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GENETIC STUDIES OF FIBER QUALITY CHARACTERS IN UPLAND COTTON

A. Hussain, F. M. Azhar* M. A. Ali*, S. Ahmad and K. Mahmood

Cotton Research Station, Vehari, Pakistan
*Department of Plant Breeding & Genetics, University of Agriculture, Faisalabad, Pakistan
Corresponding authors E-mail: ahussain771@yahoo.com

ABSTRACT

Five upland cotton cultivars were crossed in a complete diallel crossing system to investigate inheritance pattern and combining ability of parents for different fiber quality traits like staple length, fiber strength, fineness and uniformity. The study was carried out in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the years 2005-07. Highly significant differences were found among the genotypes for all the traits under study. Genetic analysis of the data also revealed highly significant effects due to general as well as specific combining ability ($P \leq 0.01$) for all the fiber quality characters. The magnitude of variance due to dominance was greater than that of additive effects for all the traits which showed that these traits were controlled by non-additive gene action. The parent CIM-707 showed best general combining ability for staple length and fiber strength, FH-1000 for fiber fineness and LA-17801 for fiber uniformity. The best specific combining ability was shown by the cross CIM-707 x DPL-2775 for staple length, CIM-707 x LA-17801 for fiber strength, FH-1000 x DPL-2775 for fiber fineness and CIM-707 x TH-41/83 for fiber uniformity. Correlation analysis demonstrated positive association between fiber strength and staple length while fiber fineness displayed negative relationship with staple length and fiber strength. Therefore, genetic information acquired from this study offer opportunities for cotton breeders to intensify the rapid improvement for the fiber quality traits in cotton crop while utilizing the genetic resources.

Keywords: cotton, fiber quality, combing ability, gene action, correlation

INTRODUCTION

Upland cotton (*Gossypium hirsutum* L.) is the most important fiber crop in the world, and in Pakistan it is the mainstay of the economy (Ali and Khan, 2007). Cotton is the main source of foreign exchange earnings and brings about 65 % of the total annual earning from the export of raw cotton material and the finished products. The crop not only meets the needs of fiber requirements of local industry but also provides food in the form of edible oil (Ali and Awan, 2009). Due to immense importance of cotton crop in the country's economy, the cotton breeders made great strides for improving cotton plant utilizing available genetic resources which resulted in numerous high yielding cultivars with better fiber quality traits. But due to the increasing consumption of fiber, there is need to further speed up efforts for continued genetic improvement in cotton plant for yield and fiber quality traits.

Fiber quality of a particular cotton genotype is a combination of different characters including staple length, fiber strength, fineness, and uniformity with extreme importance (Poehlman and Sleper, 1995, Ali *et al*. 2008a). In fact, fiber traits that establish fiber quality set the basis for marketing and sale of cotton through out the world (Asif *et al*. 2008). Furthermore, these characteristics are well associated with the proficient spinning and weaving processes that alter the fiber into fabrics. Keeping this in view, it is need of the day to improve fiber quality in locally dominating cotton genotypes to accomplish the requirements of growing textile industry, processing and end uses (Ali *et al*. 2008a).

Unfortunately, the available commercial cotton cultivars are limited in genetic variability for most of the fiber traits (Bradow and Davidonis 2000). Besides that due to polygenic inheritance, these traits are highly affected by the environmental factors which cause difficulties in breeding for improvement of these characters (Yuan *et al*. 2005, Ali *et al*. 2009b). The existence of heritable variability and favorable correlation among various characters is critical for launching of any breeding program aimed at selection of desirable genotypes (Ali *et al*. 2008b). Therefore the creation and quantification of genetic variability and associated response of fiber quality parameters among the prevailing cultivars is vital (Ali *et al*. 2008a). This information could direct the breeders for genetic upgrading of cotton genotypes with improved fiber quality characteristics in addition to high seed cotton yield.

Diallel analysis is one of the efficient biometric methods that have been used frequently by the researchers for creating and studying the pattern of heritable variation in the metric plant characters (Hayman, 1954, Griffing, 1956). Additionally, analysis of the data following Griffing´s (1956) approach provides information on the potential of cultivars with respect to their general combining ability and specific combining ability. Moreover, combining ability analysis of the data yields information that which crosses are likely to be superior in producing desirable segregates and the possibility of utilizing heterosis for improving crop yield and other characters like fiber quality traits.

Therefore in the present study, five-parent diallel cross data was analyzed following Griffing´s approach to obtain the knowledge on the genetic mechanisms controlling fiber characters of cotton. The information derived from this study may be helpful for other cotton researchers working for the improvement of cotton genetic material under local conditions.

MATERIALS AND METHODS

Genetic material: The investigation pertaining to the genetic studies for fiber quality traits in cotton (*Gossypium hirsutum* L.) were carried out in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the years 2005-07. The genetic material for these studies was developed by crossing diverse germplasm i.e. two indigenous cultivars/genotypes namely FH-1000, CIM-707 and three exotics i.e. DPL-2775, LA-17801 and TH-41/83, in a complete diallel crossing system.

Green house experiment: The five parents were planted in 30 x 30 cm earthen pots placed in glasshouse during November 2005 in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The proper growing conditions were provided for germination and optimum growth of the plants. An artificial environment was maintained inside the glasshouse with a temperature of 30°C to 35°C during the day and about 25°C at night with the help of steam and electric heaters. Moreover, the plants were exposed to supplement artificial lighting as well to provide optimum photoperiod of 16 hours. The seedlings were thinned to one plant per pot after 14 days of planting with immediate application of 25 g of urea (46% N) to each pot and plants were watered daily. At flowering, all possible crosses were made among the parents following all the essential preventive measures to avoid contamination of the genetic material. Numerous pollinations were made in order to produce sufficient quantity of hybrid seed.

Field experiment: The obtained hybrid seeds of 20 hybrids along with their five parents were sown in field in triplicate under randomized complete block design (RCBD) during June, 2006. Each of the 25 entries including 5 parents and their F_1 hybrids, in a replication was planted on ridges in a single row having 15 plants spaced at 30 cm within and 75 cm between the rows. All the recommended agronomic and plant protection practices were followed from sowing till harvesting of the crop. The matured bolls were picked from 10 guarded plants on the individual plant basis after every two weeks till complete harvesting of crop in January 2007. Picking was done after the evaporation of dew. Seed cotton was collected in Kraft paper bags and was dried in sunlight for two days and was weight to determine yield per plant in grams.

Laboratory testing: The total seed cotton from the plants in each entry was ginned with a single roller electrical gin in the laboratory on individual plant basis to obtain lint for fiber analysis. Before fiber analysis, lint was conditioned by placing at 65% humidity and 18-20°C temperature in an air conditioned room using humidifier. High Volume Instrument (HVI-900-SA; Zelwiger, Uster, UK) was used for fiber analysis of staple length (mm), fiber strength (g/tex), fiber fineness (µg/inch) and fiber uniformity.

Statistical analysis: The collected data were subjected to simple analysis of variance technique following Steel *et al*. (1997) in order to see whether the genotypic differences for fiber characters are significant or not. The characters showing significant differences among the crosses and their parents were further analyzed genetically following Griffing (1956) using 'Method I', Model II'. Phenotypic correlations were calculated by using statistical software SPSS 12.0 for windows.

RESULTS AND DISCUSSION

In the present investigations, data on four fiber quality characters i.e. staple length, fiber fineness, fiber strength and fiber uniformity were subjected to analysis of variance. Highly significant differences ($P \leq 0.01$) were found among the genotypes for all the traits (Table-1). Significant mean squares for each of the characters allowed the use of Griffing's approach (1956) to study the magnitude of variance due to the effects of combining abilities of the parents and inheritance pattern of various fiber traits.

Genetic analysis of the data revealed highly significant effects due to general and specific combining ability ($P \leq 0.01$) for all the fiber quality characters (Table-1). The reciprocal effects were non-significant for staple length, fiber strength and fiber fineness while fiber uniformity, demonstrated significant reciprocal effects. The magnitude of genetic variance due to specific combining ability (0.347, 0.428, 0.046 and 5.996) appeared to be greater than that of general combining ability (0.233, 0.231, -0.001 and 0.082) for staple length, fiber strength, fiber fineness and fiber uniformity respectively resulting in the magnitude of variance due to dominance was greater than that of additive effects. These results revealed that staple length, fiber strength, fiber fineness and fiber uniformity were conditioned largely by non-additive gene effects as the magnitude of dominance variance was greater than additive variance for all the characters suggesting the occurrence of heterosis. Thus based on this information, the present genetic material may be utilized for exploitation of hybrid vigor through the development of hybrid seed for the characters. In case of fiber fineness similar reports had already been reported by Irfanullah *et al.* (1994) and Islam *et al.* (2001), however reports of Ahmad and Azhar (2000), Hendawy *et al.* (1999) and Ali *et al*. (2008a) did not agree with the present findings. Ali *et al*. (2008a) reported similar findings to the present study for fiber strength. Non-additive gene effects for fiber uniformity ratio were supported by the report of Rajan *et al.* (1999). However, fiber uniformity was under the control of additive gene effects according to Liu and Han (1998), Ali *et al*. (2008a). Ali *et al*. (2009a).

The potential of the five parents was assessed for gca (general combining ability), sca (specific combining ability) and reciprocal effects for these fiber traits (Table-2). The comparisons of variations revealed that CIM-707 was the best general combiner for staple length (0.514) and fiber strength (0.743). Similarly, FH-2000 and LA-17801 exhibited the best general combining ability for fiber fineness (0.138) and fiber uniformity (1.385). On the other hand, FH-1000 obtained the maximum negative general combining ability for all the traits except fiber fineness.

Table-1: Analysis of variance for various fiber quality traits in cotton

Source of variation	df	Staple length (mm)	Fiber strength (g/tex)	Fiber fineness (µg/inch)	Fiber uniformity (Ratio)
Replications	2	0.045^{ns}	0.040^{ns}	0.024^{ns}	0.152^{ns}
Genotypes	24	1.717**	1.831**	0.151**	18.243**
GCA	4	1.793**	1.847**	0.078**	10.142**
SCA	10	0.655**	0.725**	0.089**	0.324^{ns}
Reciprocals	10	0.002^{ns}	0.0006^{ns}	0.0007^{ns}	10.21**
δgca		0.233	0.231	-0.001	0.082
δsca		0.347	0.428	0.046	5.996

Where ns = Non-significant * = Significance at 5% probability level, **= Significance at 1% probability level

Table-2: Estimates of general and specific combining abilities of parents for different fiber quality parameters

Fiber quality traits	Staple length (mm)		Fiber strength (g/tex)		Fiber fineness (µg/inch)		Fiber uniformity (Ratio)	
Parents	**Estimation of gca**	**Means**	**Estimation of gca**	**Means**	**Estimation of gca**	**Means**	**Estimation of gca**	**Means**
FH-1000 (1)	-0.619	26.267	-0.360	24.667	0.138	5.367	-0.565	47.367
CIM-707 (2)	0.514	27.800	0.743	26.633	-0.105	5.200	0.611	47.700
DPL-2775 (3)	-0.106	28.433	-0.183	24.467	-0.005	4.833	-1.175	50.733
LA-17801 (4)	-0.029	28.567	-0.063	24.833	-0.032	4.933	1.385	46.667
TH-41/83 (5)	0.241	28.100	-0.137	24.633	0.005	4.967	-0.255	47.033
Cd1(gi - gj)	0.234		0.065		0.093		0.325	
Direct combinations	**Estimation of sca**		**Estimation of sca**		**Estimation of sca**		**Estimation of sca**	
1x2	-0.071	27.600	0.087	26.233	-0.158	4.833	-1.011	48.933
1x3	-0.367	26.667	-0.770	24.433	0.325	5.400	-0.391	46.533
1x4	0.273	27.433	0.510	25.833	-0.115	4.933	2.532	51.967
1x5	0.436	27.767	0.533	25.767	-0.185	4.900	-0.995	46.800
2x3	0.699	28.867	0.560	26.867	-0.348	4.467	-1.701	46.300
2x4	0.073	28.300	-0.227	26.167	-0.055	4.767	2.289	52.933
2x5	0.303	28.833	0.180	26.533	0.109	4.933	2.579	51.500
3x4	-0.907	26.700	0.750	26.233	0.095	5.033	-0.975	47.800
3x5	-0.294	27.600	0.373	25.767	0.042	5.000	-1.385	45.800
4x5	-0.287	27.733	-0.247	25.300	0.035	4.967	0.889	50.667
Cd1(Sij - Sik)	0.467		0.129		0.187		0.650	
Indirect combinations	**Estimation of rec**		**Estimation of rec**		**Estimation of rec**		**Estimation of rec**	
2x1	0.000	27.600	0.017	26.200	0.000	4.833	1.267	46.400
3x1	-0.017	26.700	0.000	24.433	-0.017	5.433	0.033	46.467
4x1	0.033	27.367	0.000	25.833	-0.017	4.967	-0.017	52.000
5x1	-0.067	27.900	-0.017	25.800	-0.017	4.933	-0.017	46.833
3x2	-0.017	28.900	0.000	26.867	-0.033	4.533	-0.067	46.433
4x2	-0.033	28.367	-0.033	26.233	0.000	4.767	0.017	52.900
5x2	0.000	28.833	-0.000	26.533	-0.033	5.000	-0.067	51.633
4x3	-0.033	26.767	-0.017	26.267	0.017	5.000	-0.067	47.933
5x3	-0.017	27.633	-0.033	25.833	0.000	5.000	-0.017	45.833
5x4	0.033	27.667	-0.000	25.300	0.000	4.967	0.017	50.633
Cd1(rij - rkl)	0.522		0.145		0.209		0.727	

However, among different crosses, the best specific combining ability was shown by the cross CIM-

707 x DPL-2775 (0.699) for staple length, DPL-2775 x LA-17801 (0.750) for fiber strength, FH-1000 x DPL-2775 (0.325) for fiber fineness and CIM-707 x TH-41/83 (2.579) for fiber uniformity as compared to other combinations (Table-2). It had been reported that the parents having good general combining ability for a particular character are expected to yield good hybrids (Khan *et al.*, 1991; Haq and Azhar, 2005) and it was partially substantiated in the present investigations in case of CIM-707 e.g. CIM-707 x DPL-2775, CIM-707 x LA-17801, CIM-707 x LA-17801 for staple length, fiber strength and fiber uniformity respectively. However, Patel *et al*. (1997) concluded that for hybrid production, it is not necessary that the parents must possess better general combining ability, sometimes the parents showing poor general combining ability may combine well to produce good hybrids e.g. FH-1000 x DPL-2775 for fiber uniformity in this study.

In reciprocal crosses (Table-2), LA-17801x FH-1000, CIM-707 x FH-1000, LA-17801 x DPL-2775 and CIM-707 x FH-1000 with the highest positive values showed the best reciprocal estimates than the remaining combinations for staple length, fiber strength, fineness and uniformity respectively.

Table-3: Phenotypic correlations among various fiber characteristics in cotton

Fiber traits	Cor.	Staple length (mm)	Fiber strength (g/tex)	Fiber fineness (µg/inch)	Fiber uniformity (Ratio)
	r	1.000	0.425*	-0.739***	0.260
	Sig.	.	0.034	0.000	0.210
	r		1.000	-0.597**	0.155
	Sig.		.	0.002	0.460
	r			1.000	-0.179
	Sig.			.	0.391

Where ns = Non-significant * = Significance at 5% probability level, **= Significance at 1% probability level and ***= Significance at 0.1% probability level

The patterns of correlation between various fiber traits revealed that there was a prominent positive association between fiber strength and staple length (0.425) (Table-3). Obviously, this may help the breeders to select both these important traits simultaneously. The results of Ulloa (2006) and Asif *et al*. (2008) supported positive correlation between these traits but those of Ali *et al* (2009b) did not agree with these findins. Fiber fineness revealed significant and negative relationship with staple length (0.739) and fiber strength (0.597). This suggested that application of selection for fine fiber along with longer and strengthened fiber together could not be possible for this set of genotypes. The results of Ali *et al*. (2009b) were contradictory to this finding. However, the results of Asif *et al*. (2008) also demonstrated that long fiber would result in coarser fiber.

The results concluded that these quality parameters were controlled largely by non-additive gene effects suggesting the incidence of heterosis for these traits. Hence on the basis of this information, the current plant material could be exploited for utilization of hybrid vigor through the development of hybrid seed for improving the quality traits. Moreover, favorable correlation might help plant breeders in developing cotton genotypes with optimum fiber quality.

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