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LINE X TESTER ANALYSIS FOR YIELD AND FIBER QUALITY IN COTTON (*Gossypium hirsutum* L.)

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ABSTRACT

This experiment was conducted in order to estimate gene action, combining ability and heterotic effects for yield and quality characters by the line x tester analysis, involving 5 lines and 4 testers with 20 crosses in cotton (*Gossypium hirsutum* L.). The ratio of general and specific ability variance revealed non-additive gene action effects for seed cotton yield, fiber length, fiber strength and ginning percentage and additive gene action for fiber fineness and reflectance degree. Claudia, Gloria and Bali 308 with high general combining ability were the best combiner parents and could be used for breeding multi-parent combinations. ST-468 x Claudia, Carisma x Carmen, Bali 308 x Gloria and Bali 308 x Claudia were promising combinations for further selection. Heterosis and heterobeltiosis values of most cross combinations for seed cotton yield, fiber strength and ginning percentage were negative direct. It was concluded that due to non-additive gene actions, it is advisable to select individual plants for seed cotton yield, ginning percentage and fiber traits in later generations (F_4-F_6).

Key words: Combining ability, cotton, fiber quality, gene action, heterosis, yield

INTRODUCTION

The primary objectives of a cotton breeding are high yield and suitable fiber quality parameters. The information on heritability, combining ability and heterotic effects for yield and yield components, quality parameters directs to suitable parents and promising cross combination in a breeding programme. It was revealed that parents and cross combinations should be selected by their combining ability and gene action according to the efficacy of phenotypic performance. The line x tester analysis is one of the most important statistic-genetic methods which provides available knowledge about general and specific combining abilities of parents (GCA) and crosses (SCA) (Usharani et al., 2016). The number of evaluated genotypes using line x tester method is more than those of diallel analysis, scaling test etc.

The most important economic character, lint yield, is a product of seed cotton yield and ginning percentage. The color grade of cotton is determined by reflectance degree (Rd) and yellowness (+b), and reflectance degree indicates the more stable quantitative behavior than yellowness (Greveniotis et al., 2018). The ratio of σ^2GCA / σ^2SCA could be useful in order to estimate the behavior of a segregating generation. Many researchers reported that seed cotton yield, fiber length, fiber strength and ginning percentage controlled by non-additive gene effect (Khokhar et al., 2018; Munir et al., 2018; Patil et al., 2018). Therefore, selection for improvement should be delayed to late generations (F_4-F_6). Reflectance degree exhibited moderate heritability estimates (Amanu, 2018).

Heterosis is to estimate the performance of an F_1, produced by the crossing of two varieties or pure lines but the use of heterosis in cotton has not yet reached the successive level. In conventional breeding programmes, heterotic effects are used to determine the dominance or/and epistatic variance and the promising cross combinations. Zerihun et al. (2004), Lingaraja et al. (2017), Coban and Unay (2017) and Adsare et al. (2017) reported the moderately high and positive heterosis values for seed cotton yield whereas mostly low and negative values for ginning percentage and fiber quality parameters were determined by Dhamayanthi (2011).

The present study was aimed to evaluate gene action, combining ability and heterotic effects of yield and fiber quality characters in cotton consisting of five lines and four testers. Especially, there is little information on genetic-statistics parameters of reflectance degree of fiber. The parents use as the tester in our study, Claudia, Gloria, Julia and Carmen, are prominent cotton varieties in terms of reflectance degree of cotton fiber.

MATERIALS AND METHODS

This research was conducted at the experimental area of Soke Oil Company, Aydın/Turkey during 2013 and 2014 growing years. The experimental material consists of five lines viz., Lider, ST-468, Carisma, Flash and Bali 308, and four testers; Gloria, Claudia, Julia and Carmen were crossed in line × tester mating design to produce twenty F_1 crosses. Parents and their crosses were grown in randomized complete block design with three replications. All the cultural managements such as plant density, sowing date, fertilization and irrigation were applied as recommended for the cotton growing of Aegean Region. Seed cotton yield (SCY; kg ha^{-1}), fiber fineness (FF; mic.), fiber length (FL; mm), fiber strength (FS; g tex^{-1}) and ginning percentage (GP; %) and reflectance degree of fiber (Rd) were recorded.

The variance analysis of line x tester suggested by Singh and Chaudhary (1979) were estimated using Microsoft Excel. Combining ability effects, heterosis and heterobeltiosis were computed for each characteristic.The critical values (CD) for the significance of the heterosis (Ht) and heterobeltiosis (Hb) was tested by following standard errors.

CD for Ht at 5% and 1%= (3Mean square of error/ $2r)^{1/2}$ x $t_{(0.05)}$ and $t_{(0.01)}$

CD for Hb at 5% and 1%= (2Mean square of error/ $r)^{1/2}$ x $t_{(0.05)}$ and $t_{(0.01)}$

RESULTS AND DISCUSSION

Line x Tester Analysis and ratios of σ^2GCA / σ^2SCA

Analysis of variance showed that genotypic differences were significant for the characters (Table 1). Also, significant differences among parents and crosses indicated the presence of genetic diversity for all characters. The mean squares of parent versus crosses were significant for SCY, FF, FL and Rd. The differences between the overall mean of parents and their crosses indicate that crosses have advantages for FF, FL and Rd whereas parents have higher values for SCY. The interaction of line x tester was significant for all characteristics except FF.

Table 1. Analysis of variance for combining effects of different cotton characters.

Source	df	SCY		FF		FL		FS		Rd		GP	
Replications	2	2741.18		0.03		0.25		0.90		1.49		0.07	
Genotypes	29	31963.96	**	4.18	**	2.49	**	7.11	**	12.17	**	6.56	**
Parents	8	34170.25	**	5.81	**	2.91	**	19.20	**	5.32	**	3.65	**
Crosses	19	33352.03	**	2.76	**	2.15	**	2.63	**	12.65	**	8.48	**
P versus C	1	19904.15	**	22.22	**	8.14	**	2.62		70.09	**	0.05	
Lines	4	61877.42	**	7.10	**	4.32	**	1.64		43.11	**	4.92	**
Testers	3	54905.75	**	3.04	**	2.85	**	3.46	**	4.19	**	17.00	**
Line x Tester	12	18455.14	**	1.25		1.25	**	2.76	**	4.61	**	7.64	**
Error	58	3439.70		0.43		0.26		1.19		1.32		0.28	
GCA/SCA		0.72		1.79		0.78		-0.18		2.93		-0.09	

*, **; significant at 1% and 5% probability level, respectively.

High GCA to SCA variance ratio indicated preponderance of additive gene action. The additive gene actions for FF and Rd; non-additive gene actions (dominant or epistasis) for SCY, FL, FS and GP were estimated. The variance ratio of GCA to SCA below 1 (0.72) indicates the role of non-additive gene action for the inheritance of SCY. Similar results were reported by Kaleem et al. (2016), Shakeel et al. (2016), Khokhar et al. (2018), Komala et al. (2018), Patil et al. (2018), Prakash et al. (2018) and Roy et al. (2018).

Also, non-additive gene effects for FL, FS and GP were predominant according to variance ratio of GCA to SCA with below 1. Our findings were in accordance with Khokhar et al. (2018); Munir et al. (2018); Patil et al. (2018). But Prakash et al. (2018) revealed that these characteristics were controlled by additive gene effects.

In our study, variance ratio values of GCA to SCA for FF and Rd were determined as 1.79 and 2.93, respectively. It was shown that FF and Rd were managed largely by additive gene effects. Our results were similar to Prakash et al. (2018) but Munir et al. (2018) and Patil et al. (2018) were found non-additive gene effects for FF. This contradiction may be due to genotypic material and different mating design.

GCA and SCA effects

Significant GCA effects were detected for yield components, SCY and all fiber quality characteristics (Table 2). Among the parents Bali 308, Claudia and Carmen exhibited significant positive GCA effects for SCY. However, Lider, ST-468 and Julia were significant negative GCA effects for SCY. For FF, Lider would be promising to develop thinner fiber progenies. GCA effects of other parents and SCA effects of all crosses were non-significant in terms of FF. Bali 308, Flash and Carmen with positive and significant GCA effects contributed to the increase in FL in their combinations which crossed with. Carmen was the best combiner for FS because of its significant and positive GCA effects. Bali 308, Flash and Gloria for Rd; Claudia and ST-468 for GP had significant and positive GCA effects.

Table 2. GCA and SCA effects of observed characters.

	SCY	FF	FL	FS	Rd	GP
Lines						
Lider	-53.75**	-0.35*	-0.40**	-0.16	-0.60*	-0.78**
ST-468	-54.75**	0.08	-0.31**	0.25	-2.13**	0.26*
Carisma	-9.42	0.24	-0.56**	0.50	-1.12**	0.83**
Flash	-3.08	0.18	0.42**	-0.15	1.29**	0.17
Bali 308	121.00**	-0.15	0.84**	-0.16	2.56**	-0.50**
Tester						
Gloria	24.72	-0.11	0.02	-0.43	0.50*	-0.31**
Claudia	34.32*	0.19	0.17	0.05	0.05	1.55**
Julia	-90.55**	-0.11	-0.61**	-0.27	-0.74**	-0.76**
Carmen	31.52*	0.03	0.42**	0.65*	0.19	-0.48**
Crosses						
Lider x Gloria	129.28**	0.22	0.01	-0.52	2.84**	-0.31
Lider x Claudia	-82.32**	0.16	0.25	-0.27	-1.24*	0.46
Lider x Julia	-65.78*	-0.41	-0.38	-0.78	-0.38	0.57*
Lider x Carmen	18.82	0.03	0.12	1.56**	-1.22*	-0.71**
ST-468 x Gloria	-55.05	-0.14	-0.57*	-0.86	-0.86	-0.30
ST-468 x Claudia	71.02*	0.19	0.38	0.66	0.99	0.74**
ST-468 x Julia	-1.78	0.09	0.16	0.55	-1.05	0.09
ST-468 x Carmen	-14.18	-0.14	0.03	-0.35	0.92	-0.53*
Carisma x Gloria	-42.38	-0.07	-0.39	-0.47	-0.60	1.29**
Carisma x Claudia	86.35**	-0.28	-0.65*	-0.52	-0.35	-3.61**
Carisma x Julia	-70.78*	0.26	-0.15	0.47	0.38	-0.53*
Carisma x Carmen	26.82	0.08	1.19**	0.51	0.58	2.86**
Flash x Gloria	-60.72*	0.05	0.62*	0.35	-1.21*	0.14
Flash x Claudia	-29.65	-0.07	0.42	0.83	0.37	0.81**
Flash x Julia	117.22**	0.03	0.10	-0.24	0.90	0.05
Flash x Carmen	-26.85	-0.02	-1.15**	-0.94	-0.07	-1.00**
Bali 308 x Gloria	28.87	-0.06	0.32	1.49**	-0.18	-0.82**
Bali 308 x Claudia	-45.40	-0.01	-0.40	-0.70	0.23	1.61**
Bali 308 x Julia	21.13	0.02	0.27	-0.01	0.16	-0.17
Bali 308 x Carmen	-4.60	0.05	-0.19	-0.80	-0.21	-0.62*

*, **; significant at 1% and 5% probability level, respectively.

The SCA effects revealed that the best specific combinations were Lider x Gloria, Flash x Julia, Carisma x Claudia and ST-468 x Claudia for SCY; Carisma x Carmen for FL; Lider x Carmen and Bali 308 x Gloria for FS; Lider x Gloria for Rd; Carisma x Carmen, Bali 308 x Claudia and Carisma x Gloria, Flash x Claudia and Lider x Julia for GP (Table 2).

Mean performance of F_1 crosses and parental cultivars

There was a significant change in the performance of the parents for each character (Table 3). The range of SCY was between 302.67 kg da^{-1} (Flash) and 649.67 kg da^{-1} (Claudia). Lider was the highest FF value (5.43) whereas Gloria gave the lowest FF value (4.18). The longest fiber (31.13 mm) was calculated for Claudia, while Bali 308 was the shortest FL of 27.74 mm. Among parents, FS varied from 34.7 g tex^{-1} (Gloria) to 28.3 g tex^{-1} (Carisma). Also, among the lines and testers, the highest and lowest GP were obtained for Claudia (45.37 %) and Bali 308 (41.90 %). In the case of Rd, the lowest (73.70) and the highest (78.37) values were produced by ST-468 and Gloria, respectively. The mean of lines and tester were 75.1 and 76.8 for Rd, respectively.

The crosses differenced dramatically for each trait (Table 3). The mean SCY ranged between 241.00 kg da^{-1} (Lider x Julia) and 625.67 kg da^{-1} (Bali 308 x Gloria). ST-468 x Claudia revealed the highest FF value (5.00 mic.) whereas revealed the lowest FF value (3.68 mic.) was obtained for Lider x Julia. Bali 308 x Gloria was the longest fibers (30.50 mm) while Lider x Julia gave the shortest FL of 28.06 mm. Among combinations, Lider x Carmen had the strongest fibers (34.50 g tex^{-1}) and Lider x Julia had the weakest fibers (30.70 g tex^{-1}). Also, among the hybrids Carisma x Carmen had the highest GP (46.50 %) and Lider x Carmen had the lowest GP (41.33 %). In case of Rd, the highest (77.25) and the lowest (74.75) values were produced by Carisma x Gloria and ST-468 x Carmen, respectively. The mean of crosses (76.05) shown that F_1 population had higher values in a positive direction.

Table 3. Mean values of observed characters.

	SCY	FF	FL	FS	Rd	GP
Lines						
Lider	452.00	5.43	28.73	31.23	75.27	44.23
ST-468	519.67	4.83	28.67	34.07	73.70	43.20
Carisma	522.00	5.40	27.93	28.37	76.13	44.43
Flash	302.67	5.34	28.90	31.80	75.03	42.93
Bali 308	408.33	4.75	27.74	28.73	75.53	41.90
Tester						
Gloria	607.67	4.18	29.11	34.70	78.37	42.87
Claudia	649.67	4.95	31.13	34.47	77.10	45.37
Julia	406.33	4.44	28.39	34.53	76.60	42.83
Carmen	485.67	4.65	28.42	34.10	75.80	42.40
$Mean_{(Parents)}$	483,77	4,89	28,78	32,44	75,94	43,35
Crosses						
Lider x Gloria	551.33	4.30	29.08	32.30	76.82	41.90
Lider x Claudia	349.33	4.55	29.47	32.50	76.18	44.53
Lider x Julia	241.00	3.68	28.06	30.70	75.93	42.33
Lider x Carmen	447.67	4.25	29.58	34.50	75.53	41.33
ST-468 x Gloria	366.00	4.36	28.59	31.37	76.03	42.97
ST-468 x Claudia	501.67	5.00	29.65	33.37	75.40	45.87
ST-468 x Julia	304.00	4.60	28.69	32.93	75.15	42.90
ST-468 x Carmen	413.67	4.50	29.57	32.97	74.75	42.57
Carisma x Gloria	424.00	4.60	28.52	32.17	77.25	45.10
Carisma x Claudia	562.33	4.70	28.40	32.60	76.62	42.07
Carisma x Julia	280.33	4.94	28.13	33.27	76.37	42.83
Carisma x Carmen	500.00	4.89	30.49	34.23	75.97	46.50
Flash x Gloria	412.00	4.66	30.50	33.23	76.70	43.30
Flash x Claudia	452.67	4.84	30.46	34.20	76.07	45.83
Flash x Julia	474.67	4.65	29.35	32.80	75.82	42.77
Flash x Carmen	452.67	4.72	29.13	33.03	75.42	42.00
Bali 308 x Gloria	625.67	4.22	30.62	33.73	76.95	41.67
Bali 308 x Claudia	561.00	4.58	30.05	32.03	76.32	45.97
Bali 308 x Julia	502.67	4.31	29.94	32.40	76.07	41.87
Bali 308 x Carmen	599.00	4.47	30.50	32.53	75.67	41.70
$Mean_{(crosses)}$	451,08	4,54	29,51	32,84	76,05	43,30
$LSD_{(0.05)}$	79.40	0.88	0.69	0.49	1.56	0.72

Heterotic Effects

Heterosis estimates of crosses combinations are presented in Table 4. Heterosis values for SCY ranged from 34 % (Bali 308 x Carmen) to -43.84 % (Lider x Julia). Bali 308 x Carmen, Flash x Julia, Bali 308 x Julia and Bali 308 x Gloria were significant and positive heterosis. Among the F_1 crosses, the significantly but negative heterosis was estimated -25.50 % (Lider × Julia) and -15.58 % (Lider x Carmen) for FF.

For FL, heterosis values were between -3.83 to 8.63 % for the crosses. Bali 308 x Carmen, Carisma x Carmen, Bali 308 x Gloria, Bali 308 x Julia, Flash x Gloria, ST-468 x Carmen and Lider x Carmen combinations showed significant and positive heterosis. Regarding FS, the significant and positive heterosis values were estimated for Carisma x Carmen (9.61 %), Bali 308 x Gloria and Lider x Carmen combinations. Although, Bali 308 x Carmen (6.30) were the highest significant positive heterosis Lider x Julia (-59.57) exhibited the lowest significant negative heterosis for Rd. The most significant positive and negative heterosis values for GP were found for Carisma x Carmen (7.10 %) and Carisma x Claudia (-6.31 %) combinations.

Heterobeltiosis estimates of hybrids were varied significantly for each character (Table 5). The values of heterobeltiosis ranged between -46.68 % (Lider x Julia) and 23.33 % (Bali 308 x Carmen) for SCY; -17.19 % (Lider x Carmen) and 11.40 % (Flash x Gloria) for FF; -8.76 % (Carisma x Claudia) to 7.32 % (Bali 308 x Carmen) for FL; -7.28 % (Carisma x Claudia) and 4.66 % (Carisma x Carmen) for GP; -11.09 % (Lider x Julia) and 1.17 % (Lider x Carmen) for FS; -59.92 (Lider x Julia) and 6.11 % (Bali 308 x Carmen) for Rd. Unlike, no significant the value of heterobeltiosis for the crosses was estimated for FF.

Table 4. Heterosis values of observed characters

	SCY	FF	FL	FS	Rd	GP
Lider x Gloria	4.06	-10.55	0.54	-2.02	-57.95**	-3.79**
Lider x Claudia	-36.58**	-12.42	-1.54	-1.07	-57.34**	-0.60
Lider x Julia	-43.84**	-25.50**	-1.77	-6.64**	-59.57**	-2.76**
Lider x Carmen	-4.51	-15.58*	3.52**	5.61**	-54.32**	-4.58**
ST-468 x Gloria	-35.07**	-3.14	-1.03	-8.77**	-0.83	-0.15
ST-468 x Claudia	-14.20*	2.11	-0.84	-2.63	1.86*	3.58**
ST-468 x Julia	-34.34**	-0.79	0.56	-3.98*	-1.57	-0.27
ST-468 x Carmen	-17.71*	-4.99	3.61**	-3.28	2.83**	-0.55
Carisma x Gloria	-24.93**	-3.86	-0.02	2.01	-0.76	3.32**
Carisma x Claudia	-4.01	-9.27	-3.83**	3.77	-0.20	-6.31**
Carisma x Julia	-39.61**	0.41	-0.13	5.78*	0.04	-1.83*
Carisma x Carmen	-0.76	-2.65	8.23**	9.61**	2.06*	7.10**
Flash x Gloria	-9.48	-2.14	5.17**	-0.05	2.30*	0.93
Flash x Claudia	-4.94	-6.02	1.47	3.22	4.65**	3.81**
Flash x Julia	33.90**	-4.98	2.47*	-1.11	4.64**	-0.27
Flash x Carmen	14.84	-5.41	1.65	0.25	5.15**	-1.56*
Bali 308 x Gloria	23.16**	-5.41	7.74**	6.36**	4.96**	-1.69*
Bali 308 x Claudia	6.05	-5.63	2.10*	1.37	5.79**	5.35**
Bali 308 x Julia	23.40*	-6.24	6.68**	2.42	5.00**	-1.18
Bali 308 x Carmen	34.00**	-4.96	8.63**	3.55	6.30**	-1.07

*, **; significant at 1% and 5% probability level, respectively.

Table 5. Heterobeltiosis values of observed characters

	SCY	FF	FL	FS	Rd	GP
Lider x Gloria	-9.27	2.79	-0.11	-6.92**	-58.79**	-5.27**
Lider x Claudia	-46.23**	-8.15	-5.33**	-5.72*	-57.85**	-1.84**
Lider x Julia	-46.68**	-17.19	-1.17	-11.09**	-59.92**	-4.29**
Lider x Carmen	-7.82	-8.53	4.08**	1.17	-54.49**	-6.55**
ST-468 x Gloria	-39.77**	4.39	-1.79	-9.61**	-3.79**	-0.54
ST-468 x Claudia	-22.78**	3.45	-4.78**	-3.20	-0.39	1.09**
ST-468 x Julia	-41.50**	3.60	0.17	-4.62*	-3.44**	-0.69*
ST-468 x Carmen	-20.40*	-3.15	3.15*	-3.32	1.41	-1.47**
Carisma x Gloria	-30.23**	10.13	-2.04	-7.30**	-2.17*	1.51**
Carisma x Claudia	-13.44*	-5.12	-8.76**	-5.43*	-0.82	-7.28**
Carisma x Julia	-46.30**	11.26	-0.93	-3.66	-0.26	-3.59**
Carisma x Carmen	-4.21	5.16	7.30**	0.39	1.84	4.66**
Flash x Gloria	-32.20**	11.40	4.79**	-4.23*	0.12	0.86*
Flash x Claudia	-30.32**	-2.29	-2.16*	-0.78	3.24**	1.02**
Flash x Julia	16.82	-12.98	1.57	-5.01*	3.57**	-0.38
Flash x Carmen	-6.80	1.58	0.80	-3.13	4.62**	-2.17**
Bali 308 x Gloria	2.96	1.04	5.20**	-2.79	3.06**	-2.81**
Bali 308 x Claudia	-13.65*	-7.54	-3.46**	-7.07**	4.71**	1.32**
Bali 308 x Julia	23.10*	-2.93	5.46**	-6.17**	4.26**	-2.25**
Bali 308 x Carmen	23.33*	-3.94	7.32**	-4.59*	6.11**	-1.65**

*, **; significant at 1% and 5% probability level, respectively.

It was determined that heterotic effects for SCY, FS and GP were mostly negative direction whereas numerous cross combinations showed positive heterosis and heterobeltiosis for FF, FL and Rd. Our results are similar to the findings of Solanki et al. (2014) and Khokhar et al. (2018).

CONCLUSION

The non-additive gene effects were predominant for seed cotton yield, fiber length, fiber strength and ginning percentage. Cultivar Claudia was the most suitable parent to combine crossing blocks for all traits. Also, Gloria and Bali 308 were good combiners for seed cotton yield but the cross combinations of these parents should be crossed with a combined with high GCA effects in terms of ginning percentage and fiber traits. The hybrids ST-468 x Claudia, Carisma x Carmen, Bali 308 x Gloria and Bali 308 x Claudia were the most promising for improving the yield and fiber traits. Moreover, out of four, two crosses viz., Bali 308 x Gloria and Bali 308 x Claudia involved both the parents have GCA effect for seed cotton yield. Higher heterosis and heterobeltiosis for SCY were

observed whereas mostly lower values for fiber traits and ginning percentage were estimated. It was concluded that due to non-additive gene actions, it is advisable to select individual plants for seed cotton yield, ginning percentage and fiber properties in later generations (F_4-F_6).

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