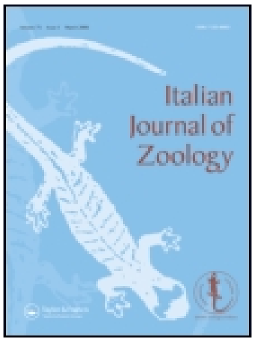

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Combining ability of seven silk technological characters in mulberry silkworm, *Bombyx mori*

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Combining ability of seven silk technological characters in mulberry silkworm, *Bombyx mori*

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ABSTRACT

The combining ability (abbreviated, CA) effects of five races (KA, CC1, CA2, NB4D2 and NB18) of mulberry silkworm *Bombyx mori* and their 20 F_1's, including reciprocals, were analyzed in a 5×5 diallelic crossing system for the following seven silk technological characters: cocoon weight, shell weight, cocoon shell ratio, raw silk percentage, silk filament length, silk reelability and silk neatness. The parental race CA2 did not show the best general CA for any of these seven characters, whereas the other parental races did for different characters as follows: race KA for raw silk percentage, silk filament length, silk reelability and silk neatness; race CC1 for cocoon weight, shell weight, and cocoon shell ratio; race NB4D2 for cocoon weight, raw silk percentage; race NB18 for cocoon shell ratio. Values of race CA2 for general CA were negative for cocoon weight, shell weight, cocoon shell ratio and raw silk percentage, and were low for silk filament length, silk reelability and silk neatness. This indicated a poor performance of this race in hybrid combinations with the remaining races. The results of specific CA effects suggested the restricted use of race CA2 as a female parent in hybrid combinations with males of races NB18 or NB4D2. Crosses CA2 × NB4D2 and CA2 × NB18 showed the desired positive specific CA effects for all characters except silk reelability and silk neatness, respectively. Cross CC1 × NB4D2 showed desired positive specific CA effects for all characters. Variances of general and specific CA revealed that the non-additive type of gene control plays a predominant role in the inheritance of all the seven characters analyzed. The races and crosses showing best values of general and specific CA effects will be used in future breeding programmes.

KEY WORDS: Silk technological characters - Non-additive gene control - Combining ability.

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INTRODUCTION

Commercial exploitation of mulberry silkworm *Bombyx mori* yielded 92 743 tons of global raw silk production in 1992. India is the second largest producer of mulberry raw silk (13 000 tons in 1992) in the world, next only to the China (Datta, 1994). Some European countries, like France, Italy and Spain which formerly had large-scale sericulture, are no longer engaged in rearing the silkworm, although Italy is still the most technologically advanced silk processing country in the world.

The standard breeding methodology for improvement of silk yield attributes has been limited to very few genetic investigations of strain differences and selection from induced variability (Nacheva, 1980, 1989; Gamo & Hirabayashi, 1983; Petkov *et al.*, 1984; Pershad *et al.*, 1986a, b; Jeong, 1989; Bhargava *et al.*, 1993a, b, c, d, 1994; Chatterjee & Datta, 1993; Thiagarajan *et al.*, 1993a, b; Bhargava, 1995a, b, c). Exploitation of heterosis (Kremky, 1970; Bhargava *et al.*, 1993a, b) and the selection of parents for hybridization on the basis of their combining ability (Kremky, 1970; Pershad *et al.*, 1986a; Bhargava *et al.*, 1992; Bhargava, 1995b) are possible methods for the genetic improvement of *Bombyx mori*. The diallelic crossing system (Griffing, 1956) is one of the best approaches in assessing the nicking ability of parents. This aids in selecting the parents which when crossed would give rise to more desirable segregants.

For improving the silk technological characters, identification of parental races through combining ability is essential before utilizing them in future breeding programmes. General and specific combining ability (hereafter abbreviated as general and specific CA) were defined by Sprague & Tatum (1942). The former is the average performance of a line or race in hybrid combinations; the latter designates those crosses that performed relatively better, or worse, than would be expected on the basis of average performance of the parents involved. The purpose of the present investigation was to study the type of gene control involved in the inheritance of silk technological characters and to identify the superior races and/or crosses for utilization in silkworm breeding programmes.

MATERIALS AND METHODS

Five inbred races of the silkworm (*Bombyx mori*), namely KA, CC1, CA2, NB4D2 and NB18, formed the material of the present study. Crosses in all possible combinations, including reciprocals, were made from the five parents. Thus, 20 F_1's along with their five parents were reared during July-August 1994, under standard rearing conditions as described in an earlier paper (Bhargava *et al.*, 1993c). For each race/cross, three replications were made. A replication refers to the whole population of silkworms hatched out of one egg laying. The observations were made on the following seven silk technological characters. (1) Cocoon weight. (2) Shell weight (*Cg*); the mean weight of 10 male and 10 female cocoons and cocoon shells for each replication was considered as the weight of a cocoon and shell; a total of 30 specimens (n = 30) in each parental race and

F_1 were examined. (3) Cocoon shell ratio (the ratio of shell weight to the cocoon weight expressed in percentage). (4) Raw silk percentage (silk is obtained in the form of a long filament or fibre from the outer cocoon shell through the reeling process with the semi-automatic machine; the value denotes the percentage of raw silk reeled from the cocoons). (5) Silk filament length (*m*). (6) Silk reelability (%), which is the percentage of silk fibre reeled easily without any breakage. (7) Silk neatness (%). The average values for four silk technological characters, namely, raw silk percentage, silk filament length, silk reelability, and silk neatness were obtained from the reeling results of cocoons made through the standard reeling process as described in an earlier paper (Bhargava, 1995b).

Data recorded on all seven characters were subjected to combining ability analysis using Model-1 and Method-1 of Griffing (1956). The type of gene control in the inheritance of these characters was noted from the predictability ratio ($2\ \sigma^2g/2\ \sigma^2g + \sigma^2s$) as described by Baker (1978), where σ^2g and σ^2s are known as general and specific CA variances, respectively. General Ca effects of the five races were compared through LSD (least significant difference). A race is found to be significantly superior ($P < 0.05$ and 0.01) when its general CA effect exceeds LSD (g_i) 5 and 1%, respectively. LSD ($g_i - g_j$) 5 and 1% was used in comparing two races. Similarly, LSD (S_{ij}) and LSD (r_{ij}) 5 and 1% were used to find the superiority of a cross and reciprocal, respectively.

RESULTS AND DISCUSSION

Analysis of variance for combining ability

As shown in Table I, differences ($P < 0.05$ and 0.01) were observed for general CA (cocoon weight, shell weight, silk filament length, silk reelability, and silk neatness), specific CA (cocoon weight, shell weight, raw silk percentage, silk filament length, and silk reelability), reciprocal differences (cocoon weight, cocoon shell ratio and silk neatness). None of the characters except cocoon weight (0.8666), showed near to unity the predictability ratio.

General combining ability effects

The parental race CA2 did not show the best general CA for any of the seven characters (Table II). Values of race CA2 were negative for cocoon weight, shell weight, cocoon shell ratio, raw silk percentage, and were low for silk filament length, silk reelability and silk neatness. That of the remaining parental races for different characters was as follows: KA (raw silk percentage, silk filament length, silk reelability, and silk neatness); CC1 (cocoon weight, shell weight, and cocoon shell ratio); NB4D2 (cocoon weight and raw silk percentage); NB18 (cocoon shell ratio).

Specific combining ability effects

The desired specific CA effects were expressed by three out of 10 F_1's (Table III), namely CC1 × NB4D2 (all characters); CA2 × NB4D2 (all characters except silk reelability); CA2 × NB18 (all characters except silk neatness).

Reciprocal differences

Only NB4D2 × CA2 showed appreciable reciprocal differences (Table IV) for cocoon weight, shell weight, cocoon shell ratio, silk filament length, and silk neatness.

The results shown in Table I indicate that while in the case of cocoon weight it is the additive type of gene control that plays a predominant role, in the remaining characters it is the non-additive one. Our results are partly in agreement with the earlier reports on this subject. For example, Bhargava (1995b) also noticed high specific CA variances compared to general ones for shell weight, raw silk percentage, silk filament length, and silk

TABLE I - *Analysis of variance of combining ability and estimates of variance components for silk technological characters in the silkworm* Bombyx mori.

Source of variation	DF	Mean squares						
		Cocoon weight	Shell weight	Cocoon shell ratio	Raw silk percentage	Silk filament length	Silk reelability	Sil neatness
G.CA	4	0.00500*	4.5135**	0.3225	0.3612	11881.75*	26.4150**	9.2375*
S.CA	10	0.00780**	5.7861**	0.3550	2.1270**	14345.20**	17.7390*	6.4180
Reciprocal differences	10	0.00830**	3.0434*	0.5376*	0.3106	2290.75	2.9780	9.3425*
Error	48	0.00187	1.1010	0.1703	0.3010	4176.14	5.5030	3.6277
G.CA variance (σ^2g)		-0.01500	-0.1049	-0.00237	-0.1679	-184.66	0.9259	0.2952
S.CA variance (σ^2s)		0.00462	3.4440	0.1099	1.0869	7710.21	7.2830	3.8202
$2\ \sigma^2g/(2\ \sigma^2g + \sigma^2s)$		0.8666	-0.0649	-0.0451	-0.4471	-0.05	0.2027	0.1339

* and **: significant at 5% and 1% level, respectively.

TABLE II - *Estimates of the general combining ability effects for seven silk technological characters in the silkworm* Bombyx mori.

Characters	Parents					LSD(g_i) 5%	LSD(g_i) 1%	LSD(g_i--g_j) 5%	LSD(g_i--g_j) 1%
	KA	CC1	CA2	NB4D2	NB18				
Cocoon weight	-0.0202	0.0256**	-0.0135	0.0164*	-0.0083	0.0140	0.0186	0.0222	0.0295
Shell weight	-0.6328	0.9002**	-0.7038	0.2612	0.1752	0.3386	0.4494	0.5355	0.7105
Cocoon shell ratio	-0.1188	0.1952**	-0.2198	-0.0238	0.1672*	0.1332	0.1767	0.2106	0.2795
Raw silk percentage	0.2898**	-0.0242	-0.1362	0.0638**	-0.1932	0.0275	0.0365	0.2800	0.3715
Silk filament length	49.1800**	2.6800	1.9800	-6.0200	-47.8200	12.0410	15.9770	19.0390	25.2630
Silk reelability	2.3370**	-0.6400	0.6660	-2.0360	-0.3270	0.7570	1.0050	1.1970	1.5880
Silk neatness	1.4712**	-0.2468	0.3722	-0.6338	-0.9638	0.6147	0.8156	0.9718	1.2897

* and **: significant at 5% and 1% level, respectively.

TABLE III - *Estimates of the specific combining ability effects for seven silk technological characters in the silkworm* Bombyx mori.

Crosses	Characters						
	Cocoon weight	Shell weight	Cocoon shell ratio	Raw silk percentage	Silk filament length	Silk reelability	Silk neatness
KA × CC1	-0.0114	-0.5292	-0.1522	-0.3688	-6.88	-1.035	0.4638
KA × CA2	0.0197	-0.5702	-0.5022	-0.0568	18.82	-3.406	0.5088
KA × NB4D2	-0.0517	-0.3952	0.3368**	-1.1218	-19.18	-2.739	1.1008
KA × NB18	-0.0550	-1.4342	-0.1892	1.0202**	46.22**	1.812**	1.8458**
CC1 × XCA2	-0.0746	-2.4382	-0.4962	-1.1078	-26.18	-3.009	-2.7732
CC1 × NB4D2	0.0705**	2.5068**	0.5428**	1.5722**	111.32**	2.903**	0.4838
CC1 × NB18	-0.0023	-0.0422	0.0168	0.7392**	80.62**	0.309	0.4780
CA2 × NB4D2	0.0551**	1.1808**	0.0678	0.4842**	81.02**	-1.343	1.8638**
CA2 × NB18	0.0738**	1.8068**	0.1818	0.7312**	70.82**	2.438**	-0.1362
NB4D2 × NB18	-0.0671	-1.6032	-0.1542	-1.4138	-88.68	-0.025	-2.4692
LSD (S_{ij}) 5%	0.0253	0.3267	0.2401	0.3191	21.71	1.365	1.1081
LSD (S_{ij}) 1%	0.0336	0.4335	0.3185	0.4235	28.80	1.811	1.4704
LSD (S_{ii}--S_{jj}) 5%	0.0544	1.3115	0.5158	0.6857	46.63	2.932	2.3806
LSD (S_{ii}--S_{jj}) 1%	0.0722	1.7402	0.6845	0.9099	61.88	3.891	3.1588

* and **: significant at 5% and 1% level, respectively.

reelability. In addition, Krishnaswami *et al.* (1964), Sengupta *et al.* (1974), and Bhargava *et al.* (1992) also observed non-additive gene control to be operating in the inheritance of shell weight. However, the discrepancy between our results and earlier reports (Sengupta *et al.*, 1974; Bhargava *et al.*, 1992; Bhargava, 1995b) on cocoon weight may be due to variations in the genetic make-up of the silkworm races employed.

In conclusion, the races showing best general CA effects indicated their superiority for the characters analyzed. Similarly, the three crosses showing desired specific CA effects indicated their superiority over the others. Obviously, the prospects of exploiting their heterosis are good. The desired reciprocal differences noticed in NB4D2 × CA2 for some characters revealed its superiority over CA2 × NB4D2 for those characters.

TABLE IV - *Estimates of the reciprocal differences for seven silk technological characters in the silkworm* Bombyx mori.

Reciprocals	Characters						
	Cocoon weight	Shell weight	Cocoon shell ratio	Rawn silk percentage	Silk filament	Silk reelability	Silk neatness
CC1 × KA	-0.0540	-0.895	0.075	0.640	-61.50	-1.560	-2.335
CA2 × KA	-0.0200	-0.100	0.140	-0.340	-22.50	0.785	0.670
NB4D2 × KA	-0.1295	-1.660	0.465	-0.025	-15.50	0.460	0.915
NB18 × KA	-0.0495	-0.755	0.110	-0.270	-8.00	-0.310	0.830
CA2 × CC1	-0.0735	-0.195	0.630*	-0.005	-40.00	0.265	-2.330
NB4D2 × CC1	-0.0015	-0.415	-0.185	-0.295	14.50	0.145	-1.250
NB18 × CC1	0.0040	-1.370	-0.730	-0.715	-10.00	2.000	-1.415
NB4D2 × CA2	0.1170	1.615*	0.315	-0.595	35.50	-1.475	1.080
NB18 × CA2	-0.0080	-2.495	-1.160	-0.025	-60.50	-2.195	-1.250
NB18 × NB4D2	-0.0050	-0.400	-0.160	-0.040	43.00	-0.670	-5.250
LSD (r_{ij}) 5%	0.0178	1.358	0.534	0.710	83.63	3.036	2.464
LSD (r_{ij}) 1%	0.0270	2.092	0.823	1.094	128.87	4.678	3.798
LSD (r_{ij}—r_{kl}) 5%	0.0253	1.920	0.755	1.004	118.25	4.293	3.486
LSD (r_{ij}—r_{kl}) 1%	0.0389	2.958	1.164	1.547	182.23	6.616	5.372

* and **: significant at 5% and 1% level, respectively.

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