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Cytoplasmic and Combining Ability Effects on Agro-Morphological Characters in Intra and Inter Crosses of Pima and Upland Cottons (*G.Hirsutum* and *G. Barbadense*)

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Abstract

Combining ability and heterosis were determined in a population obtained from the full diallel crossing of four different cotton genotypes (G. hirsutum and G. barbadense) for agro morphological traits and yield. High variation was observed for characteristics among parents and the F1 combinations. So, selection could be done for improved yield, yield components and agro morphological traits. Barbadense 5539 and Termeze14 (G. barbadense) had positive GCA for height, bolls/plant and sympodia branch/plant, Inverse, Sahel and Sepid (G. hirsutum) had negative GCA for these characteristics. G. barbadense genotypes showed negative GCA for monopodia branch/plant, sympodia branch length and boll weight, Inverse, G. hirsutm genotypes was observed positive GCA for this traits. The GCA: SCA ratios for the studied traits were higher than one indicating the presence of additive genetic effects for most of the characteristics studied, except for sympodia branch length.

Keywords: Cotton, General combining ability (GCA), Specific combining ability (SCA), Intra and Inter specific crosses, Maternal effects

1. Introduction

Cotton (Gossypium spp) the worlds' most important natural source of fiber is comprised of about 50 diploid and tetraploid species. Commercial cotton fiber is produced from only four species: two diploids G. arboretum L. (n=13, A2A2) and G. herbaceum L. (n=13, A1A1) and two tetraploids G. barbadense (n=26, AAD2D2 genome) and G. hirsutum L. (n=26, AAD1D1 genome (Vafaie-tabar et al. 2004).

Upland cotton, *G. hirsutum*, dominates the worlds' cotton fiber production, representing 90% of the production. Compared with the upland cotton, the second most cultivated species, *G. barbadense*, has superior fiber length, strength, and fineness. *G. hirsutum* varieties, however, are usually early- maturing and higher yielding (Lacape et al.2005).

Upland cotton (*Gossypium hirsutum* L) is the most extensively cultivated of the four cultivated Gossypium species, and, as such, it has been the target of numerous genetic studies and breeding efforts. The level of genetic diversity is low in *G. hirsutum*, especially among agriculturally elite types, as revealed by all means of assessment (Gutiefrrez et al. 2002; Ulloa and Meredith 2000; wendel et al. 1989).

Gossypium barbadense (L.) is the only 52- chromosome relative of upland cotton (*G. hirsutum*, 2n=52) that is cultivated. It is valued for its fiber length and quality, whereas upland cotton is more valuated for its high yield (Saha et al. 2006).

Most genetic traits useful for cotton improvement are influenced by several genes. These are called quantitatively inherited traits (Shappley et al., 1998). The identification and characterization of genes controlling traits of use in plant improvement has long been a focus of scientists in the agricultural community. Cotton is the most important textile fiber crop and the worlds' second-most important oil-seed crop after soybean (Poehlman and Sleper, 1995). It is grown commercially in the temperate and tropical region of more than 50 countries, including the United States, India, China, central and South America, The Middle East, and Australia (Fryxell, 1979; Smith, 1999).

Increasing diversity is therefore essential to genetic improvement efforts. Each of the three major approaches to increasing genetic diversity (mutagenesis, germplasm introgression, and transformation) has advantages and disadvantages. Interspecific germplasm introgression is particularly attractive in that it utilizes abroad germplasm base, can be targeted to one or more specific traits or genes or modulated to include thousands of genes or even entire genomes. However, the biological and technical challenges of introgression increase as the phyletic distance between the donor and recipient genome increases (Saha et al. 2006).

Diallel crossing technique in cotton has been used by cotton breeders. Baloch et al. (1995) revealed the importance of specific combining ability for yield, 100- seed weight and lint percentage, and general combining ability for boll number per plant and lint percentage. Wilson (1991): Tang et al.(1993) and Nadeem et al. (1998) reported significant general and specific combining ability effects for lint yield, lint percentage, seed cotton weight per boll and boll number per plant.

Hybrid vigor in cotton has been observed in interspecific crosses as well as in crosses between varieties within the species. Fryxell et al. (1958), Hutchinson et al. (1938), Marani (1967), Stroman (1961), and Ware (1931) in particular showed that crosses between *G. barbadense* and *G. hirsutum* were much more productive than either parent. Because of the differences in the characteristics of the lint of the two species, it frequently has objectionable qualities in the hybrid. This problem is less likely to arise in intraspecific hybrids where considerable hybrid vigor has also been shown.

In a molecular analysis of *G. hirsutum* introgression into Pima (*G. barbadense*) cotton, 7.3% of the alleles of Pima cultivars were found to be derived from *G. hirsutum* (Wang et al., 1995). These alleles were not randomly distributed within the *G. barbadense* genome, since nearly 60% of the total introgression was found within five specific chromosomal regions accounting for less than 10% of the genome.

Transfer of reniform nematode resistance from *G. Longicalyx* into *G. hirsutum* requires introgression of genes from the unique diploid F genome of *G. Longicaly*x into either the A or D sub genome of allotetraploid *G. hirsutum*. As bridges, two synthetic tetraploid triple species hybrids, referred to as HLA and HHL, were developed (Bell and Robinson, 2004). Robinson et al. (2007) was studied two trispecies hybrids of *G. hirsutum*, *G. longicaly*x and either *G. armourianum Kearney* or *G. herbaceum* L. to introgress high resistance to the nematode from *G. Longicaly*x into *G. hirsutum*. Introgression was pursued from 28 resistant BC1 plants, each of which was backcrossed four to seven times to G. hirsutum to derive agronomically suitable types.

The objective of this study was to estimate parental general combining ability effects, to compare performance among F1 hybrids, and to identify those superior for yield and agro morphological traits.

2. Material and Method

During the summer of 2005, four different cotton genotypes, Thermez 14 (line 2) and barbadense 5539 (line 18) of G. barbadense species, Sepid (line 22) and Sahel (line 13) of G. hirsutum species, were crossed to produce F1 seeds. These genotypes display a continuous spectrum of morphological traits between the two parental species (Ulloa et al., 2000). Parents and F1 seed was planted in the spring of 2006. Four parents and 12 hybrids were planted in randomized complete blocks. Plots consisted of four, 10m- long row with 80 cm apart. Soil was a silt- loam. Plant density was about 33000 plants ha-1. Weed control, irrigation, and insect control were standard practices for production of cotton in the Hashemabad cotton research station, Gorgan, Iran. Boll weight was determined from 20 hand-harvested bolls, just prior to first harvest from each plot. Seed cotton yield was determined by hand harvest. Plant height was measured from ground level to the top of the plant at harvest time. Monopodia and sympodia branch length, monopodia and sympodia branches/plant was measured prior to first harvest.

The data for each measurement was tabulated and analyzed by Fisher's analysis of variance. The diallel analysis was used to evaluate traits that had significant variation among the parents. Griffing-type diallel analysis was applied to estimate the GCA and SCA effects.

3. Results

Preliminary analysis of variance indicated that parents and their hybrids were significantly different from each other for all investigated traits in the study, which enable the diallel analysis to be run (Table 1).

3.1 Female parents different

The four parents used in this study varied significantly for each components and agro morphological traits except for sympodia and monopodia branch length (Table 2). Termeze 14 had the highest values in height characters. About boll/plant, barbadense 5539 and Termeze 14 had the highest value. The maximum monopodia branch number/plant was for Sahel and Sepid cultivars. Termeze 14 and barbadense 5539 had the highest values in sympodia branch/plant. The monopodia and sympodia branch length were not significantly difference in female parents. Sahel and Sepid (G. *hirsutum* spesies) had the weightiest boll. These, also, had the highest values for yield.

3.2 Male parent's difference

The genotypes used for male parents were significantly different for each yield components and agro morphological traits except for boll/plant and boll weight characters. Barbadense 5539 had the highest value for height. *G. hirsutum* species, Sahel and Sepid, had the maximum monopodia branch/ plant and minimum sympodia branch/plant. The highest sympodia branch length was for Sahel cultivar. Barbadense 5539 had the lowest monopodia branch length. Sepid had the highest value for seed cotton yield.

3.3 F1 performance

The data in Table 3 were significantly difference for each yield components and agro morphological traits for F1 hybrids used in this study. Sahel×barbadense 5539 hybrid had the highest value for height (170 Cm). Sahel×Sahel had the lowest height (114 Cm). Bolls/plant were significantly different among the genotypes, where barbadense 5539×Sahel (37.5), barbadense 5539×Termeze 14 (38.3), Termeze 14×barbadense 5539 (35.4) and Termeze 14×Termeze 14 (35.1) crosses had many bolls, while Sahel×Sepid (19.13) hybrid had significantly lower numbers of boll/plant. Among the crosses, Sepid×Sepid had the highest values for monopodia branch number/plant, also, Sahel×barbadense 5539 (20.1), barbadense 5539×barbadense5539 (19.8), barbadense 5539×Termeze 14 (19.7) and Termeze 14×barbadense 5539 (20.1) crosses had the highest sympodia branch number/plant. Sympodia branch length in Termeze 14*Sahel crosses was the highest (62.9 Cm). Sahel×Termeze 14 (98.5 Cm) and Termeze 14×Sahel (102.7 Cm) had the highest value for monopodia branch length. Sahel×Sepid (128.0 gr) and Sepid×Sahel (133.1 gr) crosses had the weightiest boll and Termeze 14×Sepid crosses had the lowest boll. Sepid×Sahel crosses had the highest yield/plot (4977 gr) and Termeze 14×Sahel had the lowest yield/plot (2195 gr).

3.4 Agro morphological GCA and SCA

Analysis of variance for genotypes indicated the presence of significant differences among genotypes (Table 4). Combining ability mean squares for the characteristics are presented in Table 4. Significant GCA mean squares for yield components, height, bolls/plant, monopodia branches/plant, sympodia branches/plant, monopodia and sympodia branch length, boll weight and seed cotton yield indicated that additive genes controlled most of the characteristics. GCA mean square values were higher compared to the mean squares for SCA except for sympodia branch length (Table 4).

Results for GCA effects are given in Table 6. Sahel had negative GCA effects for height, bolls/plant, sympodia branches/plant and yield. Sahel, known to have big bolls, had positive and significant GCA effects for boll weight, monopodia branches/plant, sympodia and monopodia branch length. GCA effects for barbadense 5539 on height, bolls/plant and sympodia branches/plant were positive. GCA effects for sympodia branches/plant, sympodia and monopodia branch length, boll weight and yield were negative at Hashemabad research station (Table 6). The GCA effect for Sepid cultivar was positive for monopodia branches/plant, sympodia and monopodia branch length, boll weight and yield. Negative GCA effects were observed for bolls/plant, height, sympodia branches/plant. Positive GCA effects were shown by Termeze 14 genotype for height, bolls/plant, sympodia branches/plant and monopodia branch length while the values for monopodia branches/plant, sympodia branch length, boll weight and yield were negative.

SCA effect estimates for height, bolls/plant, sympodia branches/plant, monopodia branches/plant, sympodia branch length, monopodia branch length, boll weight and yield are presented in Table 7. SCA effects for some characteristics indicated variation among F1 hybrids. For height, three combinations had positive SCA effects. Four combinations had positive SCA effect for bolls/plant, sympodia branches/plant, sympodia and monopodia branch length. For monopodia branches/plant, five combinations had positive SCA effects. Sahel×Sahel, Sahel×Sepid, barbadense 5539×barbadense 5539, barbadense 5539×Termeze14 and Termeze14×Termeze14 had positive SCA effects for boll weight. Sahel×Sahel, Sahel×barbadense5539, Sahel×Sepid, Sahel×Termeze14, barbadense5539*barbadense5539, barbadense5539×Sepid had the positive SCA effects for seed cotton yield (Table 7).

3.5 Cytoplasmic effects

Results for cytoplasmic effects are given in Table 8. Sahel×barbadense 5539 and barbadense 5539×Sepid combinations had positive effect. For height, positive maternal effect was showed at barbadense5539×Sepid crosses. Barbadense5539×Termeze 14 combinations had positive maternal effect for bolls/plant. Maternal effect was positive for monopodia branches/plant at barbadense5539×Termeze14 crosses. About sympodia branches/plant Sahel×barbadense5539, barbadense5539×Sepid and Sepid×Termeze14 had positive maternal effects. Positive cytoplasmic effects were observed for sympodia branch length at barbadense5539×Sepid crosses. The observed maternal effect for boll weight, Sahel×Termeze14 and barbadense5539×Termeze14 combinations were positive. For seed cotton yield, Sahel×barbadense5539 and Sahel×Termeze14 had the positive cytoplasmic effect (Table 8).

3.6 Heterosis estimates

Heterosis values for the combination varied from negative to positive (Table 5). Height heterosis was positive for all of the combinations. Sahel×Termeze14 had high positive heterosis. Heterosis values for bolls/plant were positive for most of the combinations except for Sahel×Sepid and Sahel×Termeze14, and Sahel×barbadense5539 combination had the highest heterosis (6.83). The heterosis value for monopodia branches/plant for all combinations except for Sahel×Termeze14 was negative. Heterosis estimates recorded on combinations for sympodia branches/plant varied from negative to positive. Sahel×barbadense 5539 had the highest heterosis value, Also Sahel×Termeze14 had the highest heterosis value for sympodia and monopodia branch length, When *G. hirsutum* and *G. barbadense* species were crossed, heterosis was positive. In this study, Sahel×Sepid had the maximum heterosis for boll weight. Heterosis values for seed cotton yield were positive for most of the combinations, except for Sahel×Termeze14 and Sahel×barbadense5539. The high heterosis value were obtained in Sahel×Sepid (345.83, G. *hirsutum*×*G. hirsutum*) and Sepid×Termzeze14 (758.33, *G. hirsutum*×*G. barbadense*).

4. Discussion

High variation was observed for characteristics among parents and the F1 combinations. So, selection could be done for improved yield, yield components and agro morphological traits. GCA values obtained for Sahel, barbadense5539, Sepid and Termeze14 indicated the possibility of good combining from these parents for the some traits. Barbadense5539 and Termzeze14 (*G. barbadense*) had positive GCA for height, bolls/plant and sympodia branches/plant, inverse Sahel and sepid (*G. hirsutum*) had negative GCA for these characteristics. *G. barbadense* genotypes were showed negative GCA effect for monopodia branches/plant, sympodia branch length and boll weight, inverse *G. hirsutum* genotypes were observed positive GCA for these traits. Positive GCA for yield was observed only in Sepid. Positive SCA effects observed for same crosses. Sahel×barbadense5539 crosses had the highest positive SCA for bolls/plant. Highest positive SCA was observed for boll weight in Sahel×Sepid. In Sahel×Sahel, highest positive SCA was showed for yield.

Significant SCA mean squares observed for boll weight was reported by Echekwu and Alaba (1995). The performance of some combinations indicated the possibility of improvement of these traits. Griffing (1956) and Machado et al. (2002) reported that crosses with high SCA values from parents with highest SCA in a population should be efficient in selection in segregation population. The high and significant positive GCA were observed in crosses for seed cotton yield, lint yield, seed/boll, bolls/plant and boll weight (Lukonge, 2005).

The GCA:SCA ratios for the studied traits were higher than one indicating the presence of additive genetic effects for most of the characteristics studied except for sympodia branch length. According to Ashraf and Ahmad (2000), high additive genetic variation for these characteristics suggested a possibility of improvement in these characteristics. Therefore normal recurrent selection would be required to accumulate the additive genes in order to increase seed cotton yield (Lukonge, 2005).

Positive heterosis for height was observed for all of combinations. Positive heterosis for boll weight was showed in Sahel×Sepid, barbadense5539×Sepid and Sepid×Termeze14. Sambamurthy et al. (1995) reported that in tetraploid cotton, boll weight and boll number for intraspecific hybrids are the major components of heterosis in yield and this usually observed in *G. hirsutum* crosses and not for *G. barbadense*. The highest positive heterosis for yield was observed in Sepid×Termeze14 and Sahel×Sepid. Xian et al. (1995) and Zhang and Zhang (1997) reported high heterosis for seed cotton and lint yield. Sahel×barbadense5539 had the highest reciprocal effects for height and yield. For bolls/plant, barbadense5539×Sepid had the high positive reciprocal effects. High positive reciprocal effects for boll weight was showed in Sahel×Termeze14.

Gossypium hirsutum and *G. barbadense* differ significantly in their agronomic and fiber traits (Percey et al, 2006).*G. hirsutum* had the higher yield potential and *G. barbadense* had the best fiber quality. Interspecific hybridization and introgression, *G. hirsutum* and *G. barbadense*, has led to improve lines with the higher yield and the best fiber qualities. Efforts to improve *G. hirsutum* or *G. barbadense* through introgression have been hindered by genetic breakdown in segregating interspecific breeding populations (Stephens, 1949). Genetically stable lines have been developed after multiple cycles of breeding and selection (Tatineni et al., 1996; Cantrell and Davis, 1993). We consider commercial interspecific hybrids (F1) to cultivate in cotton farms in different region of Iran. We hope to improve and develop stable lines of interspecific crosses (*Gossypium hirsutum* and *G. barbadense*) and intraspecific crosses (*G. hirsutum* × *G. hirsutum*, and *G. barbadense*× *G. barbadense*) after lengthy cycles of selection.

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Table 1. Mean squares of yield components and agro morphological traits

source	Degrees of freedom	height	Bolls /plant	Monopodia Branches/ plant	Sympodia branches/ plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Replication	2	347.781 ns	16.101 ns	1.061ns	0.503ns	83.341ns	1595.236ns	780.667 ns	1964756.438**
Female	3	1028.921**	447.130 **	3.096*	19.683**	8.430ns	618.349ns	4979.304 **	3736243.583**
Male	3	941.856 **	44.601 ns	15.149**	24.987**	126.701*	3207.435**	882.517 ns	634808.694ns
Female* male	9	712.598 **	31.606 ns	0.511ns	4.242ns	881.942**	1079.927ns	1933.988 **	1779542.713**
Error	30	184.258	29.541	0.739	3.242	28.202	537.399	507.764	250667.638

**: significant at 0.01 level, *: significant at 0.05 level and ns: non significant

Table 2. Means of yield components and agro morphological traits for female and male parents

	height	Bolls/plant	Monopodia Branches/plant	Sympodia branches/plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Female								
Sahel	137.08bc	24.33b	2.417a	16.42b	43.37a	69.98a	90.04a	3482b
Barbadense5539	147.28ab	35.73a	1.433b	19.08a	41.92a	58.28a	58.64b	3215b
Sepid	129.97c	24.38b	2.583a	16.70b	41.40a	74.20a	99.25a	4359a
Termeze 14	149.98a	33.98a	2.100ab	18.32a	42.03a	72.47a	61.41b	3147b
Male								
Sahel	136.25b	28.32a	3.000a	16.47b	46.37a	78.98a	85.29a	3497ab
Barbadense5539	153.37a	31.00a	0.817	19.37a	39.53b	45.08b	65.41a	3498ab
Sepid	133.27b	27.62a	3.133a	16.42b	43.13ab	80.32a	81.22a	3876a
Termeze 14	141.43b	31.50a	1.583b	18.27a	39.68b	70.55a	77.42a	3333b

* Means within columns followed by the same letter(s) are not different at 0.05 probability level

Table 3. Means of yield components and agro morphological traits for hybrid combinations

	height	Bolls/plant	Monopodia Branches/plant	Sympodia branches/plant	Sympodia branch length	Monopodial branch length	Boll weight	yield
Sahel×Sahel	114.0g	22.5cde	2.933abc	14.7cd	32.3d	67.0abcde	101.2ab	4440ab
Sahel× Barbadense5539	170.6a	31.5abcd	0.933defg	20.1a	53.2abc	51.7bcde	58.6bcd	2960efgh
Sahel× Sepid	115.1fg	19.1e	3.400ab	13.8d	31.8d	62.7abcde	128.0a	4205abc
Sahel× Termeze14	148.7abcd	24.1bcde	2.400abcd	17.1abcd	56.1abc	98.5a	72.3bcd	2325gh
Barbadense5539× Sahel	144.5abcde	37.5a	2.267bcde	18.4ab	57.6ab	65.0abcde	45.5cd	2378fgh
Barbadense5539× Barbadense5539	151.9abcd	32.9abc	0.733efg	19.8a	25.3d	44.7cde	43.0cd	3260cdef
Barbadense5539× Sepid	146.2abcd	34.3ab	2.133bcdef	18.4ab	59.9ab	85.7abc	65.2bcd	3630bcde
Barbadense5539× Termeze14	146.5abcd	38.3a	0.600fg	19.7a	24.9d	37.7de	80.9bc	3592bcde
Sepid× Sahel	125.7defg	22.3de	3.533ab	15.5bcd	32.7d	81.2abcd	133.1a	4977a
Sepid× Barbadense5539	133.8cdefg	24.2bcde	1.133defg	17.5abc	52.8bc	58.5abcde	80.8bc	4132abc
Sepid×Sepid	120.3efg	22.6cde	4.000a	15.3bcd	33.3d	81.5abcd	97.8ab	4050abcd
Sepid×Termeze14	140.0bcdef	28.5abcde	1.667cdefg	18.5ab	46.9c	75.6abcd	85.3bc	4278ab
Termeze14× Sahel	160.7ab	30.9abcd	3.267abc	17.3abc	62.9a	102.7a	61.4bcd	2195h
Termeze14× Barbadense5539	157.2abc	35.4a	0.467g	20.1ab	26.9d	25.5e	79.2bc	3638bcde
Termeze14× Sepid	151.5abcd	34.5ab	3.000abc	18.2ab	47.6c	91.3ab	33.9d	3618bcde
Termeze14×Termeze14	130.5defg	35.1a	1.667cdefg	17.7abc	30.8d	70.4abcd	71.2bcd	3137defg

* Means within columns followed by the same letter(s) are not different at 0.05 probability level

Table 4. Mean squares for yield and agro morphological GCA, SCA and GCA: SCA ratio for cotton genotypes

source	d.f.	height	Bolls/plant	Monopodia Branches /plant	Sympodia branches/plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Rep	2	347.781ns	16.101ns	1.061ns	0.466ns	83.341ns	1595.236ns	71.183ns	2.956e+006**
genotypes	15	821.714**	117.310**	3.956**	11.464**	556.192**	1413.113*	1451.711**	1.918e+006**
GCA	3	1727.389**	381.946**	15.664**	44.465**	88.716*	3233.130**	3469.292**	3.663e+006**
SCA	6	856.122**	42.899ns	0.721ns	4.802ns	1316.205**	1497.564*	1778.966**	2.726e+006**
Recip	6	334.469ns	59.403ns	1.336ns	1.627ns	29.916ns	418.653**	115.666ns	238401.389ns
Error	30	184.258	29.541	0.739	3.373	28.202	537.399	220.758	241021.840
GCA: SCA		2.02	8.9	21.7	9.2	0.07	2.2	2	1.3

GCA= General combining ability, SCA= Specific combining ability, df= degree of freedom

Table 5. Mean mid-parent heterosis for yield and agro morphological traits

Female	male	height	Bolls /plant	Monopodia Branches /plant	Sympodia Branches /plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Sahel	Barbadense 5539	24.63	6.83	-0.23	2.0	26.60	2.53	-23.17	-1207.50
Sahel	Sepid	3.23	-1.87	0	-0.33	-0.57	-2.30	31.07	345.83
Sahel	Termeze14	32.43	-1.30	0.53	1.03	27.93	31.90	-19.37	-1528.33
Barbadense 5539	Sepid	3.90	1.50	-0.73	0.43	27.07	9.00	-10.65	36.67
Barbadense 5539	Termeze14	10.67	2.87	-0.67	1.17	-2.13	-25.93	9.72	227.50
Sepid	Termeze14	20.30	2.60	-0.50	1.87	15.20	7.47	2.92	758.33

Table 6. General combining ability (GCA) effects of yield and agro morphological traits

Genotypes	height	Bolls/plant	Monopodia Branches/plant	Sympodia branches/plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Sahel	-4.41	-3.28	0.58	-1.19	2.69	5.75	6.47	-114.69
Barbadense5539	9.25	3.76	-1.01	1.60	-1.45	-17.05	-12.52	-153.85
Sepid	-9.46	-3.61	0.72	-1.07	0.09	8.52	13.44	573.02
Termeze 14	4.63	3.1	-0.29	0.65	-1.32	2.78	-7.38	-304.48

Table 7. Specific combining ability (SCA) effects for yield and agro morphological traits

Female	Male	height	Bolls/plant	Monopodia Branches/plant	Sympodia branches/plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Sahel	Sahel	-18.25	-0.51	-0.35	-0.58	-15.22	-13.23	4.55	1024.06
Sahel	Barbadense5539	11.65	4.45	-0.10	1.20	11.99	0.93	-15.46	487.19
Sahel	Sepid	-6.80	-2.02	0.03	-0.73	-12.72	-11.04	26.91	437.81
Sahel	Termeze 14	13.40	-1.92	0.42	0.11	15.95	23.34	-16.00	428.02
Barbadense5539	Barbadense5539	-7.70	-4.26	0.62	-1.03	-14.00	10.03	10.87	300.73
Barbadense5539	Sepid	-0.86	-0.52	-0.22	-0.19	15.52	11.89	-11.64	100.31
Barbadense5539	Termeze 14	-3.09	0.33	-0.30	0.02	-13.50	-22.86	16.24	-183.64
Sepid	Sepid	-1.82	0.21	0.42	-0.21	-9.09	-4.25	-12.85	-545.10
Sepid	Termeze 14	9.49	2.33	-0.23	1.13	6.29	3.40	-2.42	-741.35
Termeze 14	Termeze 14	-19.80	-0.74	0.12	-1.26	-8.74	-3.88	2.18	-966.14

Table 8. Reciprocal effects for yield and agro morphological traits

Female	male	height	Bolls /plant	Monopodia Branches /plant	Sympodia branches /plant	Sympodia branch length	Monopodia branch length	Boll weight	yield
Sahel	Barbadense5539	13.03	-3.00	-0.67	0.83	-2.20	-6.63	-3.63	128.33
Sahel	Sepid	-5.33	-1.6	-0.07	-0.83	-0.43	-9.23	-2.53	-385.85
Sahel	Termeze 14	-6.03	-3.40	-0.43	-0.07	-3.37	-2.13	5.47	65.00
Barbadense5539	Sepid	6.20	5.03	0.50	0.43	3.53	13.63	-7.82	-250.83
Barbadense5539	Termeze 14	-5.33	1.43	0.07	-0.17	-0.97	6.13	0.85	-23.33
Sepid	Termeze 14	-5.73	-3.00	-0.67	0.13	-0.37	-7.83	-2.08	-73.33