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THE STUDY OF GENETIC EFFECTS OF COMBINING ABILITY IN DIALLELIC COTTON HYBRIDS WITH IMPROVED FIBER TRAITS

R.B. Mammadova[1,2*], L.A. Guseynova[1], Allah Bakhsh[3], G.S. Abdulaliyeva[1], A.O. Mammadova[4], Z.M. Mammadov[4], Sh.A. Alizade[1,4], N.R. Amrahov[4]

[1]Genetic Resources Institute, Ministry of Science and Education, Baku, Azerbaijan
[2]Western Caspian University, Baku, Azerbaijan
[3]Centre of Excellence in Molecular Biology University of Punjab, Lahore, Pakistan
[4]Baku State University, Baku, Azerbaijan

Abstract. The genetic variability of important fiber quality traits of cotton such as: uniformity Index (UI); fiber elongation before breaking (Elongation, Elg) and micronaire (Mic) were studied. Qualitative characteristics were tested on the HVI (High Volume Instrument) system, in accordance with the international classification. Local cotton varieties (Agdash-3, AP-317 and Elekberi), Turkish testers (Sezener 76, Naz 07, Ozbek and GSN 12) and 12 incomplete diallelic hybrid combinations were evaluated to determine the potential of parental varieties, F_1 and F_2 hybrids using effective method - combining ability. Analysis of variance, carried out on the basis of data from all studied combinations, made it possible to identify one local line (AP-317) and two foreign testers (Naz 07 and GSN 12), which had, to varying degrees, positive effects of total combining ability (TCA). This indicates additive types of expression of non-allelic genes responsible for the formation of the studied qualitative properties of cotton fiber. Variations in the SCS of hybrid combinations were generally lower than the effects of the GCS. When assessing second-generation hybrids, we determined that lines and testers with positive effects of GCA and hybrid combinations with their participation were distinguished by high indicators of the fiber quality in the next generation. Consequently, selection of genotypes with improved fiber quality carried out in early generations can be effective, which will accelerate the creation of new promising varieties and lines of cotton.

Keywords: *Cotton, line, tester, combination ability, fiber quality, additive effect.*

Corresponding Author: *Ruhangiz Mammadova, Genetic Resources Institute, Ministry of Science and Education; Western Caspian University, Baku, Azerbaijan; Tel.:+994553316895, e-mail: gene-res@mail.ru*

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1. Introduction

Cotton is an important agricultural crop and a source of natural fiber. Cotton fiber is widely used in the production of clothing and household items (Akparov *et al*., 2021; Alizada *et al*., 2020; Amrahov *et al*., 2023; Mammmadova *et al*., 2023). Due to its unique properties, many authors call it the “King of fiber” (Kumbhalkar *et al*., 2018; Kanasagra *et al*., 2022; Udaya *et al*., 2023). Since the demand for cotton fiber on a global market is

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growing, ongoing research on the creation of new promising varieties and lines using an effective method for assessing combining ability is relevant (Mamedova *et al*., 2011; Jenkins *et al*., 2018; Chakholoma *et al*., 2022; Balci *et al*., 2023). It is necessary to study the diversity of collection and select initial material to use in breeding programs (Amrahov *et al*., 2022; 2024; Alizade *et al*., 2023).

Indian breeders (Reddy *et al*., 2017) assessed the combining ability of forty-five diallelic hybrids along with their parents, grown under three different environmental conditions. Analysis of variance of the data showed that variation in specific combining ability (SCA) was higher than variation in general combining ability (GCA) for all traits except 50% flowering date and fiber length. This indicates the dominance of non-additive gene action. Evaluation of GCA effects identified superior parental varieties in terms of yield and component traits in the desired direction.

It is believed that the combining ability and actions of genes can help breeders to select best parents for breeding programs (Ekinci *et al*., 2018; Nazarova *et al*., 2019).

Mammadova et al. (2021) evaluated cotton hybrids with naturally colored fiber for fiber quality traits and determined low combining ability of four parental lines with naturally colored fiber and SCA of F_1 hybrids. Unay et al. (2019) studied the effect of genes based on the use of combining ability and heterosis effect in hybridization for yield and quality traits of cotton fiber. For this purpose, 5 lines and 4 testers of the species *Gossypium hirsutum* L. were used in 20 crossing combinations. Variations in general and specific combining ability showed non-additive effects of gene action on raw cotton yield, fiber yield and fiber length. However, the additive effects of the genes were noted in fiber fineness and reflectance index. The best parental varieties with high GCA have been identified and recommended for utilization in breeding programs. Thus, the authors concluded that for traits that are characterized by non-additive gene expressions, it is desirable to carry out individual selection in later generations.

In different regions of China, 719 genotypes of world collections of *G. hirsutum* L. were assessed for two years based on five quality traits of cotton fiber. A range of phenotypic data was obtained and elite lines were further screened based on single nucleotide polymorphisms. Among different regions of China, samples from the Northern and Northwest regions generally had the highest fiber length (F_1), fiber strength (FS) and best fiber micronair (Mic.). By evaluating five fiber quality traits over 2 years using genotypic data, 31 elite germplasm were selected. These results provide useful information on possible parental genotypes with high fiber quality for cotton breeding programs (Sun *et al*., 2019).

Nazir et al. (2020) examined the effects of combining ability. For this purpose, four genotypes (MARVI, FH-458, MNH-996 and VH-3330) were crossed in a complete diallelic pattern. The analysis showed that all genotypes differed in the effects of SCA. Thus, the FH-458 genotype had the greatest effect on fiber length. MARVI was recognized as the best in fiber fineness and VH-333 and MNH-996 - based on fiber strength. F_1 hybrids of the FH-458 × FH-458 combination was characterized by high SCA effects on fiber fineness. Combinations MARVI × FH-458 and FH-458 × MARVI showed high SCA in terms of strength and hybrids FH-458 × MARVI - in terms of fiber length.

Chapara et al. (2021) evaluated heterosis based on fiber quality parameters. Nine genotypes and 20 F_1 hybrids were obtained by crossing parental genotypes in a line × tester design. Hybrid combinations namely TCH1716 × GJHV 516, BGDS1033 × HYPS152 and TCH1716 × HYPS152 were found to be promising for mid-length and

upper mid-fiber length as they showed the highest positive heterosis. In addition, hybrids of the F2423 × HYPS152 combination were found to have finer fibers and the highest heterosis. However, the hybrids TCH1716 × L766 and TCH1716 × HYPS152 turned out to be the most promising in terms of fiber strength.

Mammadova et al. (2014) evaluated hybrid combinations of geographically distant parental lines and determined high heterosis and high GCA effects in fiber strength and uniformity index. The study focused on the combinational ability of parental varieties and 46 cross combinations for fiber yield and quality traits. Analysis of variance showed significant variability in the studied fiber traits. All traits were mainly controlled by non-additive effects of genes, except for the uniformity index.

Alimov and Aytonomoy (2023) established some genetic patterns in the variability and inheritance of the qualitative trait "micronaire" in inter-varietal, geographically distant hybrids of upland cotton. As a result, it was established that the analyzed trait has a polygenic structure, which largely determines the behavior of F_1 hybrids and the nature of the variability of the above-mentioned trait is determined by the selection of parental pairs, that is, the degree of genetic contrast.

Udava et al. (2023) used 8 elite lines and 5 cotton testers (*Gossypium hirsutum* L.) for crossbreeding to determine degree of hetrosis. All 40 F_1 hybrids were analyzed for productivity traits along with fiber quality. Hybrid combinations (CPD-462 × SCS-1061, FLT-36 × SCS-1061 and CPD-462 × NNDC-30) were identified as the most promising.

The purpose of the current study was to identify the frequency of transgressive variability, providing the basis for the selection of promising parental sources for hybridization and selection of new cotton recombinants with the improved fiber traits in early generations. It was revealed that GCA is of great importance for all studied traits, which indicates the important role of additive effects of genes. The specific combining ability was important for micronair (Mic), indicating non-additive gene actions, which has dominant or epistatic effects.

2. Material and methods

This study was conducted at the Institute of Genetic Resources of the Ministry of Science and Education of Azerbaijan during 2020-2022. Field experiments were carried out in the Agdash support station. The parental varieties and diallelic hybrids were sown in 2 replicates according to the 60-30-1 scheme. The local early ripening varieties (Agdash -3, AP-317 and Elekberi) resistant to wilting disease used for hybridization as maternal lines and Turkish varieties (Sezener 76, Naz 07, Ozbek and GSN 12) characterized by high fiber quality as paternal testers. All varieties belong to the G.*hirsutum* L. specie. The study included the qualitative traits of fiber: uniformity index; fiber elongation and micronair. The quality of the fiber was determined using the HVI (High Volume Instrument) system, according to the international classification. Parental varieties were assessed by the effects of General Combining Ability (GCA) and hybrid combinations - by variations in Specific Combining Ability (SCA). For this purpose, we used the method of Griffing (1956), which involves the study of direct diallelic hybrids and parents in the following sequence:

1. The effect of the GCA of a particular parent variety was calculated by the difference between the average value of the trait of all hybrid combinations involving this variety and the overall average value of the trait for all 12 studied combinations included in the diallelic cross.

2. The SCA effect of hybrid combinations was measured by the deviation of the trait value of a particular combination from the average value of the SCA effects of the two parent varieties of this combination.

3. The SCA effect for each variety was calculated based on the average SCA value of hybrid combinations involving a specific variety. Statistical analysis of the research results was carried out according to the method of Dospehov (1985) using the Microsoft Excel 2010 software package.

3. Results and discussion

The manuscript discusses aspects of genetic control over the identification of promising parental sources and geographically distant first-generation hybrids with high quality characteristics of cotton fiber. To assess the quality traits of fiber, the common method of general combining ability (GCA) and specific combining ability (SCA) was used. One of the components of fiber quality is the Uniformity Index (UI). Cotton fiber with a low uniformity index (77-79%) is unsuitable for processing. According to international standards, 80-82% uniformity is considered average, 83-85% is high and very high is above 85%.

The results showed that the minimum fiber uniformity index among local (Azerbaijan) maternal lines (81.4±0.95%) was noted in the Agdash-3 line and the maximum (85.3±1.03%) - in lines AR-317. Table 1 shows that foreign (Turkey) pollinator testers have uniformity index values that exceed the values of local lines. Based on the data of diallelic hybrid combinations, the effects of GCA of parental varieties were evaluated. Analysis of variance revealed a high variation of the studied trait depending on the crossing combination. Thus, the hybrid combination Agdash-3 x GSN 12 showed the highest uniformity index (88.1±1.08%), while the minimum uniformity index (84.4±0.88%) was distinguished in combination Elekberi x Ozbek105. The range between these indicators, equal to 3.7%, is significant at a high level of significance. Evaluation of the uniformity index for the effects of GCA revealed that the maternal line AR-317 in crosses with all testers had high indicators and on average they exceeded the entire complex of hybrid combinations participating in the experiment with a positive (0.6) effect of GCA. Among the foreign testers, Naz 07 and GSN 12 showed high rates in cross combinations with local lines and positive effects of GCA equal to 0.8 and 1.2, respectively. Consequently, additive effects of gene interaction are involved in the formation of the uniformity index. Table 1 presents the GCA and SCA variations of fiber uniformity index of both parents and a particular combination.

It is clear from the data that the variations in SCA were generally less than the effects of GCA, so successful selection of genotypes with an improved index of fiber uniformity in F_1 is possible. The next quality trait is fiber elongation (Elongation, Elg). This component of fiber strength has the ability to increase its original length before it breaks. The elongation rate usually ranges from 7.7-9.5%. An increase in the indicator has a positive effect on the quality of the fiber in general. Therefore, studying the genetic basis of the trait is necessary. An assessment was made of the general (GCA) and specific (SCA) combining ability of parental varieties and F_1 diallelic hybrids obtained from crossing local lines with foreign pollinating tethers. From the data in Table 2 it can be seen that the lowest indicator (8.8±0.18) was noted for the hybrid combination Agdash-3 x Sezener 76 and the highest (12.1±0.33) for the combination AP-317 x GSN 12. The difference of 3.3% is significant at the 5% level.

Table 1. Fiber Uniformity Index, (UI), GCA and SCA effects of parental lines and F_1 hybrids

UI of parental lines				Cross combination (line x tester)	UI of hybrids	
Local lines (Azerbaijan)						
	X±Sx, %	Effects			X±Sx, %	Effect SCA
		GCA	SCA			
Agdash-3	81.4±0,95	-0.3	-0.14	Agdash-3 x Sezener 76	84.6±0.58	-0.4
AP-317	85.3±1.03	0.6	0.33	Agdash-3 x Naz 07	86.7±0.90	0.25
Elekberi	83.0±0.82	-0.2	-0.35	Agdash-3 x Ozbek 105	84.8±0.70	-0.85
Introduced lines, (Turkiye)				Agdash-3 x GSN 12	88.1±1.08	0.45
Sezener76	87.9±0.98	-0.5	-0.22	AP-317 x Sezener 76	86.9±0.83	0.10
Naz 07	88.3±1.00	0.8	0.42	AP-317 x Naz 07	87.7±1.12	0.7
Ozbek105	87.3 ±1.5	-1.4	-0.68	AP-317 x Ozbek105	85.6±0.80	-0.4
GSN 12	89.4±1.05	1.2	0.62	AP-317 x GSN 12	87.6±0.96	0.9
				Elekberi x Sezener 76	86.0±0.88	-0.35
				Elekberi x Naz 07	87.1±1.04	0.3
				Elekberi x Ozbek105	84.4±0.88	-0.8
				Elekberi x GSN 12	87.0±1.21	0.5
				Elekberi x Ozbek105	84.4±0,88	-0.8
				Elekberi x GSN 12	87.0±1.21	0.5

Based on the indicators of all studied hybrid combinations, the effects of GCA of parental lines were calculated. Among the local varieties, the line AR-317 when crossed with all pollinator testers, forms hybrids with high performance with a GCA effect of 0.8. Among foreign varieties, in this regard, the Naz 07 tester stands out with a GCA effect of 0.9. This indicates that the elongation of the fiber before breaking is controlled by the additive type of gene action, therefore, successful selection for improvement of the trait, starting from early generations, is obvious.

Table 2. Fiber elongation, (Elg), GCA and SCA effects of parental lines and SCA of F_1 hybrids

Fiber elongation of parental lines				Cross combination (line x tester)	Fiber elongation of F_1 hybrids	
Local lines (Azerbaijan)						
	X±Sx, %	Effects			X±Sx, %	Effect SCA
		GCA	SCA			
Agdash-3	8.4±0.09	-0.4	-0.18	Agdash-3 x Sezener 76	8.8±0.18	-0.45
AP-317	9.6±0.22	0.8	0.43	Agdash-3 x Naz 07	10.9±0.25	0.25
Elekberi	8.9±0.23	-0.3	-0.13	Agdash-3 x Ozbek 105	8.9±0.21	-0.55
Introduced lines, (Turkiye)				Agdash-3 x GSN 12	9.9±0.28	0.05
Sezener76	9.7±0.20	-0.5	-0.23	AP-317 x Sezener 76	9.9±0.20	0.15
Naz 07	11.1±0.32	0.9	0.47	AP-317 x Naz 07	11.5±0.35	0.85
Ozbek105	9.9±0.15	-0.7	-0.33	AP-317 x Ozbek105	9.8±0.25	0.05
GSN 12	11.7±0.27	0.5	0.27	AP-317 x GSN 12	12.1±0.33	0.65
				Elekberi x Sezener 76	9.8±0.23	-0.4
				Elekberi x Naz 07	10.3±0.24	0.3
				Elekberi x Ozbek105	9.2±0.20	-0.5
				Elekberi x GSN 12	9.4±0.30	0.1

The variations of SCA in hybrid combinations were generally lower than the effects of GCA, indicating the absence of heterosis.

Micronair (Mic) is also an important quality trait of cotton fiber due to its direct impact on processing and the final product. The HVI (High Volume Instrument) type measuring system provides determination of the fineness (diameter) of the fiber together with its maturity. According to the international classification, the range from 3.8 to 4.9 units is considered as basic standard. A micronair below the optimal limit indicates immaturity of the fiber and above it indicates a coarse fiber. From the calculated average values of the elite varieties, it is clear that the micronair indicators differ significantly in value (Table 3). In F_1 hybrids, micronair indices, depending on the crossing combination, vary from 4.7±0.11 in the combinations AP-317 x Naz 07 and AP-317 x GSN 12 to 5.6±0.09 in the combinations Elekberi x Ozbek105; Agdash-3 x Ozbek 105 and Agdash-3 x Sezener 76. The difference between these indicators is significant at the 1% level. The assessment of general combining ability (GCA) showed that parental lines and testers are characterized by both positive and negative GCA effects. Parental lines with positive GCA effects of uniformity index and fiber elongation considered to be positive factors, while in terms of micronair, parent varieties with negative GCA effects should be considered a positive factor.

Table 3. Micronaire effects of GCA and SCA of parental lines, SCA of F_1 hybrids

Micronaire of parental lines				Cross combination (line x tester)	Micronaire of hybrids	
Local kines (Azerbaijan)						
	X±Sx, unit	Effects			X±Sx, unit	SCA effect
		GCA	SCA			
Agdash-3	5.7±0.10	0.2	0.1	Agdash-3 x Sezener 76	5.6±0.14	0.25
AP-317	5.0±0.08	-0.2	-0.1	Agdash-3 x Naz 07	4.9±0.11	-0.05
Elekberi	5.4±0.11	0.1	0.05	Agdash-3 x Ozbek 105	5.6±0.13	0.25
Introduced lines, (Turkiye)				Agdash-3 x GSN 12	5.0±0.15	-0.05
Sezener76	5.0±0.08	0.3	0.2	AP-317 x Sezener 76	5.3±0.08	0.05
Naz 07	4.8±0.09	-0.3	-0.1	AP-317 x Naz 07	4.7±0.11	-0.25
Ozbek105	5.4±0.11	0.3	0.2	AP-317 x Ozbek105	5.0±0.1	0.05
GSN 12	4.7±0.09	-0.3	-0.1	AP-317 x GSN 12	4.7±0.13	-0.25
				Elekberi x Sezener 76	5.5±0.10	0.2
				Elekberi x Naz 07	4.9±.12	-0.1
				Elekberi x Ozbek105	5.6±0.09	0.2
				Elekberi x GSN 12	4.8±0.11	-0.1

To determine lines with micronair indicator corresponding to international standards, the selection of hybrids for study in F_2 was carried out among hybrid combinations with indicators in the range of 4.6-5.0 unit. The study of the effects of SCA revealed that the most acceptable for best micronair are hybrid combinations with the participation of foreign testers Naz 07 and GSN 12 in combination with local lines. Along with studying the GCA and of parental lines and SCA of F_1 hybrids, it was advisable to study the relationship between the effects of GCA and SCA of parental varieties for the three important traits (Tables 1-3). When comparing the data, it is clear that for each trait it is possible to identify parental lines and testers with an excess of the positive effects of GCA over the effects of SCA to varying degrees. This indicates the predominance of

additive types of gene action, therefore, selection in early generations can be effective in improving the quality traits of the fiber.

A study of three quality traits of cotton fiber using the effects of general combining ability and specific combining ability was undertaken to identify promising parental lines and testers and select F_1 hybrids with improved fiber traits. However, the feasibility of continuing the study in F_2 seemed necessary. Therefore, all geographically distant first-generation diallele hybrids and parental lines and testers were sown in duplicate. Table 4 presents the indicators of hybrid combinations with a complex of studied traits. A comparative analysis of data from the first and second generations showed that individual quality traits of the fiber of the same combination changed to varying degrees and directions.

Table 4. Fiber quality traits of evaluated cotton hybrids (F_2)

Hybrid combinations	Uniformity Index, UI, %	Elongation, Elg, %	Micronaire, Mic, unit
Agdash-3 x Sezener 76	84.6±0.58	8.8±0.18	5.4±0.14
Agdash-3 x Naz 07	86.3±0.90	9.4±0.25	5.0±0.11
Agdash-3 x Ozbek 105	84.8±0.70	8,7±0.21	5.6±0.13
Agdash-3 x GSN 12	87.1±1.08	8.3±0.28	4.9±0.15
AP-317 x Sezener 76	86.9±0.83	9.9±0.20	5.4±0.08
AP-317 x Naz 07	87.7±.,12	11,5±0.35	4.8 ±0.11
AP-317 x Ozbek105	83.6±0.80	9.7±0.25	4.9±0.15
AP-317 x GSN 12	89.6±0.96	10.15±0.33	4.8±0.13
Elekberi x Sezener 76	86.0±0.88	9.8±0.23	5.5±0.10
Elekberi x Naz 07	83.1±1.04	10.3±0.24	4.9±.12
Elekberi x Ozbek105	84.4±0.88	9.2±0.20	5.6±0.09
Elekberi x GSN 12	85.0±1.21	9.5±0.30	4.9±0.11

Hybrid combinations have been identified (AP-317 x Naz 07 and AP-317 x GSN 12), whose parents in the first generation (Tables 1-3) were characterized by the positive effects of GCA and in the second generation they were distinguished by a set of traits with high rates quality traits that correspond to the international standards. This indicates that it is possible to create hybrids with a favorable combination of traits in different generations. Hybrid combinations (Agdash-3 x Naz 07 and Elekberi x GSN 12) with optimal values of the studied characteristics, as well as combinations (Agdash-3 x GSN 12 and AP-317 x Sezener 76), were identified for one or two qualitative characteristics. Hybrids of these combinations must be subjected to the individual selection in the next generations.

4. Conclusion

The present study included geographically distant local lines and Turkish testers. The main task was to study the qualitative traits of cotton fiber according to the generally accepted effective method of assessing the general combining ability (GCA) of the parental varieties, the specific combining ability (SCA) of hybrids and the nature of gene action. The results of the study provided important information about the genetic control of the studied traits. In particular, local line (AP-317) and two foreign testers (Naz 07 and GSN 12) were identified, which had positive effects of GCA. This indicates additive types

of action of non-allelic genes responsible for the formation of the studied traits. It was established that hybrid combinations obtained from the cross of lines and testers with positive effects of GCA in the first generation, were distinguished by high indicators of the quality traits of the fiber in the next generation. Consequently, the selection of genotypes with improved fiber quality carried out in early generations will accelerate the creation of new promising cotton varieties.

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