.01	-0.40	-1.18	-0.24	-0.72	-3.58	5.27	2.32	-0.75	15.89	6.34	4.68	5.62
Bt-802×IR-3701	-1.46	-16.46	15.42	-2.10	-17.94	16.10	-0.43	-1.76	0.81	-1.40	-2.02	1.00	16.75	6.09	-3.60	-14.38	-15.42	12.86
Sadori×VH-291	4.92	-1.14	20.59	4.41	-0.07	22.07	-0.59	-2.21	1.85	7.33	5.74	1.99	10.60	-1.29	0.43	25.86	22.32	-5.13
Sadori×FH-113	-2.55	-2.64	18.11	-3.40	-4.79	18.96	-0.88	-2.40	1.04	0.68	-1.96	0.00	3.69	-3.44	-6.90	21.89	19.49	-7.05
Sadori×IR-3701	3.84	-9.08	17.29	3.07	-11.36	18.80	-0.43	-2.50	1.80	2.07	1.69	1.70	10.58	10.10	-21.04	5.45	3.02	9.94
Shahbaz×VH-291	2.81	-7.60	23.71	3.31	-6.30	23.98	0.38	-0.61	0.35	2.85	2.26	1.38	9.79	1.39	1.13	5.03	2.64	-10.40
Shahbaz×FH-113	-1.64	-6.55	15.93	-1.43	-5.54	19.44	0.19	-0.69	0.40	-1.09	-4.56	-1.23	12.5	8.58	-0.64	-0.90	-2.32	4.88
Shahbaz×IR-3701	-4.03	-12.06	14.30	-4.66	-13.77	1.85	-0.49	-1.92	1.34	7.45	6.07	-1.76	14.57	11.09	-0.39	-9.94	-11.54	14.14
CRIS-342×VH-291	-2.24	-13.02	19.32	-2.67	-14.43	20.06	-0.25	-1.60	0.90	9.96	9.54	-3.65	34.94	31.43	-15.79	19.50	19.51	-12.58
CRIS-342×FH-113	1.55	-4.55	18.97	1.20	-6.18	19.37	-0.25	-1.71	0.49	14.75	9.72	-14.29	-0.50	-2.25	6.23	7.80	6.85	-12.18
CRIS-342×IR-3701	-6.31	-13.24	20.25	-5.93	-12.12	20.93	0.33	-0.58	0.88	8.57	6.18	-5.83	12.06	3.04	-17.62	17.67	17.05	1.19
Bt.ZZ.NL-370×VH-291	-3.52	-18.43	15.75	-3.34	-18.43	16.31	0.19	0.00	0.65	5.01	3.76	-1.01	5.08	-5.65	14.57	16.23	15.42	-29.57
Bt.ZZ.NL-370× FH-113	0.97	-10.16	23.41	0.66	-10.68	23.99	-0.27	-0.57	0.76	0.87	-2.03	-6.40	4.19	-2.60	8.57	17.25	15.42	-6.73
Bt.ZZ.NL-370×IR-3701	-3.24	-5.09	18.68	-3.05	-5.15	19.75	0.16	-0.08	1.32	5.62	4.96	-8.06	20.21	20.22	-12.14	12.63	11.26	-11.46

Lint yield plant^{-1}: The heterosis results showed that all theF_1 hybrid progenies expressed positive heterotic effects in their lint yield plant^{-1} to their respective parents. The range of increase varied from (2.09%) to (28.85%) and the maximum increase was recorded in the cross Shahbaz×VH-291. Whereas positive heterobeltiosis ranged between (0.52%) to (23.24%) and the maximum increased shown by VH-292 x VH-292 in F1 generation. As for the heterotic effects in F_2 generation are presented in (Table-4), which further revealed that out of twenty-one hybrid ten hybrids gave positive heterosis and only two hybrids produced positive heterobeltiosis. Maximum heterosis has been expressed by the crosses Sadori×VH-291 (4.92%) and positive heterobeltiosis effects were recorded only for the cross VH-292 × FH-113 (0.05%). The minimum inbreeding depression was expressed by the cross VH-259 × IR-3701 (12.36%).

Ginning outturn percentage (G.O.T %): The results for relative heterotic and heterobeltiosis effects for the ginning out turn percentage (Table-3) revealed that positive heterosis ranged from (0.11%) to (3.35 %) whereas positive heterobeltiosis varied between 0.19 to 0.24% among the F_1 hybrids. The highest increase (3.35%) was recorded in the cross Shahbaz×VH-291 while maximum heterobeltiosis (0.24%) was expressed by the hybrid Bt.ZZ.NL-370×VH-291. In case of F_2 hybrids out of twenty-one hybrids seven hybrids gave positive heterosis and only one hybrid produced positive heterobeltiosis. Maximum heterosis and heterobeltiosis were expressed by the cross VH-292×VH-291 (0.38% and 0.05%). The minimum inbreeding depression was expressed by the cross VH-292 x FH-113 (-0.99).

Staple length: The results indicated that F_1 hybrids expressed positive heterosis ranged from 0.50% to 10.34% and positive heterobeltiosis (0.89%) to (9.72%). The highest heterosis (10.34%) and heterobeltiosis (9.72%) was noted in cross Sadori × VH-291. The results regarding heterotic effects and inbreeding depression in F_2 generation for staple length (Table-4) indicated that out of twenty-one F_2 hybrids seventeen hybrids exhibited positive heterosis and the magnitude of positive relative heterosis ranged from 0.14% to 14.75%, whereas the highest heterosis (14.75%) and heterobeltiosis (0.72%) was noted in cross CRIS-342 × FH-113. The results regarding the inbreeding depression in F_2 hybrids showed that minimum inbreeding depression was observed in cross CRIS-342 x FH-113 (-14.29).

Fibre fineness: The results for relative heterotic and heterobeltiosis effects for fibre fineness (mic. value) in F1 generation are summarized (Table-3), which revealed that positive heterosis ranged between 2.70% and 24.70%, whereas positive heterobeltiosis varied from 0.21% to 21.84% among the F_1 hybrids. The highest heterosis (24.70%) and heterobeltiosis (21.84%) was recorded by cross VH-259×FH-113. The heterotic effects and inbreeding depression presented in (Table-4). Revealed that, eighteen F_2 hybrids gave positive heterosis. Maximum heterosis and heterobeltiosis was expressed by the crosses CRIS-342 × VH-291 (34.94% and 31.43%). The minimum inbreeding depression was expressed by the cross Sadori x IR-3701 (-21.04).

Fibre strength: The results for relative heterotic and heterobeltiosis effects summarized (Table-3), indicated that among F_1 hybrids fourteen gave positive heterosis ranging from 3.03 % to 18.21%. Thirteen crosses exhibited positive heterobeltiosis raging between 1.16% to 13.55%. The relative heterosis (18.21%) and heterobeltiosis (13.55%) was recorded by the cross Sadori × VH-291. The heterosis, heterobeltiosis and inbreeding depression presented in (Table-4). Out of twenty-one F_2 hybrids seventeen hybrids gave positive heterosis and heterobeltiosis. Maximum heterosis and heterobeltiosis was expressed by the crosses Sadori × VH-291 (25.86% and 22.32%). The minimum inbreeding depression was expressed by the cross Bt.ZZ.NL-370 x VH-291 (-29.57).

DISCUSSION

For the improvement of any plant character, plan breeders heavily rely upon the availability of genetic variability determined by various mating designs. Cotton breeders are also well known of the phenomenon the in hybridization programme, certain crosses pass more favorable genes towards the progeny that the others.The some cross combinations may be superior as compared to their parents for improving any economic traits in cotton breeding.The present research therefore was designed to estimate the heterosis of different economically important fibre traits developed through line x tester analysis along with ten parent lines of which seven parent were used as a lines / females and three parents as testers/pollinators in upland cotton (*Gossypium hirsutum* L.). Results obtained are discussed here under.

Analysis of Variance: The results of analysis of variance for F_1 and F_2 revealed that significant variation exited among the parents as well as hybrids for upland cotton generally for the characters viz lint yield (g) plant^{-1}, G.O.T (%), staple length (mm), fibre fineness (mic. value), fibre strength (g/tex). These results indicated that for three characters studied the differences between parents vs. F_1 hybrids suggested the scope of heterosis breeding. The results regarding heterotic effects in F_1 and F_2 generation shown similar trend except GOT%. Several previous researches like Kaushik and Sastry (2011), Patil *et al*. (2011), Kumbhar *et al*. (2016) observed the significant differences in F_1 and F_2 hybrids of upland cotton.

Dendogram of fibre traits in F_1 and F_2 generation: The diagram of lines, tester and their crosses for the agronomic, fibre and insect infestation for F_1 generation revealed that variety Sadori is different from rest of the genotypes for the agronomic traits and formed in a separate group whereas the variety Shahbaz kept identical for the insect infestation traits. The findings further revealed that Bt-802 is different from the rest of the genotypes for fibre traits in F_1 generation. The figures showd that as the distance increases the similarity among the genotypes increases. Cecil and Bridges (1966) explained that taxonomic dendrogram of the biological systematist, shows the class-inclusive relations between clusters and the value of the clustering criterion associated with each, whereas Gerta *et al*. (2021) reported that dendograms contributes to identifying homogeneous subgroups and examining the structure of targeted data. It is the evident that as the homozogosity increases, the genotypes with similar genes goes to the same pole and it is further assume that in the subsequent generations, few genotypes which shows difference will be selected and evaluated targeted objectives with higher seed cotton yield with quality fibre and tolerant to the insects described that it is the best method for sorting the best genotypes with the independent trais as whole, whereas Massimo (2009) reported that this methos is an indicator for sorting the genotypes.

Heterosis analysis: Studies on heterosis and inbreeding in cotton being cross pollinated crop have been reported by many pervious researchers. The main pre-condition to design a model hybrid it to obtain parental lines possessing desirable gens and recombine those genes in such a way that genes pair- up and produce Superior F_1 hybrids. Heterosis or hybrid vigor is defined as the difference in percent between the hybrid and the mean of two parents (Falconer, 1989). This the line × tester analysis through heterosis estimates the targeted interest in the material trait that the cotton breeder in interested in and is selecting for while developing cotton breeding population of cultivars development programme. Hussain *et al*. (2010) the occurrance of heterosis is common phenomenon in plant species but its level of expression is highly variable.

The loss of vigor a common phenomenon seen in the performance of F_2 hybrids which is referred as breeding depression which occurs due to homozygosity. It is also expected that some F_2 might manifest superiority over their better parents when grown under stress conditions and can produce better combinations for yields. In some studies, F_2 yield performance was highly correlated with F_1s and their parents. It is anticipated that F_2. Progenies manifested only 50% of useful heterosis expressed by F_1 hybrids and even less when heterosis is characterized it terms of higher yielding parent. Nevertheless, F_2 hybrids with lower inbreeding depression in yield of higher yielding and superior performance over cultivars have been reported in many crop species, specially, in cotton. The existence of such populations lands creditability to use them as profitable F_2 hybrids. Studies on inbreeding depression therefore has great advantage of F_2 hybrids with less inbreeding depression are identified.

Lint yield plant^{-1}: For lint yield plant^{-1}, the ANOVA revealed significant difference between genotypes, parents, crosses, lines and testers, whereas the parent vs crosses was non-significant. Among the parents Bt-802 and VH-292 in female parents VH-291 and FH-113 in the male parents gave the higher *per se* performance for this character. The mean performance of hybrids *per se* showed that hybrids VH-292 × VH-291and Shahbaz × VH-291set at high lint yield (g) plant^{-1}. Our results are agreement with those reported by Shabana *et al*. (2014), Kumbhar *et al*. (2016), Talpar *et al*. (2016). The heterotic performance revealed that most the F_1 hybrids expressed positive desirable relative mid and better parent heterosis. Yet, maximum positive heterosis and heterobeltiosis were manifested by the hybrids VH-292 × VH-291, Sadori × VH-291 and Shahbaz × VH-291 which also superior as regarded relative heterosis. Similar findings were obtained by Ekinici *et al*. (2016). As for the mean performance *per se* of F_2 hybrids VH-292 × VH-291 and Sadori × VH-291 gave highest lint yield plant^{-1}. In case of female parents VH-292 and Bt-802 gave maximum lint yield plant^{-1}and among the testers VH-291followed by FH-113 gave highest lint yield plant^{-1}. Present results are in conformity was those of Lu and Myers (2011) and Kumar *et al*. (2014). In the review, previous researcher reported heterotic effects from 100 to 200% in lint yield. This is probably the reason that's why heterosis has become successful in cotton being predominantly self-pollinated crop. All the twenty-one F_2 hybrids showed highly positive related heterosis VH-292 × VH-291, Sadori × VH-291. Whereas showed one positive related heterobeltiosis VH-292 × VH-291.The high heterotic effects for lint yield plant^{-1} perfectly. As far as inbreeding depression the crosses VH-292 × FH-113, Bt.ZZ.NL-370 × FH-113 and Shahbaz × VH-291 showed the maximum highest among the F_2 inbreeding depression. Present results are in conformity was those of El-Hashah (2013) Ranganatha *et al*. (2013) and Tyagi *et al*. (2014) and Ekinci *et al*. (2016).

Ginning our turn percentage (G.O.T%): It is complex character which is controlled by many genes being polygenic in nature primarily it depends on the proportion of lint weight from seed cotton sample (Ali et al., 2008). The ANOVA results depicted the non- significant difference between genotypes, parents, crosses, lines and testers, whereas the parent's vs crosses were non-significant ginning out turn percentage. Similar to present results, Hamoud (2014), Patel and Kumar, (2014), also reported that G.O. T percent was controlled by additive and non-additive genes. The heterotic results indicated that the hybrids with maximum heterosis were VH-292 × VH-291 and Bt.ZZ.NL-370 × VH-291. The findings are in accordance with those of Campbell and Bowman (2010), who also estimated heterosis for G.O.T percent. As for the mean performance each of F_2 hybrids Shahbaz × VH-291, Sadori × FH-113 and Shahbaz × FH-113 gave highest ginning out turn percentage, mean performance of the female parent *per se* Sadori and Shahbaz gave maximum ginning out turn percentage. Among the testers *per se* performance FH-113 and followed by VH-291 gave highest ginning out turn percentage. Present results are in conformity was those of Singh *et al*. (2010), Dhivya *et al*. (2014) and Rajmani (2014). All the twenty-one F_2 hybrids showed highly positive related heterosis VH-292 × VH-291, Shahbaz × VH-291, VH-259 × IR-3701.Whereas showed one positive related heterobeltiosis VH-292 × VH-291.The high heterotic effects for ginning out turn percentage perfectly. As far as inbreeding depression such as Sadori × VH-291 and Bt-802 × VH-291 recorded the maximum highest among the F_2 inbreeding depression present results are in conformity was those of Rasheed *et al*. (2014), Tyagi *et al*. (2014) and Usman and Yazdan (2015).

Staple length: Among the fibre properties, staple length is one of the most important properties from economic point of view. However, length is more useful in yarn manufacturing. The ANOVA results revealed significant differences between genotypes, parents, crosses, lines and testers. The mean performance of lines long staple length was maximum for VH-292 and FH-113 was superior their other lines and testers. Among the mean performance of F_1 hybrids top two hybrids were VH-259 × FH-113 and VH-292 × IR-3701 with long staple length. Basal *et al*. (2011) and Iqbal *et al*. (2013), also reported significant GCA and SCA variances showing importance of both additives and non-additive genes involved in the expression of staple length.The results regarding heterosis suggested that most of the crosses manifested positive heterosis and heterobeltiosis for the character staple length nonetheless, the highest scoring hybrids was Sadori × VH-291.The next maximum scoring hybrid were Shahbaz × IR -3701 and CRIS-342 ×VH-291. Iqbal *et al*. (2013) and Rajamani (2014) detected significant additive effects for staple length and high positive mid parent heterosis. This study revealed that these genetic lines under study can be used for inbred line development, consequently for hybrid crop development. The average performance of hybrid *per se*. indicated that cross CRIS-342 × FH-113, VH-259 × FH-113 and Bt-802 × VH-291produced maximum Staple length. From the lines VH-292 and VH-259 and testers VH-291 developed desirable staple length. The present results are in agreement with those of Hussain *et al*. (2010), Feng *et al*. (2011). Among the twenty-one F_2 hybrids, only seventeen hybrids showed positive relative heterosis and the highest relative herterosis shown by CRIS-342 × FH-113 and Bt-802 × VH-291. Whereas highest positive heterobeltiosis shown by Bt-802 × VH-291. As far as inbreeding depression such as VH-292 × IR-3701, recorded the maximum highest among the F_2 inbreeding depression. Those findings are in conformity with those of Dhivya *et al*. (2014) and Rasheed *et al*. (2014) and Monicashree *et al.* (2019).

Fibre fineness: One of the most important among fibre properties is the fibre fineness from economic point of views. The results of ANOVA revealed significant differences between genotypes, parents, crosses and testers. Whereas, looking to the mean performance of F_1 hybrids top scoring four hybrids VH-292 × FH-113, VH-259 × FH-113, Shahbaz × IR-3701 and Bt.ZZ.NL-370 × VH-291 exhibited high mic.value and produced coarse fibre. Among lines Bt-802 showed lowest mic.value termed as fine fibre quality whereas, other lines having average values of micronaire possessed acceptable fibre quality for spinning while among tester (male) parent the VH-291 produced fine fibre whereas, other tester parents having average mic. values produced acceptable fibre. Heterotic effects for fibre fineness indicated that sixteen hybrids exhibited positive mid parent and better parent heterosis and heterobeltiosis, yet crosses VH-259 × FH-113 exhibited highestheterosis and heterobeltiois (24.70% and 21.84%) next high (21.62% and 14.40%) values. Our findings are in accordance with those obtained by Basal *et al*. (2011), Kumar *et al*. (2014), Liu *et al*. (2014) and Senthil *et al*. (2015). The average performance of hybrid *per se*. indicated that cross Bt. ZZ. NL-370 × IR-3701, Shahbaz × IR-3701 and CRIS-342 × VH-291 produced maximum fibre fineness mean performance of the female parent *per se* Sadori and Bt.ZZ.NL-370 gave maximum fibre fineness. Among the testers *per se* performance IR-3701and followed by FH-113 displayed maximum fibre fineness. The present results are in agreement with those of Hussain *et al*. (2010), Karademir and Gencer (2010), Kumar *et al*. (2016), Feng *et al*. (2011), Rajmani (2014). All the twenty-one F_2 hybrids showed positive related heterosis, the highest heterosis displayed by CRIS-342 × VH-291 and VH-292 × FH-113. Whereas CRIS-342 × VH-291 showed high positive heterobeltiosis. As far as inbreeding depression such as VH-259 × VH-291 recorded the maximum highest among the F_2 inbreeding depression. Those findings are in conformity with those of Kumar *et al*. (2010), Rasheed *et al*. (2014) and Usman and Yazdan (2015).

Fibre strength: Fibre strength has secured a unique importance among the quality parameters of cotton because it is more useful for textile mills in yarn manufacturing; fibre strength (g/tex) affects the yarn appearance, tis uniformity and strength. The ANOVA results revealed significant differences between genotypes, crosses, lines and testers and mean values of F_1 hybrids were lines CRIS-342 and Bt. ZZ.NL-370 indicated highest fibre strength (g/tex), whereas mean values of testers were FH-113 and IR-3701 showed highest mean performance of Fibre strength (g/tex). However mean performance of heterotic F_1 hybrids twenty-one hybrids this top two scoring crosses Sadori × VH-291 and CRIS-342 × IR-3701. The results regarding fiber strength suggested that most of the crosses manifested positively over their mid-parent and better parent for the character fiber strength (g/tex) relative heterosis and heterobeltiosis. These results indicated that an increase in fibre strength (g/tex) can used for a corresponding decrease in these traits. Usman and Yazdan, (2015), Mehmet and Aydyn (2015), and Kumbhar et al. (2016) observed that the heterosis effect among fiber strength (gt/tex), fiber length, and micronaire was consistent and suggested the development of high-yield cultivars with high fiber quality was emphasized. The average performance of hybrid *per se*. indicated that cross Sadori × VH-291 and CRIS-342 × VH-291 gave maximum fiber strength; among female parents per se, VH-259 and VH-292 gave produced maximum fiber fineness, while the testers VH-291 followed by IR-3701 gave maximum fiber strength. The present results are in agreement with those of Hussain *et al*. (2010), Karademir and Gencer (2010) Basal *et al*. (2011), Kumar *et al*. (2016), Feng *et al*. (2011), Dhivya *et al*. (2014), Rajmani (2014) and Rasheed *et al*. (2014). Among the twenty-one F_2 hybrids only seventeen showed positive related heterosis, the crosses Sadori × VH-291 and Sadori × FH-113 displayed highest relative heterosis. Whereas, Sadori × VH-291 and CRIS-342 × VH-291 showed highest positive heterobeltiosis. The high heterotic effects for produced maximum fibre strength perfectly. As far as inbreeding depression such as Shahbaz × IR-3701, recorded the maximum highest among the F_2 inbreeding depression Those findings are in conformity with those of Kumar *et al*. (2010) Rasheed *et al*. (2014), Usman and Yazdan (2015) and Thiyagu *et al*. (2019).

CONCLUSIONS

It is concluded from present research that the parents and hybrids differed significantly for their mean performance regarding all the traits studies. The mean performance of F_1 hybrids for all traits was better over their parents and F_2 hybrids may be due to heterotic effects in F_1 and inbreeding depression effect in F_2s. The cluster analysis showed as the indicator for selecting different genotype among the crosses as well as the cultivars used in the experiment. Among the lines, parents VH-259 and Bt-ZZ.NL-370 and from the testers, IR-3701 expressed higher GCA effects, hence was the best general combiner and are suitable parents for hybridization and selection of desirable plants from secreting population in F_1 hybrids.

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