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Diallel Analysis for Lint Yield per Plant, Lint Index and Staple Length in Upland Cotton

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Abstract: A half diallel model using Qalandri, Acala-P_3, Sarmast, DPL-7340-424 and DPL-25were used to investigate the gene action for lint yield per plant, lint index and staple length. Randomized Complete Block Design with four replications was applied during kharif season of 2004. Qalandri proved to be the best general combiner for Lint yield per plant while DPL-7340-424 for staple length and lint index. Cross Qalandri×Sarmast was the best combination for lint yield per plant and Acala-P_3×DPL-7340-424 was best specific combination for staple length and lint index. Lint yield per plant and lint index were controlled by dominant type of gene action while staple length was controlled by recessive genes. Lint index was controlled by one set of genes; staple length was controlled by two whereas lint yield per plant was controlled by three sets of genes. Narrow sense heritability was high for lint yield per plant and staple length but low for lint index.

Key words: Upland cotton · Half Diallel · Gene action · Lint index · Staple length

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) as a cash crop is of great importance for economy of Pakistan as well as other cotton producing countries. Besides its use in oil industry and production of animal feeds, cotton has a key role in textile industry. Mostly of the breeders emphasized to develop the improved varieties for fiber traits. As the fabrics quality depends upon the quality of fiber, the improvement in fiber traits is the demand for cotton and textile industries. So it is needed to develop the new improved cotton varieties was high lint yield and lint quality.

The genetic variation among the breeding material, the information about inheritance pattern and nature of gene action are the prerequisites for the development of a new breeding strategy. Diallel technique is not only a way to create the variability in genetic material but also provides an elegant method to evaluate genetic parameters in terms of components of total variance and finally helps to select a promising parental genotype to develop a successful breeding program.

The present study describes the inheritance pattern, type and magnitude of gene action for lint yield per plant, lint index and staple length for five commercially cultivated varieties and their ten F_1 hybrids obtained by 5×5 half diallel crossing. The results will help to select the breeding material and to design a breeding plan for fiber related traits.

MATERIALS AND METHODS

Present research work was carried out during the kharif season of 2004, to evaluate the gene action of lint index, lint yield per plant and staple length between the intraspecific crosses of upland cotton, *Gossypium hirsutum* L. The experiment was conducted in the experimental field of Botanical Garden of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam. Ten F_1 intraspecific crosses developed from five parental varieties of *Gossypium hirsutum* L.*viz*. Qalandri, Acala-P_3, Sarmast, DPL-7340-424 and DPL-25 according to half diallel mating system. The genotypes were sown in field by dibbler in Randomized Complete Block Design (RCBD)

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with four replications. Three seeds per hill were sown and plants were thinned to one seedling per hill to ensure uniform stand of one plant per hill. The distance between plants and rows was maintained 30 cm and 75 cm respectively. All the standard agronomic practices were carried out at proper time.

For data collection, ten guarded plants were selected at random, from each replication per genotype and tagged. After harvest evaluation for lint yield per plant, lint index (g) and staple length (mm) was performed

Lint yield per plant (g) was considered as weight in grams of lint produced by individual cotton plant of a genotype. It was recorded by weighing the lint in grams produced by every index plant. The lint index represents the absolute weight of lint in grams obtained from one hundred seeds. It was determined by applying the formula mentioned below.

$$\text{Lint index (g)} = \frac{\text{Seed index X Lint weight}}{\text{Seed cotton weight}}$$

Staple length, the most important physical property of cotton wasmeasured from representative samples of lint of each plant in mm with the help of digital fiberograph, model 330. The classification of staple length is as under:

1.	Up to 20 mm	Short
2.	22.1 mm to 25.5	Medium
3.	25.6 mm to 29.0	Medium long
4.	29.1 mm and above	Long

Data Analysis: The analysis of variances (ANOVA) was performed as described by Steel *et al.* 1997 [1]. of the material was evaluated by analyzing data for yield and. Breeding value, Genetic differences and the nature of gene action for different quantitative and qualitative traits was studied through different genetic parameters estimated by diallel analysis proposed by Hayman [2, 3].

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) of means for their differences in the characters studied is presented in Table 1 revealed the highly significant variation (P>0.01) among genotypes which was required for selection for a suitable genotype, whereas, the mean performance of 5 parental varieties and their 10 F1 hybrids for various traits is shown in Table 2.

The non-significant value of t-test for all three traits (Table 3) confirmed the adequacy of the additive-dominance model with no epistasis and that genes were independently making their random combinations. However the regression analysis revealed that regression coefficient (b) differed non-significantly from both zero and unity which do not fulfill the assumptions of Hayman-Jinks additive-dominance model and make the model partially adequate.

Lint Yield per Plant

Combining Ability: For the character lint yield per plant, the varieties Sarmast and Qalandri proved to be the best general combiners with its maximum array mean (34.960g) and (30.173g) respectivelyand could be utilized for varietal improvement program of cotton, whereas the crosses of Qalandri with Sarmast and Acala-$P_3$with 45.071g and 47.708g lint yield,proved to be the best specific combiners with maximum lint yield and could be utilized for hybrid cotton breeding programs (Table 4). Mehetre *et al.* [4] and Mert and Boyaci [5] have also obtained significant values of general and specific combining ability variances for this trait.

Gene Action: The Wr/Vr graph indicated that this character was controlled by over dominance type of gene action (Figure 1a) and the negative value of "r" showed that this character was controlled by dominant genes (Fig. 1b). These results are in accordance with the results of Chandio *et al*. [6] who also reported over dominance type of gene action for this trait. Deshpande and Baig (2003) [7], Mehetre *et al*. [4] and Zhang *et al*. [8] have also reported preponderance of dominant genes in the control of this character.

Amongst components of variance, additive (D), dominance components (H_1, H_2) and h^2 were highly significant while F and E were non-significant for F_1 lint yield per plant. The values of dominance components (H_1, H_2) were greater than the additive and average degree of dominance (vH_1/D=1.8945) denoted over-dominance type of gene action for this trait. The dominance components (H_1, H_2) being almost equal in values which indicated symmetrical distribution of positive and negative genes which was also confirmed by $H_2/4H_1$ (0.2454). However the negative and non-significant value of F (-16.4675) and the value of $v4DH_1$+ F/$v4DH_1$-F (0.8347) revealed marginal excess of recessive genes in increasing position due to positive and highly significant value of h^2 (380.1958). The value for h^2/H_2 (2.2360) suggested that the lint yield per plant was probably controlled by three groups of genes which exhibited dominance at some degree (r^2=0.72100). Recorded narrow sense heritability at 5% level of significance was medium indicating mediocre level of heritability of additive genes (Table 7).

Table 1: ANOVA (mean squares) for various quantitative characters

Source of variation	d.f	Lint yield plant (g)	Staple length	Lint index (g)
Replications	3	5.577	0.052	0.031
Genotypes	14	308.6**	1.559**	0.467**
Error	42	9.312	0.103	0.025

** = Significant at P>0.01.

Table 2: Average performance of ten F_1 hybrids and their five parents for various characters in cotton (*Gossypium hirsutum L.*).

Genotypes	Lint yield per plant (g)	Lint index (g)	Staple length (mm)
Qalandri X Sarmast	45.07	4.302	27.50
Qalandri X Acala-P_3	47.71	4.690	27.15
Qalandri X DPL-25	40.19	4.307	27.87
Qalandri X DPL-7340 –424	35.36	4.527	28.32
Sarmast X Acala-P_3	41.68	4.122	27.27
Sarmast X DPL-25	34.61	4.840	27.87
Sarmast X DPL-7340-424	43.18	4.112	28.17
Acala-P_3 X DPL-25	36.22	4.570	27.32
Acala-P_3 X DPL-7340 –424	27.25	5.045	26.85
DPL-25 X DPL-7340-424	30.58	4.342	28.17
Qalandri	30.17	4.150	28.05
Sarmast	34.96	4.355	28.92
Acala-P_3	26.61	3.640	28.27
DPL-25	21.07	4.420	28.32
DPL-7340-424	17.07	4.100	29.00
LSD (5 %)	3.627	0.188	0.381
LSD (1 %)	5.212	0.270	0.548

Table 3: Regression Analysis.

Parameters	t^2-Test	b/SE	bo	b1
Lint yield	0.1108^{NS}	0.9123 ± 0.1501	6.0781**	0.5836^{NS}
Staple length	0.7121^{NS}	0.4006 ± 0.3178	1.2607^{NS}	1.8857^{NS}
Lint index	0.3583^{NS}	0.3061 ± 0.3851	0.7947^{NS}	1.8014^{NS}

Table 4: 5×5 diallel average lint yield per plant (g) variance (Vr) and covariance (Wr) for F1 generation of *Gossypium hirsutum* L.

Varieties	Qalandri	Sarmast	Acala-P_3	DPL-25	DPL-7340-424	Wr+Wr	Vr	Wr
Qalandri	30.173	45.071	47.708	40.195	35.365	63.0707	50.692	12.379
Sarmast	45.070	34.960	41.678	34.615	43.183	17.0341	23.253	-6.219
Acala-P_3	47.708	41.678	26.610	36.223	27.255	126.2363	83.49	42.747
DPL-25	40.195	34.615	36.223	21.073	30.578	84.6529	52.953	31.70
DPL-7340-424	35.365	43.183	27.255	30.578	17.070	156.6940	93.8117	62.882
Total	198.511	199.507	179.474	162.684	153.451	447.688	304.198	143.489
Mean	39.7022	39.901	35.8948	32.5368	30.6902	89.5376	60.84	28.698

- Bold diagonal values represent parental values.
- Upper diagonal values represent direct cross values.
- Lower values represent reciprocal cross values.
- Vr represent variance values.
- Wr represent covariance values.

Wr/Vr graph, Wr+Vr/Vp graph (Fig. 1a and b) and Fr-values of each cultivar revealed that varieties Qalandri and Sarmast had maximum positive Fr-values and were close to the origin proving that these varieties had maximum dominant genes (Table 8). The negative sign of Acala-P_3, DPL-25 and DPL-7340-424 cultivars as well as their being away from the origin showed that they had recessive genes for lint yield per plant.It infers that the varieties Sarmast and Qalandri could be successfully utilized in the development of hybrid cottons.

Table 5: 5×5 diallel average lint index variance (Vr) and covariance (Wr) for F_1 generation of *Gossypium hirsutum* L.

Varieties	Qalandri	Sarmast	Acala-P_3	DPL-25	DPL-7340-424	Wr+vr	Vr	Wr
Qalandri	4.15	4.303	4.690	4.308	4.528	-0.0047	0.0452	-0.0498
Sarmast	4.303	4.355	4.123	4.840	4.113	0.1527	0.0875	0.0652
Acala-P_3	4.690	4.123	3.640	4.570	5.045	0.3820	0.2956	0.0864
DPL-25	4.308	4.840	4.570	4.420	4.343	0.0521	0.0471	0.0050
DPL-7340-424	4.528	4.113	5.045	4.343	4.10	0.0547	0.1512	-0.0965
Total	21.979	21.734	22.068	22.481	22.129	0.6368	0.6266	0.0103
Mean	4.3958	4.3468	4.4136	4.4962	4.4258	0.1274	0.1253	0.0021

• Bold diagonal values represent parental values.
• Upper diagonal values represent direct cross values.
• Lower values represent reciprocal cross values.
• Vr represent variance values.
• Wr represent covariance values.

Table 6: 5 x 5 diallel average staple length variance (Vr) and covariance (Wr) for F1 generation of *Gossypium hirsutum* L.

Varieties	Qalandri	Sarmast	Acala-P_3	DPL-25	DPL-7340-424	Wr+ Vr	Vr	Wr
Qalandri	28.05	27.50	27.15	27.875	28.325	0.2528	0.2136	0.0393
Sarmast	27.50	28.925	27.275	27.875	28.175	0.6398	0.4163	0.2236
Acala-P_3	27.15	27.275	28.275	27.325	26.85	0.1878	0.2872	-0.0994
DPL-25	27.875	27.875	27.325	28.325	28.175	0.1948	0.1468	0.0480
DPL-7340-424	28.325	28.175	26.85	28.175	29.00	0.7707	0.6086	0.1621
Total	138.90	139.75	136.875	139.575	140.525	2.0459	1.6725	0.3736
Mean	27.78	27.95	27.375	27.915	28.105	0.4092	0.3345	0.0747

• Bold diagonal values represent parental values.
• Upper diagonal values represent direct cross values.
• Lower values represent reciprocal cross values.
• Vr represent variance values.
• Wr represent covariance values

Table 7: Genetic components of variance for F1.

Components	Lint yield per plant	Staple length	Lint index
D	48.2555 ± 5.9903**	0.1532 ± 0.1474 ^{NS}	0.0877 ± 0.0778 ^{NS}
H_1	173.1981 ± 16.1776*	1.1522 ± 0.3114*	0.5707 ± 0.2103*
H_2	170.0265 ± 14.6733**	0.9811 ± 0.2824*	0.4769 ± 0.1907*
F	-16.4675 ± 15.9317 ^{NS}	0.0277 ± 0.3067 ^{NS}	0.1723 ± 0.2071*
h^2	380.1958 ± 9.9067**	1.8883 ± 0.190**	0.3155 ± 0.1287*
E	2.2657 ± 2.4455 ^{NS}	0.0250 ± 0.0470 ^{NS}	0.0062 ± 0.0317^{NS}
vH_1/D	1.8945	2.7416	2.5504
$H_2/4H_1$	0.2456	0.2128	0.2089
$v4DH_1+F$ /$v4DH_1-F$	0.8347	1.0682	2.2522
h^2 /H_2	2.2360	1.9246	0.6615
R	-0.8491	0.9384	-0.7255
r^2	0.7210	0.8805	0.0354
Heritability (h^2) (n.s)	0.4312	0.3542	0.0354
S^2	29.9036	0.0110	0.0354

Lint Index

Combining Ability: The results for lint index depicted in the Table 5 revealed that variety DPL-25 was the best general combiner with maximum array mean (4.42g) for lint index, followed by the varieties DPL-7340-424 and Acala-P_3(4.4258g). Therefore, these varieties can give better results if used for the improvement of cotton varieties with respect to the lint index. The table further revealed the crosses DPL-7340-424×Acala-P3(5.045g) and DPL-25×Sarmast (4.840g) as the best specific combiners which could be utilized in the development of hybrid cottons. Khorgade *et al*. [9], El-Adl *et al*. [10], Zia *et al*. [11], Laxman and Ganesh [12] and Odhano [13] also reported significant GCA and SCA values for this trait.

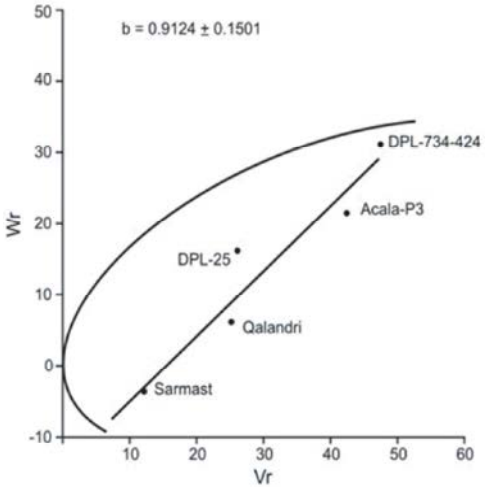

Fig. 1a: Wr/Vr Graph of Lint Yield per Plant

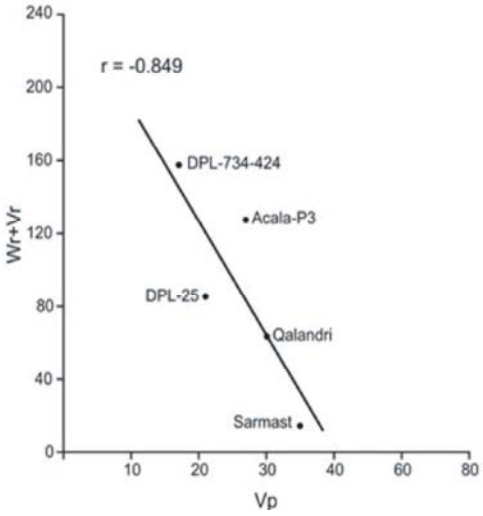

Fig. 1b: Wr+Vr/Vp Graph of Lint Yield per Plant

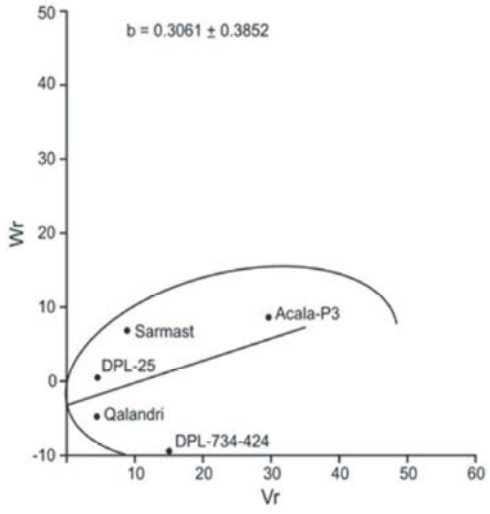

Fig. 2a: Wr/Vr Graph of lint Index

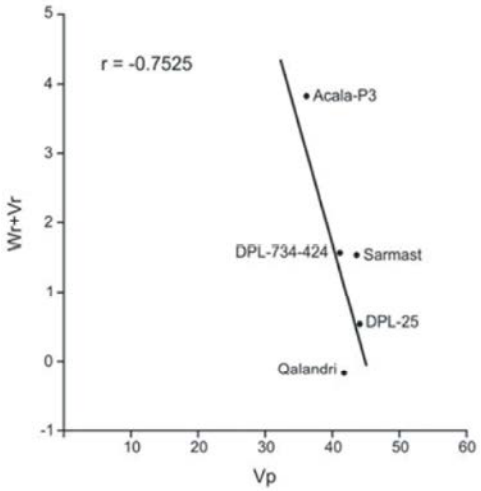

Fig. 2b: Wr+Vr/Vp Graph of Lint Index

Gene Action: A perusal of Wr/Vr graph shows that this character is controlled by over dominance type of gene action (Fig. 2a) and negative "r" value indicated that this character was controlled by dominant genes (Fig. 2b). These results are in accordance with those of Sayal and Sulemani [14] and Subhan *et al*. [15], who also reported over dominance type of gene action for this trait. Laxman and Ganesh [12] and Mehetre*et al.* [4] also reported preponderance of dominant genes in their material. A further study of Wr/Vr graph and Wr+Vr/Vp showed that varieties Qalandri and DPL-25 possessed the most dominant genes.

For components of variance, the additive (D), F and E value were non-significant while dominance components (H_1, H_2) and h^2 were significant. Both dominance components of variance surpassed the additive one and the average degree of dominance ($vH_1/D=2.5504$) displayed over dominance type of gene action for this trait. The unequal values of H_1 and H_2indicated to some extent the symmetrical distribution of positive and negative genes which was confirmed by the value of $H_2/4H_1$ (0.2089). The positive but non-significant value of F (0.1723) and $v4DH_1+1/v4DH_1$-F (2.2522) revealed that dominant genes were in excess in parents which was also confirmed by the positive and significant value of h^2 (0.3155). The proportion of complete dominant parent was 0.5662 as indicated by r^2. The ratio h^2/H_2 (0.6615) manifested that only one group of genes governed the trait lint index. Recorded narrow sense heritability at 5% level of significance was negligible (0.0354) which showed no part of additive genes in the inheritance of this character (Table 7).

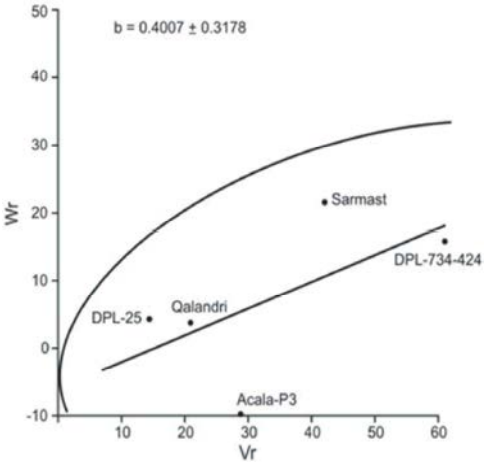

Fig. 3a: Wr/Vr Graph of Staple Length

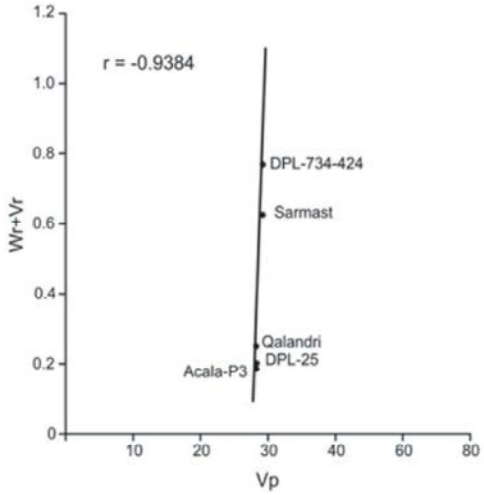

Fig. 3b: Wr+Vr/Vp Graph of State Length

Table 8: F_1, Fr-values

Cultivars	Lint yield per plant	Staple length	Lint index
Qalandri	36.4662	0.3403	0.4363
Sarmast	128.5394	-0.4336	0.1217
Acala-P_3	-89.8649	0.4704	-0.3369
DPL-25	-6.6982	0.4565	0.3229
DPL-7340-424	-150.7803	-0.6952	0.3176
Fri	-16.4675	0.0277	0.1723

Table 8 also supported the above mentioned results. The maximum positive Fr-values of Qalandri, Sarmast, DPL-25 and DPL-7340-424 showed frequency of dominant alleles, whereas, Acala-P_3 had the maximum amount of recessive genes. Graphic presentation of Wr+Vr/Vp also gave the similar results. Therefore, these varieties could confidently be utilized for the development of hybrid cottons, whereas variety DPL-25 could be successfully utilized in the evolution of cotton varieties with improved lint index.

Staple Length

Combining Ability: With respect to the character staple length, the results depicted variety DPL-7340-424 have given the highest value 29mmfollowed by the variety Sarmast (27.950mm) and proved as best general combiner for this trait, followed by varieties Sarmast and DPL-25, whereas the crosses of DPL-7340-424 with Qalandri, Sarmast and DPL-25 made the best specific combinations (Table 6). Therefore, the variety DPL-7340-424, Sarmast and DPL-25 could be successfully exploited for the production of pure lines and hybrid cotton with respect to increased staple length. Iqbal *et al*. [16], Odhano [13] and Anisa *et al*. [17] have also reported significant GCA and SCA values for this trait.

Gene Action: In Wr/Vr graph the below origininterception of regression line on Wr axis forstaple length,proved that the character staple length was controlled by over dominance type of gene action (Figure 3a). These results are in accordance with the findings of Sayal and Sulemani [14] and Ahmed *et al*. [18], who also reported that this character was controlled by over dominance type of gene action. The correlation coefficient between Wr+Vr and parental means revealed that increased staple length was the function of recessive genes.

As far as components of variance are concerned, the additive (D), F and E were non-significant while dominance components (H_1, H_2) and h^2 were significant for F_1 staple length (Table 7). The dominance components were greater than the additive and the average degree of dominance (vH_1/D=2.7416) being more than one showed over dominance type of gene action and was in increasing position due to positive and highly significant value of h^2. The residual heterozygosity in parents was observed when H_1 showed greater value than H_2 and revealed that positive and negative genes were nearly symmetrical as also confirmed by the value of (H_2/H_1 (0.2128). The ratio of dominant and recessive genes ($v4DH_1$+F/$v4DH_1$-F=1.0682) indicated that dominant and recessive genes in the parents were in equal proportion. However the positive and non-significant value of F and significant value of h^2 manifested that dominant genes were more frequent than the recessive genes with increasing position with r^2 (0.8805) showing the proportion of completely recessive parent. The value to h^2/H_2 (1.9246) predicted that there were at least two groups of genes which governed this trait. The recorded narrow sense heritability was medium at 5% level of significance (Table 7).

The Wr+Vr/Vp Graphic presentation (Fig. 3b) and the negative Fr-values (Table 8) revealed that the Sarmast and DPL-7340-424, which were away from the origin on Wr+Vr/Vp graph, had maximum amount of recessive genes. Furthermore, positive sign of correlation co-efficient for this trait suggested positive effect of recessive genes on staple length. Therefore, these two varieties viz. DPL-7340-424 and Sarmast could be successfully exploited for the improvement of staple length.

CONCLUSION

It could conclude that the lint yield per plant and lint index were governed by dominant genes. So, the genotypes Sarmast and Qalandri can be used in any breeding program aimed at improvement of lint yield and lint index. While, the staple length was found as a function of recessive genes and the varieties DPL-7340-424 and Sarmast could be selected for further improvement of staple length.

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