AAB BIOFLUX
Advances in Agriculture & Botanics-
International Journal of the Bioflux Society

Genetic studies of fiber quality parameter and earliness related traits in upland cotton (*Gossypium hirsutum* L.)

[1]Muhammad Imran, [1]Amir Shakeel, [2]Jehanzeb Farooq, [1]Asif Saeed, [2]Amjad Farooq, and [2]Muhammad Riaz

[1]Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan; [2]Cotton Research Institute, Ayub Agricultural Institute, Faisalabad, Pakistan. Corresponding author: J. Farooq, jehanzeb1763@hotmail.com

Abstract. Combining ability analysis was carried out for fiber quality and earliness related traits in a 5×5 diallel cross using Griffing, Method-I, Model-II. Analysis of variance components indicated that except days to first boll opening and boll maturation period all character were predominantly controlled by non-additive type of gene action. Genotype NIAB Krishma was the best general combiner for days to flowering and fiber strength and S-12 for boll maturation period, seed cotton yield and fiber length. Hybrids NIAB Krishma × MS-39, CP-15/2 × S-12, S-12 × MS-39 and S-12 × NIAB Krishma showed the best SCA (Specific Combining Ability) and reciprocal effects for all characters. Regarding simple correlation analysis days to flowering showed significantly positive correlation with days to first boll opening, whilst fiber length showed negative correlation with days to first boll opening. Furthermore, fiber strength association with fiber fineness was significantly negative but with fiber length the association was positive. The boll maturation period was positively correlated with days to first boll opening while negatively correlated with days to flowering. SCA variance was greater than GCA (General Combining Ability) effects for days to flowering, fiber strength and fiber fineness indicates the importance of non-additive type of gene action thus heterosis breeding could be exploited for these traits. Additive genetic effects were predominant for days to flowering and boll maturation period thus pedigree method of selection could be exploited for these traits.
Key Words: Combining ability, fiber length, cotton, boll maturation period, additive gene action.

Introduction. Cotton is an important cash crop of Pakistan. It sustains millions of people in many fields such as agriculture, textile mills, ginning factories and business. A lot of research work has already been done for developing early maturing and high yielding varieties. But in Pakistan average yield is low, which motivate the breeders to increase their efforts for developing such varieties.

Salam et al (1993) reported that late maturation of cotton cultivars resulted in poor fiber characteristics. Improvement in production and fiber related traits are possible by utilization of variation available in the local and introduced genotypes (Murtaza 2005).

The variation can also be produced by crossing unrelated strains that possesses greater genetic potential. Many breeding programs have been launched across the country which aimed at improving the cotton production and other quality parameters.

The success of breeding program is primarily based upon choice of promising parental lines (Khan et al 2009a). The selection of parents is determined by the suitable genes and gene complexes which it contained (Khan et al 2009a). Therefore, information about genetic variability and its components gives good source to the breeder for crop improvement (Murtaza 2005; Khan et al 2009b).

To increase the yield and fulfill the quality fiber demand there is need to produce earliness in the cotton varieties. For the development of plant material which holds a good promise to plant breeder, the selection of the parents during hybridization is an important step.

There are several biometric methods available for researchers which are used to study the genetic causes of variation, for example, graphic analysis of Hayman (Hayman 1954ab), Line x Tester analysis (Kempthorne 1957), Triple Test Cross Technique (Kearsey & Jinks 1968) and others, but the numerical approach of Griffing (1956), in addition to partitioning the genetic components i.e. additive and non-additive, characteristically classify the germplasm with respect to their general and specific combining abilities, and therefore was used in the present investigation to evaluate combining ability effects for some cotton genotypes and their crosses for fiber quality traits and earliness.

Material and Method. The present experiment was conducted at the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2009-2010.

The plant material used in the present study was developed by crossing different varieties, viz. CP-15/2, NIAB Krishma, CIM-482, MS-39 and S-12. The plant material was collected from cotton germplasm from the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad.

The five parents were grown under controlled condition in glasshouse during the month of November 2009. Day and night temperatures in glass house were maintained using steam and electric heaters. The day light during winter was supplemented by lighting mercury vapor lamps. When the parental lines started to flower, there were crossed in all possible combination. Maximum number of attempts was made to develop sufficient F_0 seeds.

The F_0 seeds of 20 hybrids and 5 parents were planted in the field during 11 June, 2010. Each entry was sown in three replications by using randomized complete block design (RCBD). There were five plants in each row. Row to row and plant to plant distance was maintained 75 cm and 30 cm respectively.

Fertilizer and irrigation was not applied due to heavy rain during the whole cotton season. Attack of diseases was increased due to high humidity. Temperature was normal during the cotton growth season. This climatic data was taken from Agromet Bullet in Agriculture Meteorology Cell, Department of Crop Physiology, University of Agriculture Faisalabad Pakistan located at Latitude = 31 O- 26' N, Longitude = 73O- 06' E, Altitude = 184.4m. The graph of climatic condition during the cotton season is given in Figure 1.

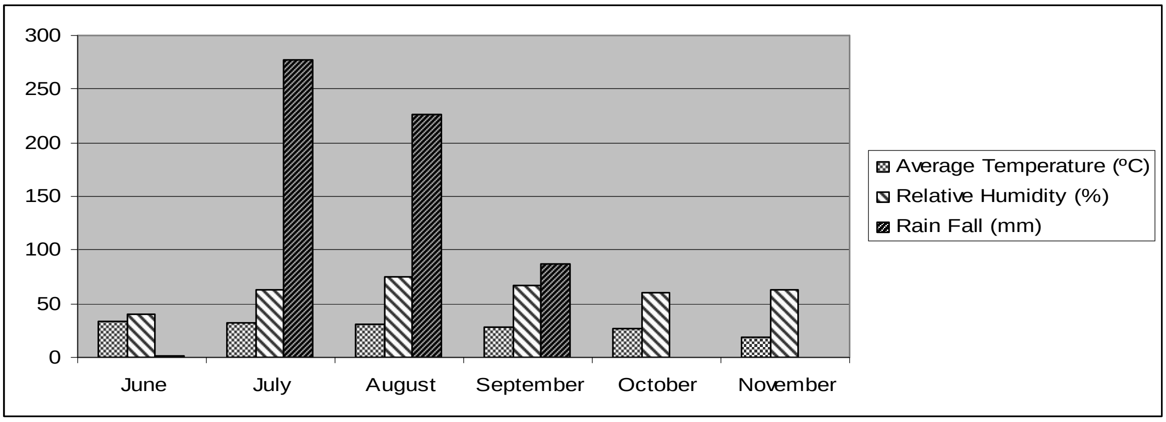

Figure 1. Climatic condition during June-November, 2010.

At maturity data's were taken on the middle of five plants, leaving two plants on either end of the row to avoid the border effects. Data's regarding days to flowering, days to first boll opening, boll maturation period and seed cotton yield per plant (g) were recorded. The matured bolls were picked after every 15 days as soon as bolls started to open and seed cotton was collected in paper bags.

Clean and dry samples of the seed cotton were weighed and then ginned separately with single Roller Electric Ginner. Total produce of the plant was ginned and the data on fiber length (mm), fiber strength (g/tex) and fiber fineness (µg/Inch) was recorded using spinlab High Volume Instrument (HVI-900) in the Department of Fiber Technology, University of Agriculture, Faisalabad.

The data collected was subjected to analysis of variance technique (Steel et al 1997) in order to determine the significance of differences among the genotypes for plant traits under study. The characters showing significant genotypic differences was further analyzed for general and specific combining ability effects as defined by Sprague & Tatum (1942) and reciprocal effects as defined by Griffing (1956) Method-I, Model-II.

Results and Discussion. The estimates for GCA (General Combining Ability), SCA (Specific Combining Ability) and reciprocal effects were presented in Table 1.

Analysis of variance revealed that mean squares for GCA were non significant for all characters except days to first boll opening and boll maturation period. While mean squares for SCA and reciprocal effects were highly significant for all traits. GCA variance was greater than SCA and reciprocal effects for days to first boll opening and boll maturation period showing the predominance of additive gene action for this trait.

Whilst SCA variance was greater than GCA and reciprocal effects for days to flowering, fiber strength and fiber fineness indicates the importance of non-additive type of gene action involved in the manifestation of characters under study. Days to first boll opening, seed cotton yield and fiber length showed high reciprocal estimates for the characters.

General Combining Ability. The GCA values of all the parents were compared (Table 2), which revealed that for seed cotton yield and fiber length S-12 has the highest positive values and lowest negative value for boll maturation. S-12 was good general combiner for all these characters.

The variety NIAB Krishma obtained highest negative and positive value for days to flowering and fiber strength, respectively. Similarly for days to first boll opening and fiber fineness, MS-39 and CIM-482 proved to be good general combiners for these traits.

Number of days taken to flowering is considered as an important determinant of earliness (Chen et al 1991). El-Feki et al (1998) reported that additive type of genetic effect is important for days to flowering. The results of Gomaa et al (1999), Iqbal et al (2003) and Neelima et al (2004) showed that additive gene effects controlled days to flowering.

Earlier maturing cultivars possessed the shortest boll maturation periods therefore, early and rapid flowering coupled with shorter boll maturation period will help to enhance earliness index. Gipson & Ray (1970) results also supported that non additive genetic effects were important for boll maturation period and days to first boll opening. Bednarz & Nichols (2005), Cravalho et al (1995), Punitha et al (1999), Shakeel et al (2001), Inam-Ul-Haq & Azhar (2004) reported that seed cotton yield were influenced by the genes acting non-additively, and in contrast the studies of Shakeel et al (2000), Kumaresan et al (1999), Murtaza et al (2002), Patel et al (2009) and Laxman (2010) indicated that both additive and non additive gene effects were important for controlling seed cotton yield.

Ahuja & Dhayal (2007) reported non-additive gene action for fiber quality parameters while Ali et al (2008) had reported dominant gene action for all fiber traits except fiber fineness. So it is suggested that S-12 and NIAB Krishma could be exploited key traits improvement for different cross combination.

Sufficient support in the literature is available to this observation (Sayal et al (1999), Goudar et al (1996) and Khorgade et al (2000) who reported that parents with good GCA produced the best yielding hybrids.

Table 1

Analysis of Variance for traits related to earliness and fiber quality

SOV	*D.F.*	*Days to flowering*	*Days to 1st boll opening*	*Boll maturation period*	*Seed cotton yield*	*Fiber length*	*Fiber strength*	*Fiber fineness*
Replication	2	0.969	2.438	8.269	0.766	1.781	3.446	3.516
Genotypes	24	6.608	4.703	5.383	5.460	1.511	3.163	0.105
GCA	4	2.117 NS	3.321 **	2.386 *	1.931 NS	0.301 NS	0.79NS	3.864 NS
SCA	10	2.567 **	1.421 **	2.247 **	1.313 **	0.630 **	1.87 **	2.759**
Reciprocal	10	1.872 **	1.014 **	1.104 **	2.281 **	0.458 **	1.12 **	4.094**
Error	48	1.110	0.874	0.886	0.783	0.266	0.48	1.664
σ^2GCA	-	-3.807	0.192	2.032	0.064	-3.11	-2.678	1.154
σ^2SCA	-	0.867	0.325	0.810	0.315	0.216	0.358	6.520
σ^2 Reciprocal	-	0.380	7.023	0.109	0.748	9.59	0.321	1.215
σ^2 A	-	-7.615	0.385	4.06	0.128	-6.22	-5.35	2.31
σ^2 D	-	0.867	0.325	0.810	0.315	0.21	0.358	6.52

Table 2

Estimates of general combining ability effects for various characters of (*Gossypium hirsutum* L.) in a 5x5 diallel cross experiment

Verities	*Days to flowering*	*Days to 1st boll opening*	*Boll maturation period*	*Seed cotton yield*	*Fiber length*	*Fiber strength*	*Fiber fineness*
CP-15/2	0.190	0.930	0.727	-0.648	-0.194	0.011	0.017
NIAB Krishma	- 0.627	-0.437	0.177	-0.201	0.119	0.408	0.020
CIM-482	0.440	0.172	-0.282	0.271	0.063	-0.292	0.057
MS-39	- 0.335	-0.453	-0.065	0.281	-0.174	-0.232	-0.107
S-12	0.332	-0.212	-0.557	0.334	0.186	0.105	0.013
S.E.(gi-gj)	0.471	0.418	0.420	0.395	0.230	0.311	5.76

Specific Combining Ability. The comparison of the crosses for their SCA values is shown in Table 3. The cross combination of CP-15/2 × NIAB Krishma shows highest negative value for days to flowering. This combination involves genotype NIAB Krishma, which is good general combiner for days to flowering and fiber strength and CP-15/2 which is poor general combiner for boll maturation period. This showed that though CP-15/2 is a poor combiner for this character yet showed its promise in this combination as well as for days to flowering in combination with NIAB Krishma. This indicated that parents having low general combining ability might show good potential in varietal combinations.

Similar results were obtained in earlier studies (Azhar & Rana 1993; Rauf et al 2004). Hybrid combination of CP-15/2 × S-12 appeared to be of great potential for days to flowering and seed cotton yield. Similarly the cross combination of CP-15/2 × NIAB Krishma performed good for days to first boll opening.

For fiber length and fiber strength, cross combination NIAB Krishma × MS-39 revealed to be the best. NIAB Krishma and CP-15/2 had produced a best cross combination with parent S-12 and CIM-482, respectively.

These results showed that better performance of these hybrids might have been results of high GCA value of S-12 and NIAB Krishma as shown in Table 3, for these characters. Siddique & Patil (1992) and Mukhtar et al (2000) also reported similar results in their studies on cotton.

Reciprocal Effects. Reciprocal effects are presented in Table 4, which showed that the cross combination S-12 × MS-39 showed best reciprocal estimates for days to first boll opening and boll maturation period followed by CIM-482× NIAB Krishma for fiber length and fiber strength and S-12 × NIAB Krishma for fiber fineness.

For days to flowering and seed cotton yield parents MS-39 had produced good reciprocal estimates with cross combination of CP-15/2 and NIAB Krishma, respectively.

In the present study the results indicates that except boll maturation period and days to first boll opening all the traits were controlled by non additive gene action for attaining the utmost improvement in earliness and fiber quality traits, similar results were founded by Ahuja & Dhayal (2007), Cravalho et al (1995), Inam-Ul-Haq & Azhar (2004), Godoy & Palomo (1999).

The parents NIAB Krishma and S-12 showed high GCA while crosses; NIAB Krishma × MS-39, CP-15/2 × S-12, S-12 × MS-39 and S-12 × NIAB Krishma showed higher SCA and reciprocal effects.

The obtained results suggested that population improvement by reciprocal recurrent selection to accumulate desirable gene and breaking undesirable linkages would be more appropriate (Rauf et al 2005).

Table 3

Estimates of Specific combining ability effects for various characters of (*Gossypium hirsutum* L.) in a 5x5 diallel cross experiment

Genotypes	*Days to flowering*	*Days to 1st boll opening*	*Boll maturation period*	*Seed cotton yield*	*Fiber length*	*Fiber strength*	*Fiber fineness*
CP-15/2 × NIAB Krishma	-0.873	-0.513	0.373	-0.084	-0.203	-0.921	0.057
CP-15/2 × CIM-482	-0.023	-0.288	-0.252	-0.806	0.071	-0.288	0.103
CP-15/2 × MS-39	0.960	1.503	0.490	-0.508	0.207	0.102	-0.217
CP-15/2 × S-12	-1.957	-0.072	1.898	1.273	0.214	0.782	-0.003
NIAB Krishma ×CIM-482	0.168	-0.505	-0.660	0.678	0.474	0.915	-0.033
NIAB Krishma ×MS-39	-0.140	0.703	0.790	-0.612	0.477	1.122	0.080
NIAB Krishma× S-12	1.735	0.545	-1.177	0.023	0.201	-0.081	0.043
CIM-482× MS-39	0.085	0.387	0.248	0.029	-0.499	0.105	0.027
CIM-482 × S-12	0.043	0.270	0.240	0.705	0.224	-0.065	-0.143
MS-39 × S-12	0.735	-0.212	-1.018	-0.118	-1.089	-0.908	-0.063
S.E(sij-sik)	0.942	0.836	0.841	0.791	0.461	0.622	0.115

Table 4

Estimates of Reciprocal effects for various characters of (*Gossypium hirsutum* L.) in a 5x5 diallel cross experiment

Genotypes	*Days to flowering*	*Days to 1st boll opening*	*Boll maturation period*	*Seed cotton yield*	*Fiber length*	*Fiber Strength*	*Fiber Fineness*
NIAB Krishma × CP-15/2	0.333	-0.333	-0.667	-0.196	-0.133	0.383	-0.100
CIM-482 × CP-15/2	0.333	0.500	0.166	1.204	0.117	0.450	0.050
MS-39 ×CP-15/2	-2.125	-1.250	0.875	1.533	0.217	-0.233	0.100
S-12 ×CP-15/2	-0.458	-0.167	0.292	-1.587	-0.183	-0.117	-0.100
CIM-482 ×NIAB Krishma	-1.542	0.000	1.542	1.296	1.233	1.650	-0.317
MS-39 × NIAB Krishma	0.292	0.333	0.042	1.758	-0.267	-0.617	0.067
S-12 × NIAB Krishma	-0.667	-0.833	-0.167	-0.021	0.117	0.883	0.117
MS-39 × CIM-482	-0.083	-0.292	-0.208	-0.087	0.433	0.300	0.117
S-12 × CIM-482	-1.208	-0.583	0.625	-0.475	0.617	0.033	-0.200
S-12 × MS-39	-0.208	-1.375	-1.167	0.213	0.67	1.117	-0.017
S.E(rij-rik)	1.054	0.934	0.941	0.885	0.515	0.695	0.129

Correlation Analysis. The result of simple correlation analysis is shown in Table 5, indicating that day to flowering showed significantly positive correlation with days to first boll opening ($p \leq 0.01$), whilst fiber length showed negative correlation with days to first boll opening ($p \leq 0.05$).

Furthermore, fiber strength association with fiber fineness ($p \leq 0.01$) was significantly negative but with fiber length ($p \leq 0.05$) the association was positive.

The boll maturation period was positively correlated with days to first boll opening ($p \leq 0.01$), while negatively correlated with days to flowering ($p \leq 0.01$).

Table 5

Simple correlation analysis of traits in cotton genotypes

Traits	*BO*	*DF*	*FF*	*FL*	*FS*	*MP*
DF	0.4318**	-	-	-	-	-
FF	0.1003	-0.0242	-	-	-	-
FL	-0.2404*	-0.2107	-0.1132	-	-	-
FS	-0.1304	0.0697	-0.3038**	0.2512*	-	-
MP	0.4932**	-0.5717**	0.1147	-0.0155	-0.1858	-
SY	0.0307	-0.1612	-0.0895	0.1963	0.1521	0.1276

BO - Days to first boll opening, DF - Days to flowering, FF - Fiber fineness, FL - Fiber length, FS - Fiber strength, MP - Boll maturation period, SY - Seed cotton yield, *.** - significantly at $p \leq 0.05$ and $p \leq 0.01$ respectively.

Shah et al (2010) concluded on the basis of correlation coefficients that all phenological traits i.e., days to flowering, boll opening and boll maturation period are important determinants of earliness index. But according to Godoy & Palomo (1999) components of earliness showed no association with yield except for date for first open boll.

Seed cotton yield has significant negative correlation with fiber fineness, fiber strength and fiber length (Cheng & Zhao 1991; Khan et al 1991; Azhar et al 2004).

Seed cotton yield was positive and significantly correlated with fiber fineness, but negatively correlated with fiber length and fiber strength (Karademir et al 2010). Similarly, Desalegn et al (2009) reported strong positive correlation between seed cotton yield and fiber fineness (micronaire).

Conclusions. Based on our results, the following conclusions were drawn:

1. Variability among 7 traits was present.
2. Additive gene effects were predominant for days to flowering and boll maturation period.
3. SCA variance was greater than GCA and reciprocal effects for days to flowering, fiber strength and fiber fineness indicates the importance of non-additive type of gene action involved in the manifestation of characters under study.
4. Days to first boll opening, seed cotton yield and fiber length showed high reciprocal estimates for the characters.
5. Genotype NIAB Krishma and S-12 contributed best results for most of the traits evaluated.
6. The hybrids, NIAB Krishma × MS-39, CP-15/2 × S-12, S-12 × MS-39 and S-12 × NIAB Krishma are recommended for the improvement of seed cotton yield, fiber quality traits and earliness.

References

Ahuja S. L., Dhayal L. S., 2007 Combining ability estimates for yield and fiber quality traits in 4 x 13 line × tester crosses of *Gossypium hirsutum*. Euphytica **153**:87-98.

Ali M. A., Khan I. A., Awan S. I., Ali S., Niaz S., 2008 Genetics of fiber quality traits in cotton (*Gossypium hirsutum* L.). Aust J Crop Sci **2**(1):10-17.

Azhar F. M., Rana A. H., 1993 Genetic analysis of three developmental plant characteristics in upland cotton. Pak J Agri Sci **30**:439–442.
Azhar F. M., Naveed M., Asif A., 2004 Correlation analysis of seed cotton yield with fiber characteristics in *Gossypium hirsutum* L. Int J Agric Biol **4**:656-658.
Bednarz C. W., Nichols R. L., 2005 Phenological and morphological components of cotton crop maturity. Crop Sci **45**(4):1497-1503.
Chen Z. F., Zhang Z. W., Li Z. Y., Wang Y. F., 1991 Study on the correlation between the earliness of Upland cotton and its yield and fibre quality. China Cottons **5**:16-17.
Cheng B. J., Zhao L. Y., 1991 Multiple correlation analysis of yield, fiber quality and plant characteristics in upland cotton. Acta Agric Shanghai **7**:29-35.
Cravalho L. P., Cruz C. D., Moraes C. F., 1995 Diallel analysis of yield and other traits in cotton. Rev Brasil Genet **18**(1):93-97.
Desalegn Z., Ratanadilok N., Kaveeta R., 2009 Correlation and heritability for yield and fiber quality parameters of Ethiopian cotton (*Gossypium hirsutum* L.) estimated from 15 (diallel) crosses. Kasetsart J Nat Sci **43**:1-11.
El-Feki T. A., Abedl-Gelil M. A., Zeina A. A., 1998 Diallel analysis of cotton hybrids (*G.barbadence* L.). Egyptian J Agri Res **76**(1):219-230.
Gaudar P. V. K., Katarki B. H., Salimath P. M., Chetti M. B., 1996 Genetics of yield, yield attributes and their implications in breeding of cotton (*Gossypium hirsutum* L.). The Indian Journal of Genetics and Plant Breeding **56**:147–155.
Gipson J. R., Ray L. L., 1970 Temperature variety interrelationships in cotton. J Agri Sci Cambridge **73**:65-97.
Godoy A. S., Palomo G. A., 1999 Genetic analysis of earliness in upland cotton (*G. hirsutum* L.). II. Yield and lint percentage. Euphytica **105**:161-166.
Gomaa A. M. A., Shaheen A. M. A., Khattab S. A. M., 1999 Gene action and selection indices in two cotton (*Gossypium barbadense* L.) crosses. Ann Agric Sci Cairo **44**: 293–308.
Griffing B., 1956 Concept of general and specific combining ability in relation to diallel crossing system. Aust J Biol Sci **9**:463–493.
Hayman B. I., 1954a The analysis of variance of diallel tables. Biometrics **10**:235-244.
Hayman B. I., 1954b The theory and analysis of diallel crosses. Genetics **39**:789-809.
Inam-ul-Haq Azhar F. M., 2004 Genetic basis of varietal differences for seed cotton yield and its components in *hirsutum* spp. Int J Agri Biol **6**(5):904-907.
Iqbal M., Chang M. A., Jabbar A., Iqbal M. Z., Hassan M., Islam N., 2003 Inheritance of earliness and other characters in upland cotton. Online J Biol Sci **3**:585–590.
Karademir E., Karademir C., Ekinci R., Gencer O., 2010 Relationship between yield, fiber length and other fiber-related traits in advanced cotton strains. Notulae Botanicae Horti Agrobotanici Cluj-Napoca **38**(3):111-116.
Kearsey M. J., Jinks J. L., 1968 A general method of detecting additive, dominance and epistatic variation for metrical traits. I. Theory. Heredity **23**:403–409.
Kempthorne O., 1957 An introduction to genetic statistics. John Wiley and Sons, New York.
Khan N. U., Hassan G., Marwat K. B., Farhatullah Kumbhar M. B., Parveen A., Umm-E-Aiman Khan M. Z., Soomro Z. A., 2009b Diallel analysis of some quantitative traits in *Gossypium hirsutum* L. Pak J Bot **41**(6):3009-3022.
Khan N. U., Marwat K. B., Hassan G., Kumbhar M. B. Farhatullah, Soomro Z. A., Khan N., Parveen A., Umm-e-Aiman Khan M. Z., 2009a Study of fiber quality traits in upland cotton using additive-dominance model. Pak J Bot **41**(3):1271-1283.
Khan M. A., Sadaqat H. A., Tariq M., 1991 Path coefficient analysis in cotton (*G. hirsutum* L.). J Agric Res **29**:177-182.
Khorgade P. W., Stange I. V., Mesham L. D., 2000 Diallel analysis in American cotton (*Gossypium hirsutum* L.). Ind J Agric Res **34**:172–175.
Kumaresan D., Senthilkumar P., Ganesan J., 1999 Combining ability studies for quantitative traits in cotton (*Gossypium hirsutum* L.). Madras Agric J **18**:430–432.
Laxman S., 2010 Diallel analysis for combining ability for seed cotton yield and its components in desi cotton (*Gossypium arborium* L.). J Cotton Res Dev **24**(1):26-28.

Mukhtar M. S., Khan T. M., Khan M. A., Khan M. K. R., 2000 Diallel analysis of some important fibre characteristics of *Gossypium hirsutum* L. Int J Agric Biol **2**(3): 261-263.

Murtaza N., 2005 Study of gene effects for boll number, boll weight and seed index in cotton. Journal of Central European Agriculture **6**(3):255-262.

Murtaza N., Khan A. A., Qayyum A., 2002 Estimation of genetic parameters and gene action for yield of seed cotton and lint percentage in *Gossypium hirsutum* L. J Res Sci **13**(2):151-159.

Neelima S., Reddy V. C., Reedy A. N., 2004 Combining ability studies for yield and yield components in American cotton (*G. hirsutum* L.). Ann Agri Biol Res **9**(1):1-6.

Patel A. D., Patel U. G., Kumar V., 2009 Diallel analysis for combining ability for seed cotton yield and its component traits in upland cotton. J Cotton Res Dev **23**(2): 222-225.

Punitha D., Raveendran T. S., Kavitha M., 1999 Combining ability studies for yield and quality traits in interspecific coloured linted cotton (*Gossypium hirsutum* L. x *Gossypium barbadense* L*.).* PKV Res J **23**:14–16.

Rauf S., Khan T. M., Sadaqat H. A., Khan A. I., 2004 Correlation and path coefficient analysis of yield components in cotton (*Gosspium hirsutum* L.). Int J Agri Biol **6**(4):686-688.

Rauf S., Shah K. N., Afzal I., 2005 A genetic study of some earliness related characters in cotton (*Gossypium hirsutum* L.). Caderno de Pesquisa Ser Bio, Santa Cruz do Sul **17**(1):81-93.

Salam C. A., Arshad M., Afzal M., 1993 Effect of picking dates on fibre character of different commercial cotton varieties of *G. hirsutum* L. Pak Cotton **37**:67–74.

Sayal O. U., Baloch M. S., Hassan I., Khan B., 1999 Exploitation of heterosis (Ht%) and heterobeltiosis (Hb%) in American cotton (*Gossypium hirsutum* L.). J Agric Res **39**(1):15-17.

Shah M. K. N., Malik S. A., Murtaza N., Ullah I., Rahman H., Younis U., 2010 Early and rapid flowering coupled with shorter boll maturation period offers selection criteria for early crop maturity in upland cotton. Pak J Bot **42**(5):3569-3576.

Shakeel A., Khan I. A., Azhar F. M., 2001 Study pertaining to the estimation of gene action controlling yield and related traits in upland cotton. J Biol Sci **1**:67–70.

Shakeel A., Khan T. M., Khan A. M., 2000 Genetic studies of some important quantitative characters in *Gossypium hirsutum* L. Int J Agric Biol **1**(2):121-124.

Siddique M. A., Patil R. A., 1992 Combining ability for yield and yield contributing traits and earliness in Upland cotton under irrigated conditions. J Maharashtra Agric Univ **17**:383–386.

Sprague G. F., Tatum L. A., 1942 General vs specific combining ability in single crosses of corn. J American Soc Agron **34**:923-32.

Steel R. G. D., Torrie J. H., Dicky D. A., 1997 Principles and procedures of statistics- A Biometrical Approach 3rd Ed. McGraw Hill Book International Co., Singapore, 204-227.

Received: 02 October 2011. Accepted: 08 December 2011. Published online: 17 December 2011.

Authors:
Muhammad Imran, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad 38040, Pakistan.
Amir Shakeel, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad 38040, Pakistan, e-mail: dramirpbg@gmail.com
Jehanzeb Farooq, Cotton Research Institute, Ayub Agricultural Institute, Jhang Road, Faisalabad 38950, Pakistan, e-mail: jehanzeb1763@hotmail.com
Asif Saeed, Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad 38040, Pakistan, e-mail: asifpbg@hotmail.com
Amjad Farooq, Cotton Research Institute, Ayub Agricultural Institute, Jhang Road, Faisalabad 38950, Pakistan, e-mail: amjad.cri@gmail.com
Muhammad Riaz, Cotton Research Institute, Ayub Agricultural Institute, Jhang Road, Faisalabad 38950, Pakistan, e-mail: riaz_1964@yahoo.com

How to cite this article:
Imran M., Shakeel A., Farooq J., Saeed A., Farooq A., Riaz M., 2011 Genetic studies of fiber quality parameter and earliness related traits in upland cotton (*Gossypium hirsutum* L.). AAB Bioflux **3**(3):151-159.