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GENETIC ANALYSIS FOR FIBER QUALITY TRAITS OF SOME COTTON GENOTYPES

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Abstract

Cotton is the basis of our national textile industry and a major source of foreign exchange. Cotton fiber quality is the physical properties related to its spinnability into yarn and textile performance. Nineteen cotton (*Gossypium hirsutum*) genotypes were screened for fiber length, fiber fineness and fiber strength. Fiber length ranged from 23 to 30 mm with mean value of 27.6 mm. Similarly, fiber fineness was variable with average micronaire reading of 4.75. Differences in fiber strength were also ranging from weak (80 tppsi) to very strong (99 tppsi) fiber. Analysis of variance depicted considerable variations in these three main fiber quality traits among 19 cotton genotypes. Coefficient of variability was 5.4%, 6.13% and 4.5% for fiber length, micronaire and fiber strength, respectively. Highly significant negative correlation was found between fiber length and fiber fineness (r = -0.850), while highly significant positive correlation was observed between fiber length and fiber strength (r = 0.712). Fiber fineness was significantly and negatively correlated with fiber strength (r = -0.499). On the basis of fiber analysis of quality traits two contrasting cotton genotypes viz., FH-883 and FH-631S were selected for further genome mapping studies.

Introduction

Cotton is the leading fiber crop worldwide with the production of 24.86 million metric tons in 2006 (Anon., 2006a) that makes possible world commerce of raw cotton of about $20 billion annually (Rong *et al.*, 2005). In fact, fiber properties that define fiber quality are the basis for the marketing and sale of cotton throughout the world (Hake *et al.*, 1990). Cotton, the main cash crop in Pakistan, is the basis of national textile industry and a major source of foreign exchange sharing 60% of the total export and hence contributes substantially to the national economy. Pakistan has preeminent position as the fourth largest producer of cotton, the third largest exporter of raw cotton and a leading exporter of yarn in the world. During 2005-06 cotton area was 3.1 million hectares and the production was 13.02 million bales in Pakistan (Anon., 2006b).

Cotton fibers are single cells that terminally differentiate from trichome primordia located in the epidermis (protoderm, the outermost cell layer) of the ovule (Rong *et al.*, 2005; Wilkins & Arpat, 2005). The fibers develop as elongated cells growing outward from the surface of the ovule. As the ovule enlarges, successive layers of the cellulose are laid down in the helical pattern by the protoplast. As the fiber matures, the protoplast dies and the cell wall, which is virtually 96% pure cellulose, collapses inward to form convoluted ribbon. The flattening and convolution of the dried cell wall promotes adhesion when the fibers are twisted together in yarn bundles during spinning (Kohel & Lewis, 1984).

Cotton fiber quality is defined by the physical properties that relate to its spinnability into yarn and contribute to textile performance and quality (Chee *et al.*, 2005a). The most important of these properties are those associated with the length, strength and fineness (micronaire) of the fiber (Poehlman & Sleper, 1995). One of the most important aspects of cotton fiber quality is fiber or staple length. Fiber length is the normal length of a typical portion of the fibers of a cotton sample. Fiber length is directly related to yarn fineness, strength, and spinning efficiency (Moore, 1996). Longer fibers can be processed at greater efficiencies and produce finer and stronger yarns by allowing fibers to twist around each other more times, while shorter fibers require increased twisting during spinning, causing low-strength, poor-quality yarns (Chee *et al*., 2005b).

Fiber fineness is another important component of fiber quality because of its direct impact on processing performance and the quality of end product. Finer mature fibers can be spun into yarns with more fibers per cross-section, resulting in stronger and better quality yarns (Bradow & Davidonis, 2000). Fiber strength is important because the inherent breaking strength of individual cotton fibers is considered to be the most important factor in determining the strength of the yarn spun from those fibers (Moore, 1996). Fiber strength is related to average length of the cellulose molecules deposited inside the cotton fiber, hence longer the cellulose chains, stronger the fiber. Fiber quality traits are quantitative in nature and highly affected by the environment, which complicate the breeding for fiber improvement (Jiang *et al*., 2000; Ulloa & Meredith, 2000). Although high quality fiber specifications are extremely difficult but important to incorporate into cotton breeding programs (Bradow & Davidonis, 2000) and therefore cotton breeders conduct indirect selection for yarn properties, by selecting the better fiber traits (May, 2002). Research work was conducted to analyze the fiber quality parameters of some cotton genotypes for the selection of two diverse genotypes for further genomic analysis.

Materials and Methods

Plant material: Nineteen cotton (*Gossypium hirsutum*) varieties/ genotypes were used for the present research work and these genotypes were collected from different cotton research institutes in Pakistan (Table 1).

Screening of cotton genotypes for fiber quality traits: All the 19 cotton genotypes were screened at NIBGE cotton field for three main fiber quality traits (fiber length, fiber fineness or micronaire and fiber strength). During normal cotton growing season (May through December) these cotton genotypes were sown in three repeats using randomized complete block design (RCBD) with 30 cm plant to plant distance and 75 cm row to row distance. All other agronomic practices were kept similar among the three repeats. At crop maturity, bulk seed cotton was harvested from each line in every repeat. After harvesting, seed cotton was ginned at NIBGE farm and the lint of these cotton genotypes were analyzed from Fiber Technology Laboratory, Cotton Research Institute (CRI), AARI, Faisalabad.

Fiber length can be accurately determined by photoelectric measurement with fibrograph and high-volume instrument (HVI) (Moore, 1996). Staple length is reported to the nearest 32nd of an inch or to the nearest millimeter (mm). For this experiment we measured fiber length in mm with fibrograph. Micronaire (Mic) has been the most widely used method of determining fiber fineness. Mic reading is a measure of resistance to airflow of a constant weight of fibers. We took micronaire reading as an indicator of fiber fineness. Bundle fiber strength is measured in grams-force tex^{-1} with HVI while in Pressley zero-gage it is reported as thousand pound per square inch (tppsi), when relative humidity of testing room is adequately controlled (Meredith *et al*., 1996). We measured the fiber strength in tppsi.

Table 1. Cotton (*G. hirsutum*) varieties/ genotypes, their parentage and centers.

S. No.	Varieties/ genotypes	Parentage	Breeding center
1.	B-557	268-F x (45-F x LSS)	CRI, Faisalabad
2.	BH-36	BS-1 x TX Bonham76C	CRS, Bahawalpur
3.	BH-118	BS-48 x 829-4190, 829-4190= (TX 339 x ST-7A) x (ST-7A x AET-5)	CRS, Bahawalpur
4.	CIM-443	CIM-109 x LRA-5166	CCRI, Multan
5.	CIM-448	492/87 (W 1104 x S-12) x CP15/2	CCRI, Multan
6.	CIM-473	CIM-402 x LRA-5166	CCRI, Multan
7.	CIM-707	CIM-243 x 738/697	CCRI, Multan
8.	CIM-1100	(W-1104 x S12) x CP-15/2	CCRI, Multan
9.	FH-87	AC-134 x paymaster	CRI, Faisalabad
10.	FH-631S	Express x Lankart-57	CRI, Faisalabad
11.	FH-634	(B557 x B574) x Cedix	CRI, Faisalabad
12.	FH-883	Selection from SLS, (SLS = AlbarA637 x Acala 4-42 AlbAcala)	CRI, Faisalabad
13.	FH-900	(FH-672 x AET-5) x B557 x LRA-5166	CRI, Faisalabad
14.	FH-901	CIM-240 x CIM-448	CRI, Faisalabad
15.	Karishma	N-86 x W 83-29 MEX	NIAB, Faisalabad
16.	MNH-93	149F x (MS-39 x Mex12)	CRS, Multan
17.	MNH-552	MS-48 x LRA-5166	CRS, Multan
18.	NIAB-78	DPL-16 x AC-134	NIAB, Faisalabad
19.	NIBGE-1	Karishma x LRA-5166	NIBGE,Faisalabad

CCRI: Central Cotton Research Institute, CRI: Cotton Research Institute, CRS: Cotton Research Station, NIAB: Nuclear Institute for Agriculture and Biology, NIBGE: National Institute for Biotechnology and Genetic Engineering

Statistical analysis: Analysis of variance (ANOVA) was applied to the fiber data of three main quality traits obtained from 19 cotton varieties/ genotypes (Steel & Torrie, 1980). Coefficient of variability (CV) was also calculated for these quality traits. Correlations were also determined between each of fiber length, fiber strength and fiber fineness. ANOVA, CV and correlation analysis were performed with MSTAT-C program. On the basis of these screening results cotton genotypes with contrasting quality traits were selected for hybridization and further genomic studies.

Results and Discussion

Variations in three main fiber related traits were observed among 19 cotton genotypes (Table 2, Fig. 1). Fiber length ranged from 23 to 30 mm with mean value of 27.6 mm. FH-883 had the longest fiber length (30 mm), while FH-631S had shortest fiber length (23 mm). Majority of the cotton fell between 27-28 mm fiber. Similarly, fiber fineness was variable with average micronaire reading of 4.75. Three varieties viz., CIM-707, CIM-1100 and FH-883 produced fine fiber (4.4 Mic) and fiber of FH-631S was coarse with 5.5 Mic, while most of the varieties had 4.8 Mic. Differences in fiber strength were also observed among cotton genotypes ranging from weak (80 tppsi) to very strong (99 tppsi) fiber. FH-631S produced weak fiber with 80 tppsi strength and the fiber of NIBGE-1 was very strong with 99 tppsi strength, while the mean fiber strength of 19 cotton varieties was 94.2 tppsi.

There were considerable differences ($p<0.01$) among 19 cotton genotypes for fiber length, fiber fineness and fiber strength when analysis of variance (ANOVA) was conducted for these fiber traits (Table 2). Although some variation in these traits existed among the three repeats, but these differences were non significant. CV was 5.4%, 6.13% and 4.5% for fiber length, Mic and fiber strength, respectively (Table 2). The correlation coefficients among fiber length, fiber fineness and fiber strength of 19 cotton varieties/ genotypes have been shown in Table 3. Highly significant negative correlation was found between fiber length and fiber fineness ($r = -0.850$), while highly significant positive correlation was observed between fiber length and fiber strength ($r = 0.712$). Fiber fineness was significantly and negatively correlated with fiber strength ($r = -0.499$).

Table 2. Fiber characteristics of 19 cotton varieties/ genotypes.

S. No.	Varieties/ genotypes	Fiber length or FL (mm)	Fiber fineness or FF (Mic = µg/inch)	Fiber strength or FS (tppsi)
1.	B-557	26.8 (ML)	4.8 (A)	91.5 (S)
2.	BH-36	27.6 (ML)	4.5 (A)	88.6 (A)
3.	BH-118	27.0 (ML)	5.0 (C)	95.5 (S)
4.	CIM-443	27.0 (ML)	4.8 (A)	97.0 (S)
5.	CIM-448	28.0 (ML)	4.6 (A)	94.5 (S)
6.	CIM-473	29.0 (L)	4.5 (A)	95.0 (S)
7.	CIM-707	29.6 (L)	4.4 (A)	97.0 (S)
8.	CIM-1100	28.8 (ML)	4.4 (A)	94.3 (S)
9.	FH-87	28.0 (ML)	4.6 (A)	95.5 (S)
10.	FH-631S	23.0 (M)	5.5 (C)	80.0 (W)
11.	FH-634	28.5 (ML)	4.5 (A)	95.4 (S)
12.	FH-883	30.0 (L)	4.4 (A)	97.0 (S)
13.	FH-900	26.5 (ML)	4.8 (A)	93.0 (S)
14.	FH-901	27.5 (ML)	5.2 (C)	94.0 (S)
15.	Karishma	26.5 (ML)	4.8 (A)	97.5 (VS)
16.	MNH-93	27.8 (ML)	4.8 (A)	95.0 (S)
17.	MNH-552	27.2 (ML)	5.0 (C)	97.0 (S)
18.	NIAB-78	27.0 (ML)	4.9 (A)	92.0 (S)
19.	NIBGE-1	28.0 (ML)	4.8 (A)	99.0 (VS)
All cotton varieties				
	Mean ± SE	27.6 ± 0.34	4.75 ± 0.07	94.2 ± 0.96
	Minimum	23.0	4.4	80.0
	Maximum	30.0	5.5	99.0
	SD	1.49	0.29	4.20
	% CV	5.4	6.13	4.5
	Mean squares	6.66**	0.25**	53.0**

ML: Medium long, L: Long, A: Average, C: Coarse, S: Strong, W: Weak, VS: Very strong, SD: Standard deviation, CV: Coefficient of variability

** Significant at 0.01 probability (P) level

Table 3. Correlation coefficients[$] among three fiber quality traits in 19 cotton varieties/ genotypes.

Traits	Fiber length (FL)	Fiber fineness (FF)	Fiber strength (FS)
FL	1		
FF	**-0.850**	1	
	0.000		
FS	**0.712**	**-0.499**	1
	0.001	*0.029*	

[$] Correlation coefficients on above (bold), while correspondent probability below (italic)

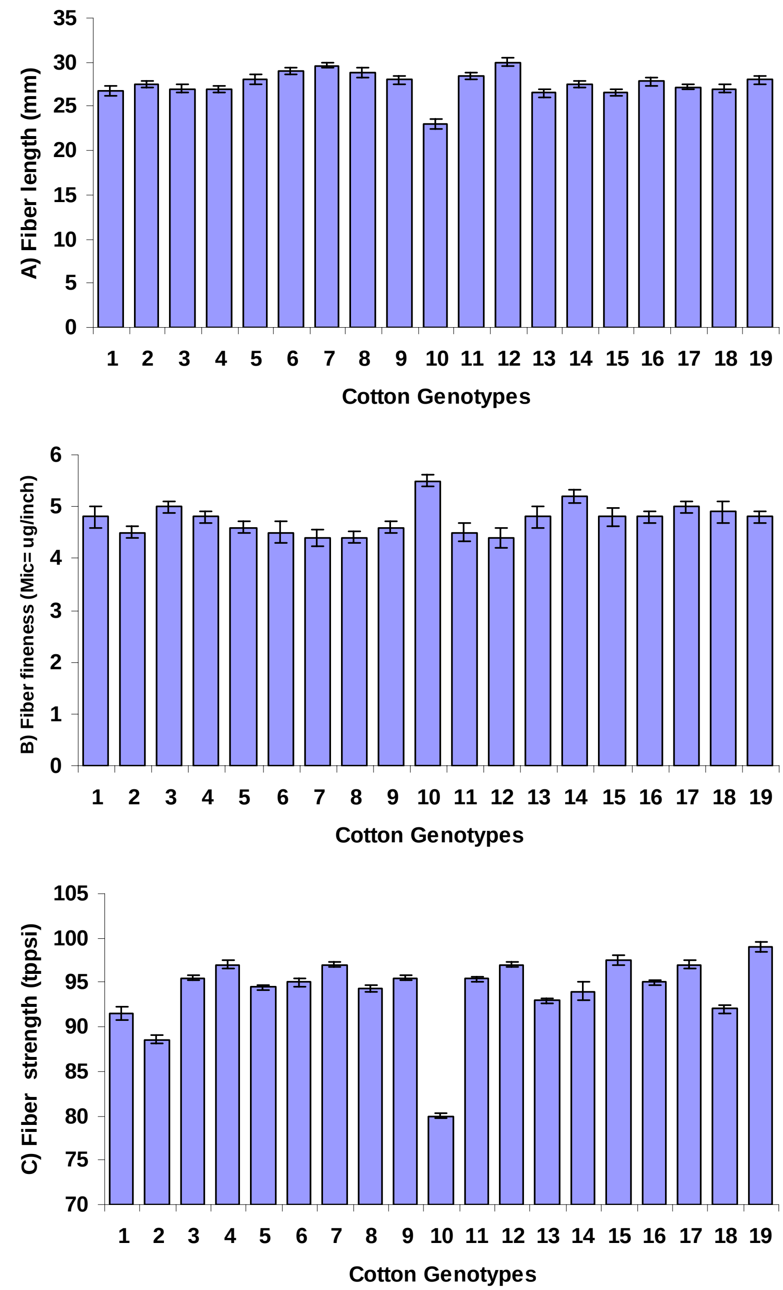

Fig. 1. Mean performances of 19 cotton varieties/genotypes for fiber length, fiber fineness and fiber strength. 1= B-557, 2= BH-36, 3= BH-118, 4= CIM-443, 5= CIM-448, 6= CIM-473, 7= CIM-707, 8= CIM-1100, 9= FH-87, 10= FH-631S, 11= FH-634, 12= FH-883, 13= FH-900, 14= FH-901, 15= Karishma, 16= MNH-93, 17= MNH-552, 18= NIAB-78, 19= NIBGE-1.

The results of this screening experiment facilitated the selection of two diverse cotton genotypes (FH-631S and FH-883) for further genome mapping. Maximum differences were examined for fiber strength followed by fiber length, while minimum variation was accounted for micronaire among 19 upland cotton genotypes. Variation among unapproved germplasm lines was more as compared to approved varieties. Despite the variations, most of the varieties had uniformity in a sense of trait standards as they could be grouped with medium long fiber length, average Mic and strong fiber. It was due to the fact that breeders mostly develop varieties to meet certain common fiber standards and requirements (Bayles *et al.*, 2005; Rahman *et al.*, 2002 & 2005). In future studies, more genotypes and preferably wild accessions (Cheatham *et al.*, 2003) would be included in multilocation field trials for germplasm screening and evaluation, which will also reveal genotypes x environment interactions (Paterson *et al.*, 2003).

Fiber length, micronaire and fiber strength were closely and significantly correlated such that cultivars with longer fiber had stronger fiber and lower micronaire reading. Moreover, varieties having stronger fiber were with lower micronaire (Table 2). Zhang *et al.*, (2005) reported similar findings while they were evaluating the field performance of commercial cotton cultivars in US. Other investigators also reported similar results (Ulloa & Meredith, 2000), however, contrary to our findings, positive association was also found between fiber fineness and fiber strength by Mei *et al.*, (2004). Correlations between different fiber traits would be employed as selection criteria for successful cotton breeding. Development of cotton varieties with improved fiber traits has been very difficult due to the quantitative inheritance of these traits, which can be mitigated using new genomic tools like molecular markers for marker assisted selection in molecular breeding programs (Rahman *et al.*, 2002; Asif *et al.*, 2006; Jauhar, 2006).

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