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The Combining Ability Analysis and Heterosis for some Quanitatives Traits in the Silkworm (*Bombyx mori* L.)

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Recently two breeding programs were carried out for isolation of new parental inbred lines in Iran. This study was undertaken in order to estimate the combining ability effects and heterosis of these lines. For this purpose an 8 × 8 diallel cross analysis including eight inbred lines of silkworm with four lines from each program were studied for their five quantitative traits. The results indicated that reciprocal effects appeared insignificant for most of traits. Japanese lines of 111 and 113 were best combiners for shell weight, cocoon weight and shell percentage traits. With respect to pupation rate, Chinese line 110 was the best and according to general combining ability (GCA) and specific combining ability (SCA) variances, it is superior in specific combinations. Hybrid 109 × 110 showed better characters for both productive and viability traits. Hybrids with high heterosis had high SCA too.

Key words: Combining ability, Diallel crosses, Heterosis, Silkworm

Introduction

The choice of the best parent for producing commercial hybrids is one of the critical tasks. The combining ability of parental lines cannot be fully judged by phenotypic performance. The success of selection for combining ability depends on understanding the population genetic structure (Nagaraja and Govindan, 1994; Malik *et al.*, 1999).

The combining ability analysis by diallel crosses method gives the required parameters for explanation of genetic backgrounds and choosing the best parent for hybridization. Many attempts have been made earlier by many breeder to identify the most productive and resistant hybrids by estimating combining ability and heterosis (Jang *et al.*, 1986; Datta and Pershad, 1987; Ashoka and Govindan, 1991; Lea and Alwis, 1995; Singh *et al.*, 2000, 2002, 2003)

The Griffing's (1956) approach of diallel analysis is the most reliable and precise methods to get information about combining ability. Also the heterosis or hybrid vigor can be estimated through diallel crossing. Some associated parameters in the diallel analysis such as $\hat{\sigma}_g^2$ and $\hat{\sigma}_s^2$ with each parent play significant role in choice of parents as a component of synthetic varieties or for creating specific combinations (Sharma, 1998).

Recently some inbred lines of silkworm were introduced in Iran silkworm germplasm bank. These inbred lines have been derived from two breeding programs including "isolation method" and "inbreeding program" followed by intra-crossing of Japanese and Chinese races. The present study was aimed to estimate GCA, SCA, variances of GCA and SCA, also heterosis of the some economic traits in newly evolved lines of silkworm in Iran.

Materials and Methods

Eight inbred lines were selected including four lines from first program with the name of 107, 109 (Japanese race), 108, 110 (Chinese race) and four lines from second program, 111, 113 (Japanese race) and 114, 118 (Chinese race).

These lines were crossed in all possible combinations including reciprocals. For each replication 500 eggs were sampled from ten laying. Parents and their 56 F_1's were reared in a partially balanced lattice design with three replications during April and May. After passing third molt, 250 larvae were counted and reared at standard rearing

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conditions. Data were collected on five traits including cocoon shell weight (SW), cocoon weight (CW), shell percentage (SP), pupation rate (PR) and effective rate of rearing (ERR). Rearing technology and recording methods were conducted according to standard method (ESCAP, 1993; Hosseini Moghaddam, 2005).

Data were analyzed using model 2 (non-random) of Griffing's (1956) for full diallel analysis that has already been used for mulberry silkworm (Jang *et al.*, 1986), multivoltine combined with bivoltine strains (Datta and Pershad, 1987) and Eri silkworm (Nagaraja *et al.*, 1996). GCA variance ($\hat{\sigma}_g^2$) and SCA variance ($\hat{\sigma}_s^2$) were estimated according to Sharma (1998) and Griffing's (1956) numerical example.

$$\hat{\sigma}_{s_i}^2 = \frac{1}{(p-2)}\sum_{j}^{p} S_{ij}^2 - \frac{p-3}{p-2} \times MSe \qquad (i \neq j)$$

$$\hat{\sigma}_{g_i}^2 = (g_i)^2 - \frac{p-1}{p(p-2)} \times MSe$$

S_{ij} = SCA effect

Table 1. Analysis of variance of combining ability for five traits in full diallel set of silkworm

Source	df	SW	CW	SP	PR	ERR
GCA	7	7.861**	39.815**	27.877**	29.717**	457.8**
SCA	28	2.801**	44.199**	0.686**	27.398**	247.739**
R	28	0.205	3.475	0.419*	3.312	73.107
Error	126	0.192	2.836	0.233	5.845	53.646

GCA: General Combining Ability
SCA: Specific Combining Ability
RCA: Reciprocal Combining Ability
*5%, **1% significant level

SW: Shell Weight
CW: Cocoon Weight
SP: Shell Percentage
PR: Pupation Rate
ERR: Effective Rate of Rearing

Table 2. GCA effects and estimates of GCA & SCA variances for 8 parents in full diallel set of silkworm

Parents	SW		CW		SP		PR		ERR	
	$\hat{\sigma}_{gi}^2$	$\hat{\sigma}_{si}^2$	$\hat{\sigma}_{gi}^2$	$\hat{\sigma}_{si}^2$	$\hat{\sigma}_{gi}^2$	$\hat{\sigma}_{si}^2$	$\hat{\sigma}_{gi}^2$	$\hat{\sigma}_{si}^2$	$\hat{\sigma}_{gi}^2$	$\hat{\sigma}_{si}^2$
J107	-0.51**		-1.91**		-0.19*		0.29		1.18	
	0.238	-0.08	3.61	-1.17	0.004	-0.089	-0.77	1.5	-12.84	-87.55
J109	-0.31**		-0.04		-0.73**		0.17		0.61	
	0.07	-0.05	-0.032	-0.85	0.5	-0.08	0.824	-3.14	-18.95	-86.44
J111	0.48**		0.59*		0.85**		-0.76		3.34*	
	0.205	0.30	0.31	5.34	0.69	-0.045	0.278	-3.28	-15.14	-47.73
J113	0.55**		0.92**		0.82**		-1.40**		4.84**	
	0.278	0.439	0.82	6.25	0.63	-0.15	1.108	-0.72	-9.9	-60.22
C108	-0.15*		0.93**		-0.87**		0.22		-3.84**	
	-0.006	-0.098	0.83	-1.52	0.72	-0.125	-0.805	-3.36	-14.26	-90.77
C110	-0.31**		-0.17		-0.66**		0.98**		-1.69	
	0.07	-0.084	-0.006	-0.18	0.40	-0.107	0.102	-2.64	-9.72	-90.81
C114	0.34**		-0.22		0.94**		-0.27		-3.4*	
	0.089	0.279	0.01	3.57	0.85	-0.105	-0.78	-3.52	-15.94	-91.30
C118	0.087		-0.11		-0.15		0.78**		-1.04	
	-0.02	0.049	-0.02	2.50	-0.01	0.014	-0.241	-3.72	9.91	-97.94
SE(gi)	0.059		0.227		0.065		0.326		0.989	
SE(gi-gj)	0.089		0.34		0.098		0.493		1.495	

$\hat{\sigma}_{gi}^2$: GCA variance, $\hat{\sigma}_{si}^2$: SCA variance,
CW: Cocoon weight, SP: Shell percentage,
SW: Cocoon shell weight, ERR: Effective rate of rearing,
PR: Pupation rate, *5%, **1% significant level.

Table 3. Estimates of SCA and heterosis (HET) percentage in different hybrid of silkworm

Crosses	SW		CW		SP		PR		ERR	
	SCA	HET	SCA	HET	SCA	HET	SCA	HET	SCA	HET
J107 × j107	-1.14**	-----	-4.81**	-----	-0.10	-----	0.85	-----	-1.08	-----
J107 × j109	0.40*	18.88**	1.14	17.17**	0.31	1.31	-1.02	0.2	-1.58	6.68
j107 × j111	0.03	14.73**	-0.18	13.34**	0.23	1.44	0.28	2.33**	2.90	16.54
j107 × j113	0.36*	22.51**	1.13	20.08**	0.26	2.3	1.34	6.5	-0.28	12.51
J107 × c108	0.00	15.32**	0.06	12.69**	-0.04	1.9	0.34	1.38	4.23	19.36
J107 × c110	-0.17	11.88**	-0.20	12.69**	-0.34	-1.08	-1.85*	-1.71	-0.74	-5.92
J107 × c114	0.32	22.14**	1.11	19.65**	0.18	2.13	0.04	2.06	-3.69	0.74
J107 × c118	0.21	17.27**	1.82**	19.98**	-0.51**	0.00	-0.05	1.07	0.23	4.98
j109 × j109	-0.98**	----	-4.76**	----	0.15	----	-2.40	----	-11.81**	----
j109 × j111	0.20	15.06**	0.10	14.00**	0.41*	1.68	1.33	5.27**	0.33	22.09*
j109 × j113	0.29	19.98**	1.40*	19.62**	-0.07	0.35	2.41**	6.08**	5.57*	29.69**
j109 × c108	0.24	16.73**	0.87	14.05**	0.15	2.27	-1.15	1.55	-0.08	23.25*
j109 × c110	0.37*	17.11**	2.06**	18.25**	-0.19	-0.97	0.68	2.58	4.50	7.72*
j109 × c114	-0.44**	10.79**	-0.87	12.89**	-0.57**	-1.69	0.02	3.83*	-1.13	13
j109 × c118	-0.07	12.07**	0.07	13.42**	-0.19	-1.21	0.14	2.89	4.19	18.92
j111 × j111	-1.24**	-----	-4.90**	-----	-0.12	-----	-4.68**	-----	-17.14**	-----
j111 × j113	-1.12**	4.41	-4.41**	3.88	-0.17	0.49	-1.32	6.92**	-5.98*	16.69
j111 × c108	0.43*	17.92**	1.07 **	14.52**	0.39	3.76**	0.51	4.62**	3.53	33.64**
j111 × c110	0.32	16.71**	1.74**	17.30**	-0.20	-0.39	0.95	6.42*	5.23	12.23
j111 × c114	1.04**	28.43**	3.92**	26.10**	0.12	1.79	0.98	6.24**	4.62	25.87**
j111 × c118	0.34*	12.99**	2.69**	20.45**	-0.66**	2.57	1.98	6.19**	6.53	26.21**
j113 × j113	-1.81**	-----	-6.77**	-----	-0.45	-----	-9.98**	-----	-17.61**	-----
j113 × c108	0.01	18.11**	0.43	15.56**	-0.19	1.92	1.95*	9.40**	10.43	44.53**
j113 × c110	0.24	19.64**	0.70	17.29**	0.20	2.05	2.49**	8.92**	-3.34	1.14
j113 × c114	1.07**	32.83**	3.89**	29.06**	0.21	2.87*	2.22*	10.92**	5.52*	27.11**
j113 × c118	0.96**	28.39**	3.63**	25.98**	0.21	1.78	0.92	8.18**	5.69*	24.87**
c108 × c108	-1.23**	-----	-4.14**	-----	-0.80**	-----	-2.83	-----	-16.36**	-----
c108 × c110	0.33	18.17**	1.73**	15.95**	-0.06	1.85	-1.05	1.00	-5.92*	-3.4
c108 × c114	0.06	18.63**	v0.01	13.98**	0.15	3.65**	1.15	5.29**	5.48*	29.67**
c108 × c118	0.16	16.44**	-0.03	11.87**	0.42*	3.79**	1.10	4.14*	-1.29	15.8
c110 × c110	-1.01**	-----	-4.48**	-----	-0.10	-----	-1.20	-----	9.20*	-----
c110 × c114	0.07	17.52**	-0.06	12.73**	0.20	2.21	0.82	3.99*	-1.36	-3.09
c110 × c118	-0.14	11.48**	-1.50*	8.69*	0.50**	2.47	-0.84	1.22	-7.58**	-12.19
c114 × c114	-1.75	-----	-6.19**	-----	-0.53*	-----	-4.70**	-----	-7.38*	-----
c114 × c118	-0.34*	12.99**	-1.80**	10.52**	0.23	2.03	-0.51	3.5	-2.07	6.72
c118 × c118	-1.12**	-----	-4.88**	-----	0.00	-----	-2.83	-----	-5.69	-----
S_{ii}-S_{jj}	0.310	SE : 0.31	1.191	SE : 1.19	0.341	SE : 0.34	1.709	SE : 1.71	5.179	SE : 5.18
SE(S_{ii}-S_{ij})	0.296		1.140		0.327		1.640		4.959	
SE(S_{ij}-S_{jk})	0.268		1.031		0.295		1.480		4.485	
SE(S_{ij}-S_{ik})	0.236		0.909		0.260		1.305		3.955	
SE(S_{ij}-s_{kl})	0.219		0.842		0.261		1.209		3.66	
SE(S_{ii})	0.22		0.851		0.241		1.221		3.700	
SE(S_{ij})	0.16		0.608		0.174		0.872		2.643	

*5%, **1% significant level.

g_i = GCA effect
MSe = Error variance, P = Number of parent

Heterosis was calculated over mid parental values as per formula outlined by Rao *et al.* (2004).

Results and Discussion

The analysis on variance of combining ability for SW, CW, SP, PR and ERR are presented in Table 1. Due to GCA and SCA, the variances for all the traits were highly significant. Reciprocal effects were insignificant. Therefore, for producing commercial F_1 hybrid both of parents can be used as female. Similar results were obtained by Jang *et al.* (1986). Also Nagaraju *et al.* (1996) reported that reciprocal differences are not observed in the crosses which involve parental strains of the same voltinism.

The GCAs of the parents and also variances of GCA and SCA are presented in Table 2. Lines 111 and 113 lines (both Japanese lines of second program) had significantly greater combining ability for SW, CW and SP. These lines that indicated good nature and magnitude of GCA are good combiners for these traits. Also they have high $\hat{\sigma}_g^2$ and $\hat{\sigma}_s^2$ for SW and CW, therefore there are specific combinations of lines 111 and 113 with other lines which yield considerably more than be expected and other combinations which yield less than expected. In this view, they are better parents for creating high-yielding specific combinations, as high $\hat{\sigma}_s^2$ arises mainly from its highly differential ability to transmit its characters (genes) into its hybrid progenies. The highest value of GCA of pupation rate is for line 110 from first program. The $\hat{\sigma}_g^2$ of line 110 is high and positive,while the $\hat{\sigma}_s^2$ is negative. Therefore line 110 can be used when viability is important and it can probably transmit its high capacity to its progenies. Also maybe it is suitable for partaking in the production of a synthetic variety. In order to using the superior of these lines, they should be tested more thoroughly.

Estimated values of SCA are presented in Table 3. Comparison of SCA related to crosses between Japanese lines with Chinese lines showed that 111 and 113 combined with all of Chinese lines had high positive SCA for SW and CW. For 107 and 109 only 107 × 114 and 109 × 110 had high positive significant SCA for SW, CW and PR. The parents of hybrid 109 × 110 with high positive SCA had negative but significant GCA for CW and SW. Totally, the parents with high positive GCA for SW and CW indicated positive SCA for SW, CW, SP and PR. Line 110 with high positive GCA for PR was combined with Japanese lines, except for 107, showed positive SCA too. Heterosis percentages based on mid parental values are presented in Table 3. The comparison of the hybrids indicated that high SW heterosis correlates with high CW and SP heterosis. Hybrids with high heterosis had high SCA too. It means we can use estimates of hetrosis instead of SCA.

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