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Heterosis and Combining Ability for Yield Components and Fiber Quality Parameters in a Half Diallel Cotton (*G. hirsutum* L.) Population[1]

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Abstract: Combining ability and heterosis were determined in a population obtained from the half diallel crossing of 6 different cotton genotypes for yield components and fiber quality parameters. For breeding purposes, to improve the investigated characters some suitable parents were selected for different characters: DPL 5690 for number of bolls per plant, Acala SJ-5 for boll weight and fiber length; Nazilli-84 and Carmen for seed cotton yield and lint percentage; Tamcot CAMD-E for earliness and fiber fineness; and PD 6168 for fiber strength. When the crosses were evaluated for the investigated characters Tamcot CAMD-E x Carmen, Nazilli-84 x PD 6168, DPL 5690 x Tamcot CAMD-E and Tamcot CAMD-E x PD 6168 are considered promising combinations for further research. It was concluded that applying 3-way crosses, or modified backcross or recurrent selection to genotypes having good combining ability would improve yield and fiber quality.

Key Words: Cotton, diallel analyses, heterosis, general and specific combining ability

Yarım Diallel Pamuk (*G. hirsutum* L.) Populasyonunda Verim Komponentleri ve Lif Kalite Özelliklerinin Heterosis ve Uyuşma Yetenekleri

Özet: Altı farklı pamuk çeşidinin yarım diallel melezlenmesiyle oluşturulan populasyonunda verim komponentleri ve lif özellikleri yönünden uyuşma yetenekleri ve heterosis değerleri saptanmıştır. Ele alınan özelliklerin geliştirilebilmesine yönelik olarak yapılacak ıslah çalışmaları bakımından, bitkide koza sayısı için DPL 5690; koza kütlü pamuk ağırlığı ve lif uzunluğu için Acala SJ-5; bitki kütlü pamuk verimi ve çırçır randımanı için Nazilli-84 ve Carmen; erkencilik oranı ve lif inceliği için Tamcot CAMD-E ve lif kopma dayanıklılığı için ise PD 6168 çeşitlerinin uygun olabileceği belirlenmiştir. Tüm özellikler birlikte incelendiğinde, Tamcot CAMD-E x Carmen, Nazilli-84 x PD 6168, DPL 5690 x Tamcot CAMD-E ve Tamcot CAMD-E x PD 6168 melezlerinin gelecekteki çalışmalar için ümit verici olduğu saptanmıştır. Çalışma sonucunda, genel uyuşma yeteneği yüksek olan genotiplerle üçlü melezleme, değiştirilmiş geri melezleme veya tekrarlamalı seleksiyon yöntemi uygulanarak verim ve lif kalite özelliklerinin birlikte geliştirilebileceği kanısına varılmıştır.

Anahtar Sözcükler: Pamuk, diallel analiz, heterosis, genel ve özel uyuşma yetenekleri

Introduction

The improvement of a new variety with high yield and fiber quality parameters is the unique target of all cotton breeders. The first step in a successful breeding program is to select appropriate parents. Diallel analysis provides a systematic approach for the detection of appropriate parents and crosses superior in terms of the investigated traits. It also helps plant breeders to choose the most efficient selection method by allowing them to estimate several genetic parameters (Verhalen and Murray, 1967).

Heterosis is the superiority in performance of hybrid individuals compared with their parents. Regarding previous studies on heterosis in cotton, researchers reported different heterosis values for yield components and fiber quality parameters. The amount of exploitable heterosis for seed cotton yield ranged from 15.5% (Al-Rawi and Kohel, 1969) to 35% (Thomson and Luckett, 1988). The amount of heterosis for fiber properties was usually lower (5-10%) than that for yield and its components (Turan, 1979; Luckett, 1989; Kaynak, 1990; Meredith and Brown, 1998).

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Combining ability describes the breeding value of parental lines to produce hybrids. Sprague and Tatum (1942) used the term general combining ability (GCA) to designate the average performance of a line in hybrid combinations, and used the terms specific combining ability (SCA) to define those cases in which certain combinations do relatively better or worse than expected on the basis of the average performance of the lines involved.

In order to choose appropriate parents and crosses, and to determine the combining abilities of parents in the early generation, the diallel analysis method has been widely used by plant breeders. This method was applied to improve self- and cross-pollinated plants (Jinks and Hayman, 1953; Hayman, 1954; Jinks, 1956; Griffing, 1956; Hayman 1960). The purposes of this research were to estimate the amount of heterosis, the GCA and SCA effects for yield components and fiber quality parameters among 6 different cotton genotypes and to determine appropriate parents and crosses for the investigated traits.

Materials and Methods

Six upland cotton genotypes, namely, Nazilli-84, Acala SJ-5, Deltapine 5690, Carmen, Tamcot CAMD-E and PD 6186, representing a range of yield and fiber quality were (hand) crossed in a half diallel mating scheme in 1999. Parents and their 15 F_1 populations were grown at the Adnan Menderes University, Agriculture Faculty Experiment Fields in 1 row plots 6 m by 0.70 m in a randomized block design with 4 replications in 2000. Twenty well developed open bolls were hand harvested randomly from each row of parents and F_1s. The bulked bolls from each genotype were ginned on a laboratory roller gin. Seed cotton weight per boll (SCW/B) and lint percentage (LP) were obtained from each boll sample. Seed cotton weight per plant (SCW/P) was determined by dividing total seed cotton harvested by the number of plants in each plot. Earliness ratio (ER) was the ratio of first hand harvest over total harvested seed cotton. The number of bolls per plant (B/P) was calculated by counting the open bolls from 10 randomly chosen plants in each plot. A High Volume Instrument (HVI) was used to measure fiber bundle strength (Str.), fiber fineness (Mic.) and fiber length (UHM).

Griffing's Method 2 Model 1 was used to analyze data obtained from the 15 F_1 progenies and 6 parents. Griffing-type diallel analysis was applied to estimate the GCA and SCA effects of yield components and fiber quality parameters using the TarPopGen program (Özcan and Açıkgöz, 1999).

Results and Discussion

The 6 parents used in this study varied significantly for each yield component and fiber quality parameter evaluated (Table 1). These data indicated that the highest values of yield components and fiber quality parameters do not follow the same pattern in every genotype. The GCA effects of parents are given in Table 1. As expected from Nazilli-84's parental values and significant positive GCA effects, Nazilli-84 would be the genotype to develop progeny having higher SCW/P, ER and LP. On the other hand, Nazilli-84 contributed less to SCW/B and decreased fiber quality. Acala SJ-5 had a positive GCA effect for SCW/B and UHM. The GCA of DPL 5690 was negative for SCW/B and ER, but positive for B/P and fiber strength. Tamcot CAMD-E had negative GCA effect for all examined traits except for ER and a suitable micronaire value. The use of PD 6168 would result in lower LP, but increased fiber strength and UHM. Carmen would be a suitable parent for increasing SCW/B, LP, Str., and UHM.

Preliminary analysis of the variance and combining ability of variance shown in Table 2 indicated that crosses were significantly different from each other for all the traits measured in the study. The significant GCA effects for all the traits measured in this study suggest an additive gene action for yield components and fiber quality parameters. There was also a non-additive gene action for SCW/B, SCW/P, ER, UHM, and Mic., as indicated by significant SCA effects (Table 2).

The SCA effects of yield components and fiber quality parameters for crosses among 6 cotton genotypes are given in Table 3. Nazilli-84 x Acala SJ-5 and Nazilli-84 x PD 6186 combinations had positive and significant SCA effects on LP and SCW/P, respectively, while Nazilli-84 had the coarsest fibers among the 6 parents, and also had significant and positive GCA effects on Mic., which in turn increased Mic. values. SCA elements of Nazilli-84 in combination with Tamcot CAMD-E and Carmen were found to be negative and significant for fiber fineness (Mic).

Table 1. Average yield components and fiber characteristics of 6 cotton genotypes and GCA estimates of measured traits. For abbreviations see Materials and Methods.

	B/P		SCW/B		SCW/P		ER		LP		Str.		UHM		Mic.	
Parents	no	GCA	g	GCA	g	GCA	%	GCA	%	GCA	g tex^{-1}	GCA	mm	GCA	units	GCA
Nazilli-84	15.6bc*	0.4	6.3b	-0.04	71.00 a	6.9*	75.8 a	1.6**	44.79a	1.3**	23.28c	-1.8**	28.80b	-0.38**	5.33 a	0.082*
Acala SJ5	14.0bc	-1.0*	7.3a	0.64**	61.56ab	0.7	70.4 b	-0.5	39.17d	-0.9**	27.48b	0.3	30.40a	0.55**	4.78bc	0.001
DPL 5690	19.8a	1.8**	5.4c	-0.21**	68.84 a	2.2	66.9bc	-1.6**	42.65b	-0.1	28.50ab	0.7**	28.65b	-0.05	5.10ab	0.067
T. CAMD-E	11.2c	-2.5**	5.4c	-0.29**	42.79 b	-16.7**	77.1a	2.5**	41.31c	-0.8**	24.10c	-1.3**	26.85c	-0.88**	4.65bc	-0.21**
PD 6186	16.0abc	0.5	5.8c	-0.11	63.29 a	0.1	72.1ab	0.6	42.60bc	-0.1	30.15ab	0.9**	29.25b	0.45**	4.93bc	-0.011
Carmen	14.9 bc	0.7	5.7c	0.01	74.11 a	6.8*	64.9c	-2.5	43.32ab	0.7**	28.15a	1.2**	29.75b	0.31**	5.13ab	0.073
LSD 0.05	3.9		0.6		20.01		5.3		1.69		2.39		1.13		0.36	
S.E. ($\breve{g}_i$)		0.4		0.07		1.8		0.5		0.2		0.3		0.11		0.040

The * and ** indicate significant differences at 0.05 and 0.01 levels, respectively.

Table 2. Mean squares obtained from preliminary analysis of variance and combining ability of variance for the traits measured in the F_1 generation in 2000. For abbreviations see Materials and Methods.

Source	df	B/P	SCW/B	SCW/P	ER	L. P.	Str.	UHM	Mic.
Rep.	3	21.89*	0.15	25.33	14.23	1.47	13.98**	0.50	0.14
Crosses	20	21.94**	1.19**	848.08**	50.54**	8.06**	14.63**	3.27**	0.19**
Error	60	5.88	0.19	132.74	8.48	1.99	2.25	0.44	0.06
GCA	5	17.53**	0.88**	603.38**	29.28**	5.85**	12.47**	2.45**	0.10**
SCA	15	1.48	0.10*	81.57**	7.09*	0.74	0.72	0.27**	0.03*
Error	60	1.47	0.04	33.19	2.11	0.50	0.56	0.11	0.01

The * and ** indicate significant differences at 0.05 and 0.01 levels respectively.

Table 3. Specific combining ability estimates for yield components and fiber quality parameters among 6 cotton genotypes. For abbreviations see Materials and Methods.

Crosses	B/P No	SCW/B g	SCW/B g	ER %	L. P. %	Str g tex^{-1}	UHM mm	Mic units
Nazilli-84 x Acala SJ-5	0.45	-0.13	5.20	1.51	1.07*	0.155	0.021	-0.06
Nazilli-84 x DPL 5690	-0.61	-0.18	6.20	1.11	0.20	-1.48**	0.071	-0.03
Nazilli-84 x T. CAMD-E	-0.14	-0.05	-4.36	-1.21	-0.12	-0.488	-0.19	-0.22*
Nazilli-84 x PD 6168	0.67	-0.14	20.78**	0.61	0.51	1.15*	-0.25	-0.12
Nazilli-84 x Carmen	-0.96	0.20	-5.15	1.76	-0.30	-0.55	-0.36	-0.23*
Acala SJ-5 x DPL 5690	-1.96*	0.36*	3.39	0.26	0.20	0.57	0.54*	0.03
Acala SJ-5 x T. CAMD-E	-0.74	0.01	-2.81	0.70	0.63	0.16	-0.25	0.01
Acala SJ-5 x PD 6168	-1.42	-0.01	-2.47	1.26	1.01	-1.23*	-0.08	0.13
Acala SJ-5 x Carmen	0.95	0.19	13.64	1.92	0.95	-0.77	-0.42	-0.01
DPL 5690xT.CAMD-E	-1.55	0.30	-2.47	3.30**	0.26	-0.65	0.18	-0.21*
DPL 5690 x PD 6168	-0.49	0.50**	-1.47	2.11	-1.12*	0.16	0.20	-0.03
DPL 5690 x Carmen	1.14	-0.20	2.55	1.51	0.82	-0.43	-0.07	-0.04
T.CAMD-E x PD 6168	-0.52	-0.28	-8.27	0.05	-0.68	0.10	1.13**	-0.13
T.CAMD-E x Carmen	0.11	0.48**	2.76	1.20	0.01	-0.21	0.30	0.06
PD 6168 x Carmen	0.67	0.24	2.24	2.76*	-0.12	-0.50	0.69**	-0.09
S.E. (S_{ij})	0.89	0.16	4.22	1.07	0.52	0.53	0.24	0.09

The * and ** indicate significant differences at 0.05 and 0.01 levels, respectively.

The Acala SJ-5 and DPL 5690 combination exhibited positive and significant SCA effects on SCW/B and UHM. Tamcot CAMD-E, having the highest ER of the 6 genotypes, had positive and significant GCA for ER. In all combinations of Tamcot CAMD-E, except for Nazilli-84 x Tamcot CAMD-E, positive SCA elements were identified for ER, and the SCA of Tamcot CAMD-E with DPL 5690 was not only positive but also significant. The DPL 5690 x Tamcot CAMD-E combination had negative and significant SCA effects on Mic., suggesting some recessive genes for fiber fineness in the Tamcot CAMD-E genotype, which is consistent with Coyle and Smith's results (1997). Tamcot CAMD-E x Carmen and PD 6168 x Carmen combinations had positive and significant SCA elements for SCW/B and ER, respectively. PD 6168 combined well with Nazilli-84, the region's standard variety, for fiber strength. Positive and significant SCA elements for UHM were identified in Acala SJ-5 x DPL 5690, Tamcot CAMD-E x PD 6168 and PD 6168 x Carmen combinations.

The heterosis values estimated for yield components and fiber quality parameters in a 6 x 6 half diallel of upland cotton crosses are given in Table 4. Among the crosses, the estimated heterosis values for B/P varied from –20.71% (Acala SJ-5 x DPL 5690) to 7.10% (PD 6168 x Carmen). Boyacı (1980) reported 5.6% heterosis for B/P, whereas Khan et al. (1981) stated that heterosis values of B/P varied from –52.9% to 107.9%. Tamcot CAMD-E x Carmen (14.69%) and DPL 5690 x PD 6168 had the highest (13.93%) heterosis values for SCW/B, and Nazilli-84 x PD 6168 had the lowest (-2.31%). Luckett (1989) and William and Meredith (1990) estimated 6.9% and 8.2% heterosis for SCW/B, respectively. Acala SJ-5 x Carmen (24.34%) and Acala SJ-5 x DPL 5690 (23.15%) crosses showed positive heterosis over 20% for SCW/P, and Acala SJ-5 x Carmen also had the highest heterosis values (5.87%) for LP. Previous studies reported that heterosis values varied from 1% to 32.3% for SCW/P, and from –11.05% to 0.6% for LP (Luckett, 1989; Meredith and Brown, 1998). Tamcot CAMD-E x PD 6168, Nazilli 84 x Tamcot CAMD-E and DPL 5690 x PD 6168 showed the lowest heterosis values, -8.77%, 0.81% and –2.56% for SCW/P, ER and LP, respectively.

As seen in Table 4, none of the crosses had positive heterosis values for fiber strength. The estimated heterosis values of crosses for UHM varied from –1.71% (Nazilli-84 x Carmen) to 6.60% (Tamcot CAMD-E x PD 6168). The estimated heterosis values for fiber strength and UHM herein are consistent with those given by Luckett (1989) and Ünay et al. (1995). Although very high heterosis (22.53%) was found for micronaire, it is not desirable heterosis as it encourages coarse fibers.

Heterosis for fiber properties are usually lower than that for yield components; this is in agreement with the results of Luckett (1989), Kaynak (1990), Ünay et al. (1995), and Meredith and Brown (1998). The differences between the estimated heterosis values for all investigated characters in this study and those reported previously might be due to the use of different genetic materials and different environmental conditions.

Conclusion

In order to improve investigated characters, some suitable parents were determined, namely, DPL 5690 for B/P, Acala SJ-5 for SCW/B, and UHM, Nazilli-84 and Carmen for SCW/P and LP; Tamcot CAMD-E for ER and

Table 4. The heterosis values of yield components and fiber quality parameters in 6 x 6 half diallel crosses of upland cotton. For abbreviations see Materials and Methods.

Crosses	B/P No	SCW/B g	SCW/B g	ER %	L. P. %	Str g tex^{-1}	UHM mm	Mic units
Nazilli-84 x AcalaSJ-5	-2.70	-1.48	7.01	5.01	4.79	-1.69	-0.68	19.41
Nazilli-84 x DPL 5690	-7.34	-0.86	10.87	5.73	1.62	-8.65	0.42	15.52
Nazilli-84 x T.CAMD-E	-7.46	-0.34	6.95	0.81	0.33	-4.47	-0.29	14.83
Nazilli-84 x PD 6168	0.82	-2.31	19.81	4.45	1.69	-0.89	0.02	19.88
Nazilli-84 x Carmen	-3.27	5.81	-6.65	7.25	-0.14	-2.29	-1.71	18.16
Acala SJ-5 x DPL 5690	-20.71	10.44	23.15	5.56	3.10	-0.57	2.44	28.54
Acala SJ-5 x T.CAMD-E	-18.25	3.63	18.42	4.11	3.58	-1.51	0.02	28.81
Acala SJ-5 x PD 6168	-12.00	2.75	12.96	6.41	4.79	-8.98	1.01	28.60
Acala SJ-5 x Carmen	6.21	7.82	24.34	8.46	5.87	-2.84	-1.43	27.02
DPL 5690 x T.CAMD-E	-18.06	11.32	19.41	9.01	0.91	-5.21	2.52	17.83
DPL 5690 x PD 6168	-7.82	13.93	10.70	8.85	-2.56	-4.71	2.94	24.10
DPL 5690 x Carmen	5.17	3.95	14.30	8.58	2.56	-2.22	0.68	20.11
T.CAMD-E x PD 6168	-9.56	-1.78	-8.77	4.11	-1.48	-4.61	6.60	22.76
T.CAMD-E x Carmen	0.04	14.69	7.32	6.34	0.76	-0.88	2.23	27.40
PD 6168 x Carmen	7.10	9.31	9.81	9.85	-1.30	-4.52	3.90	24.85

Mic.; and PD 6168 for fiber strength. These results suggest that these varieties could be used in 3-way crosses, or modified backcross or recurrent selection to produce progenies having high levels of yield components with high fiber quality. In addition, Tamcot CAMD-E x Carmen, Nazilli-84 x PD 6168, DPL 5690 x Tamcot CAMD-E, and Tamcot CAMD-E x PD 6168 crosses were identified as promising combinations in terms of SCW/B, SCW/P, ER, and UHM for further research.

References

Al-Rawi, K.M. and R.J. Kohel. 1969. Diallel analaysis of yield and other agronomic characters in *Gossypium hirsutum* L. Crop Sci. 6: 779-783.

Boyacı, S. 1983. *Gossypium hirsutum* L. türü sekiz pamuk çeşitlerinin yarım diallel melezlerinde önemli kantitatif özelliklerin genetik analizleri üzerinde araştırmalar. Doktora tezi. Ç.Ü. Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı. Adana.

Coyle, G.G. and C.W. Smith. 1997. Combining ability for within-boll yield components in cotton, *Gossypium hirsutum* L. Crop Sci. 37: 1118-1122.

Griffing, L.B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Austr. Jour. Biol. Sci. 9: 463-493.

Hayman, B.I. 1954. The theory and analysis of diallel crosses. Genetics 39: 789-809.

Hayman, B.I. 1960. The theory and analysis of diallel crosses III. Genetics 45: 155-172.

Jinks, J.L. and B.I. Hayman. 1953. The analysis of diallel crosses. Maize Genet. Coop. News Letter 27:48-54.

Jinks, J.L. 1956. The F2 and backcross generation from a set of diallel crosses. Heredity 10: 1-30.

Kaynak, M.A. 1990. Harran ovası koşullarında, *Gossypium hirsutum* L. türü içindeki 12 pamuk çeşidinin eksik diallel melezlerinde, verim, verim unsurları ve lif özelliklerinin kalıtımı üzerinde araştırmalar. Doktora Tezi. Ç.Ü. Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı. Adana.

Khan, W.S., F.M. Azhar and H. Rana. 1981. Heterosis and combining abilities in intra-specific crosses of *Gossypium hirsutum* L. yield and its components. Cott. Trop. Fib. Abst. 6.9. 166.

Luckett, D.J. 1989. Diallel analysis of yield components, fiber quality and bacterial blight resistance using spaced plants of cotton. Euphytica 44: 11-21.

Meredith Jr., W.R. and J.S. Brown. 1998. Heterosis and combining ability of cottons originated from different regions of the U.S. Journal of Cotton Science 2: 77-84.

Özcan, K. and N. Açıkgöz. 1999. Populasyon genetiği için bir istatistik paket program. 3. Tarımda Bilgisayar Uygulamaları Sempozyumu. 3-6 Ekim. Çukurova Üniversitesi. Adana.

Sprague, G.F. and L.A. Tatum. 1942. General vs. specific combining ability in single crosses of corn. J. Am. Soc. Agron. 34: 923-932.

Thomson, N.J. and D.J. Luckett. 1988. Heterosis and combining ablity effects in cotton. II Heterosis. Aust. Jour. Agric. Res. 39: 991-1002.

Turan, Z.M. 1979. Pamuğun bazı agronomik ve tarımsal özelliklerinin diallel analiz yöntemi ile populasyon analizleri. Doktora Tezi. E.Ü. Zir. Fak. Agronomi-Genetik Bölümü. İzmir.

Ünay, A., O. Inan., M. Çetinkaya and C. Gençkal. 1995. An investigation of fiber characters by HVI motion control 4000 tests in cotton. Proceedings. Joint meeting of working groups "Cotton Breeding" "Cotton Variety Trials" "Cotton Technology" Adana-Turkey. p 137-139.

Verhalen, L.M. and J.C. Murray. 1967. A diallel analysis of several fiber properties traits in upland cotton (*Gossypium hirsutum* L.). Crop. Sci. 7: 501-505.

William, R. and W.R. Meredith Jr. 1990. Yield and fiber quality potential for second generation cotton hybrids. Crop. Sci. 30: 1045-1048