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Manifestation of Hybrid Vigour and Combining Ability in Polyvoltine x Bivoltine Hybrids of Silkworm, *Bombyx mori* L.

D. Raghavendra Rao*, Ravindra Singh, V. Premalatha, B. K. Kariappa, M. Rekha and K. P. Jayaswal
Central Sericultural Research and Training Institute, Mysore-570 008, Karnataka, India.

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The general and specific combining abilities and hybrid vigour of seven polyvoltine breeds [BL24, BL62, BL65, BL67, BL68, BL69, and Pure Mysore (PM)] with five bivoltine breeds (NB4D2, CSR2, CSR5, CSR18 and CSR19) were evaluated in a line x tester design by analysing six quantitative traits viz., fecundity, yield /10,000 larvae both by number and weight, cocoon weight, shell weight and cocoon shell ratio. ANOVA estimates showed significant effects for all the traits indicating the role of both additive and non- additive gene actions. Estimation of GCA revealed that the breed BL67 exhibited significant positive effects for all the six traits followed by BL68 for four important economic traits viz., fecundity, cocoon weight, shell weight and cocoon shell ratio. Among testers, CSR5 showed significant GCA effects for five traits whereas CSR2 exhibited for shell weight and shell ratio. Three hybrids viz., BL67 x NB4D2 , BL67 x CSR5 and BL67 x CSR19 excelled in four quantitative traits for SCA. Majority of the hybrids expressed positive hybrid vigour for cocoon yield/10,000 larvae by weight, cocoon weight and shell weight. Four hybrids namely PM x NB4D2, BL67 x NB4D2, BL67 x CSR5 and BL67 x CSR19 manifesting positive hybrid vigour for five economic traits were adjudicated as best heterotic hybrids and recommended for commercial exploitation to increase the silk yield.

Key words : *Bombyx mori* L., Combining ability, Hybrid vigour

*To whom correspondence should be addressed.
Central Sericultural Research and Training Institute, Mysore-570 008, Karnataka, India. Tel: (0821) 362406; Fax: (0821) 362845; E-mail: raghavendra_1957@yahoo.com

Introduction

The main aim of the silkworm breeding is not only to synthesise new genotypes but also to adjudicate the productive hybrids for commercial exploitation. India is primarily considered as producer of polyvoltine silk as more than 90% silk produced is either from polyvoltine x polyvoltine or polyvoltine x bivoltine hybrids popularly known as cross breeds (PM x C.Nichi, PM x NB4D2 or Nistari x NB4D2). The silk produced from these hybrids are poor in quality and quantity (Datta, 1984). Several attempts have been made to replace the indigenous polyvoltine races resulted in the isolation of improved polyvoltine breeds viz., Kollegal Jawan, Mysore Princess, Tamilnadu White, Kolar Gold, Hosa Mysore, MY1 and RD1 (Siddu *et al.*, 1969; Pershad *et al.*, 1986; Datta and Pershad, 1988 and Noamani *et al.*, 1990). However, these breeds could not be exploited due to their instability in the field (Kalpana *et al.*, 1998). Keeping in view the above, the silkworm breeders working in polyvoltine breeding laboratory of Central Sericultural research and Training Institute, Mysore initiated few breeding programmes during 1995 which resulted in the evolution of five polyvoltine genotypes viz., BL62, BL65, BL67, BL68 and BL69. In the present study an attempt has been made to know the general combining ability of new genotypes along with BL24 and Pure Mysore, specific combining ability and heterosis of their hybrids by line x tester programme in order to identify potential parents for future breeding programme and to adjudicate best hybrids for commercial exploitation with the farmers to increase silk yield in India.

Materials and Methods

In the present study seven polyvoltine genotypes (BL24, BL62, BL65, BL67, BL68, BL69 and PM) and five bivol-

Table 1. Characteristics of polyvoltine lines and bivoltine testers utilised in the study

Sl. No.	Lines	Origin	Larval pattern	Cocoon characters
1	BL24	Evolved at CSR&TI, Mysore, India	Plain, bluish white	Dark greenish yellow, oval with coarse grains.
2	BL62	do	Plain, bluish white	Light greenish yellow, oval with coarse grains.
3	BL65	do	Plain, bluish white	Light greenish yellow, oval with coarse grains.
4	BL67	do	Plain, bluish white	Light greenish yellow, oval with medium to coarse grains.
5	BL68	do	Plain, bluish white	Light greenish yellow, elongated oval with coarse grains.
6	BL69	do	Plain, bluish white	Light greenish yellow, oval with coarse grains.
7	Pure Mysore	Karnataka, India	Plain, bluish white	Light greenish yellow, spindle shape with flossy cocoons.
Testers				
1	NB4D2	Evolved at CSR&TI, Mysore, India	Plain bluish white	Dumbbell cocoons,white with medium to coarse grains.
2	CSR2	do	Plain bluish white	Oval with round ends,white with fine to medium grains.
3	CSR5	do	Plain, creamish white	Dumbbell, creamish white with medium to coarse grains.
4	CSR18	do	Sex-limited, male plain and female marked, dull white.	Oval, creamish white cocoons with coarse grains.
5	CSR19	do	Sex-limited, male plain and female marked, dull white.	Dumbbell, creamish white cocoons with coarse grains.

tine breeds viz., NB4D2, CSR2, CSR5, CSR18 and CSR19 were used as lines and testers respectively and prepared 35 hybrid combinations. Characteristics of polyvoltine lines and bivoltine testers are presented in Table 1.

The F1 hybrids along with lines and testers were reared following Completely Randomized Design (CRD) with three replications each and 300 larvae in each replication. A standard schedule of silkworm rearing was followed as suggested by Krishnaswami (1978). The General Combining Ability (GCA) of lines and testers as well as Specific Combining Ability (SCA) and Heterosis of the hybrids were evaluated with respect to fecundity, cocoon yield /10,000 larvae both by number and weight, cocoon weight shell weight and shell ratio. The data obtained on the performance of each one of the metric traits were pooled and subjected to stastistical analysis as suggested by Kempthorne (1957) to evaluate GCA of lines and testers, SCA and heterosis of hybrids as detailed below:

1. General combining ability:

a) Lines $gi = \frac{Xi}{tr} - \frac{X}{ltr}$, $i = 1$ to 1

b) Testers $gj = \frac{Xj}{lr} - \frac{X}{ltr}$, $j = 1$ to 1

2. Specific combining ability:

Hybrids $Sij = \frac{Xij}{r} - \frac{Xi}{tr} - \frac{Xj}{lr} + \frac{X}{ltr}$

Where
gi = General combining ability of lines
gj = General combining ability of testers
Sij = Specific combining ability of hybrids
l = Number of lines
t = Number of testers
r = Number of replications
Xi = Performance of i^{th} line with t testers
Xj = Performance of j^{th} tester with l lines
Xij = Performance of $(i \times j)^{th}$ hybrid
X = Grand total

3. Heterosis:

$$\text{Heterosis} = \frac{F1 - MP}{MP} \times 100$$

Table 2. Mean performance of multi x bi hybrids of silkworm, *Bombyx mori*

Sl. No.	Hybrid/ Combination	Fecundity	Yield/10,000 larvae		Cocoon weight (g)	Shell weight (g)	Shell ratio (%)
			By No.	By Wt. (kg)			
1	BL62 x NB4D2	478	8566	15.655	1.976	0.363	18.37
2	BL62 x CSR2	475	9510	14.437	1.898	0.358	18.87
3	BL62 x CSR5	427	9055	15.584	1.890	0.389	20.60
4	BL62 x CSR18	451	9044	18.547	2.078	0.407	19.57
5	BL62 x CSR19	471	8277	16.069	2.028	0.393	19.40
6	BL65 x NB4D2	453	8666	15.259	1.850	0.365	19.70
7	BL65 x CSR2	401	8599	15.184	1.971	0.404	20.50
8	BL65 x CSR5	424	8833	16.331	2.017	0.416	20.60
9	BL65 x CSR18	442	8410	14.123	1.877	0.389	20.73
10	BL65 x CSR19	435	8655	14.158	1.916	0.388	20.23
11	BL67 x NB4D2	469	9133	18.281	2.038	0.412	19.83
12	BL67 x CSR2	433	8921	18.178	2.054	0.400	19.47
13	BL67 x CSR5	514	8699	17.315	2.115	0.427	20.20
14	BL67 x CSR18	445	8455	16.636	2.020	0.402	19.87
15	BL67 x CSR19	506	9522	17.860	1.804	0.390	21.57
16	BL68 x NB4D2	435	7855	16.755	2.133	0.406	19.37
17	BL68 x CSR2	434	8344	15.972	1.913	0.414	19.87
18	BL68 x CSR5	468	7788	15.637	2.017	0.381	19.90
19	BL68 x CSR18	523	8466	15.132	1.913	0.402	19.57
20	BL68 x CSR19	512	8799	15.057	1.903	0.375	19.40
21	BL69 x NB4D2	413	8766	15.455	1.807	0.369	18.90
22	BL69 x CSR2	428	7988	14.654	1.890	0.342	20.30
23	BL69 x CSR5	476	8766	14.336	1.909	0.384	20.47
24	BL69 x CSR18	448	7688	14.754	1.926	0.391	19.80
25	BL69 x CSR19	423	8266	14.184	1.927	0.382	19.53
26	PM x NB4D2	437	9066	16.284	1.989	0.365	18.33
27	PM x CSR2	419	8977	16.222	1.979	0.366	18.43
28	PM x CSR5	400	9355	16.990	1.985	0.359	18.07
29	PM x CSR18	371	8533	15.420	1.784	0.330	18.47
30	PM x CSR19	375	8933	16.826	1.800	0.340	18.07
31	BL24 x NB4D2	489	8933	16.765	1.881	0.328	17.37
32	BL24 x CSR2	440	8655	16.783	1.973	0.401	20.32
33	BL24 x CSR5	530	8655	15.935	1.995	0.359	17.97
34	BL24 x CSR18	443	8388	15.317	2.003	0.369	18.40
35	BL24 x CSR19	470	8622	16.209	1.823	0.311	17.06

Results

Per se performance of 35 F1 hybrids and ANOVA of combining ability computed for six traits are presented in Table 2 and 3 respectively. Perusal of data revealed that a great deal of variation was observed in all the traits of F1 hybrids such as fecundity of F1 hybrids ranged from 401 (BL65 x CSR2) to 530 (BL24 x CSR5), cocoon yield/ 10,000 larvae by number ranged from 7688 (BL69 x CSR18) to 9522 (BL67 x CSR19), cocoon yield/10,000 larvae by weight ranged from 14.123 kg (BL65 x CSR18) to 18.547 kg (BL62 x CSR2), cocoon weight ranged from 1.800 g (PM x CSR18) to 2.138 g (BL68 x NB4D2), shell weight the ranged is from 0.311 g (BL24 x CSR19) to 0.427 g (BL67 x CSR5) whereas Shell ratio ranged from 17.06% (BL24 x CSR19) to 21.57% (BL67 x CSR19). Analysis of variance for combining ability computed for six quantitative traits exhibited highly significance vari-

Table 3. ANOVA for combining ability of six characteristics in some multi x bi hybrids of silkworm

Source of variation	D.f.	Fecundity	Yield /10,000 larvae		Cocoon weight	Shell weight	Shell ratio
			By no.	By Wt.			
Replications	2	314.9066	6530.8886	0.00594	0.2565	0.05300	0.27438
Crosses	34	4448.735**	600229.497**	4.77574**	0.02246**	0.00230**	3.47282**
Lines	6	12275.987**	1180048.78*	9.49289*	0.02304	0.00552**	9.90241**
Testers	4	2635.7	423205.22	0.47033	0.02306	0.00248	3.05276
Line x Tester	24	2794.094**	484778.739**	4.31403**	0.02222**	0.00147**	1.93543**
Error	38	403.086	83980.817	0.11413	0.00154	0.00005	0.07115
Total	104	1778.509	263698.810	1.63604	0.00884	0.00079	1.18714

*, ** Significant at 5% and 1% level respectively.

Table 4. Contribution of lines, testers and line x testers in the present study

	FEC.	Yield/10,000 larvae		SCWT.	SSWT.	SR%
		By No.	By Wt.(kg)			
Lines	48.6959	34.6940	35.0776	18.1052	42.3166	50.3189
Testers	6.9701	8.2950	1.1586	12.0783	12.6853	10.3417
Line x testers	44.3340	57.0110	63.7638	69.8165	44.9982	39.3394

ances for crosses, lines and line x testers whereas testers did not exhibit any variability for all the component traits. Percent contribution of lines, testers and line x testers is presented in Table 4. It is evident from the data that contribution percentage of lines was more for the traits like fecundity (48.69) and shell ratio (50.31) whereas line x tester possesses high contribution for cocoon yield/10,000 larvae both by number and weight, (57.01 and 63.76), cocoon weight (69.81) and shell weight (44.99). Testers contribution was minimum for all the traits studied.

General Combining Ability (GCA)

Expression of general combining ability of lines and testers are presented in Table 5. From the data it is clear that the genotype BL67 exhibited significant GCA effects for all the six traits followed by BL68 for four traits viz., fecundity, cocoon weight, shell weight and shell ratio. Among testers, CSR5 exhibited desirable GCA effects for five traits viz., fecundity, cocoon yield/10,000 larvae by weight, cocoon weight, shell weight and shell ratio where as CSR2 exhibited significant positive GCA effects for shell weight and shell ratio only.

Table 5. General combining ability effects of lines and testers utilised in the present studies

Sl. No.	Lines	Fecundity	Yield/10,000 larvae		Cocoon weight	Shell weight	Shell ratio
			By No.	By Wt. (kg)			
1	PM	-49.676	296.571**	0.353**	-0.024	-0.027	-1.157
2	BL24	24.390**	-25.695	0.354**	-0.013	-0.021	-1.010
3	BL62	8.457	214.238*	0.210	0.027*	0.003	-0.070
4	BL65	-18.943	-43.495	-0.837	-0.021	0.013**	0.923**
5	BL67	16.924*	269.771*	1.208**	0.059**	0.027**	0.756**
6	BL68	31.257**	-425.695	-0.137	0.028*	0.009**	0.190*
7	BL69	-12.410	-285.695	-1.151	-0.056	-0.004	0.370**
TESTERS							
1	NB4D2	2.295	104.124	-0.087	0.006	-0.009	-0.592
2	CSR2	-17.276	37.410	0.071	0.006	0.008**	0.389**
3	CSR5	12.914*	59.743	0.228*	0.042**	0.013**	0.255*
4	CSR18	4.867	-249.876	-0.144	-0.004	0.000	0.055
5	CSR19	-2.800	48.600	-0.067	-0.050	-0.012	-0.107

*, ** Significant at 5% and 1% level respeectively.

Table 6. Specific combining ability effects in poly x bi hybrids of silkworm

Sl. No.	Hybrid/ Combination	Fecundity	Yield/ 10,000 larvae		Cocoon weight	Shell weight	Shell ratio
			By No.	By Wt.			
1	BL62 x NB4D2	7.638	-428.52	-0.316	-0.004	-0.010	-0.401
2	BL62 x CSR2	33.876**	582.52**	-1.692	-0.083	-0.032	-0.882
3	BL62 x CSR5	44.314**	104.86	-0.702	0.126**	-0.006	0.985**
4	BL62 x CSR18	34.219**	-306.34	-0.968	0.067**	0.008*	-0.242
5	BL62 x CSR19	15.400	-662.00	0.078	0.104**	0.023**	0.147
6	BL65 x NB4D2	19.371	-70.79	0.335	-0.082	-0.018	-0.061
7	BL65 x CSR2	-12.390	-70.74	0.102	0.038	0.003	-0.242
8	BL65 x CSR5	-19.581	140.26	1.092**	0.048*	0.011**	-0.009
9	BL65 x CSR18	5.800	27.54	-0.744	-0.045	-0.003	0.325*
10	BL65 x CSR19	6.800	-26.27	-0.785	0.040	0.008*	-0.013
11	BL67 x NB4D2	34.105**	-10.85	-1.968	0.060*	0.022**	0.652**
12	BL67 x CSR2	-16.924	-62.01	1.052**	0.042	-0.015	-1.109
13	BL67 x CSR5	-12.600	403.14*	2.632**	0.108**	0.024**	0.151
14	BL67 x CSR18	-19.400	-241.39	-0.276	0.018	-0.004	-0.375
15	BL67 x CSR19	-14.495	-499.59	1.132**	0.151**	0.035**	0.339*
16	BL68 x NB4D2	33.933**	527.13**	-1.128	-0.152	-0.004	1.487**
17	BL68 x CSR2	-30.257	55.79	0.190	-0.069	-0.016	-0.142
18	BL68 x CSR5	-26.114	-521.88	-0.301	-0.001	0.001	0.025
19	BL68 x CSR18	37.267**	465.41**	-0.435	-0.059	-0.013	-0.109
20	BL68 x CSR19	33.600**	500.27**	-0.587	-0.023	-0.007	-0.113
21	BL69 x NB4D2	-26.829	749.08**	-1.154	-0.091	-0.024	-0.308
22	BL69 x CSR2	7.410	-439.54	-0.114	-0.008	0.000	0.111
23	BL69 x CSR5	25.886*	315.79	-0.588	-0.025	0.003	0.411*
24	BL69 x CSR18	5.600	-452.26	0.201	0.039	0.007	-0.055
25	BL69 x CSR19	-12.067	-173.07	1.654**	0.085**	0.014**	-0.160
26	PM x NB4D2	-31.829	82.61	1.320**	0.026	0.015**	0.239
27	PM x CSR2	35.676	-32.81	-0.050	0.049*	0.005	-0.229
28	PM x CSR5	-12.848	322.52	1.962**	0.019	-0.006	-0.462
29	PM x CSR18	-34.133	-190.19	-0.637	-0.135	-0.022	0.138
30	PM x CSR19	-22.800	-88.67	0.692**	0.007	0.000	-0.100
31	BL24 x NB4D2	12.038	178.08	0.650**	-0.060	-0.020	-0.461
32	BL24 x CSR2	-17.390	-33.21	0.511*	0.031	0.055**	2.491**
33	BL24 x CSR5	42.752**	-55.21	-0.494	0.018	-0.012	-0.709
34	BL24 x CSR18	-35.867	-12.26	-0.741	0.073**	0.011**	-0.075
35	BL24 x CSR19	-1.533	-77.40	0.075	-0.062	-0.034	-1.247

*, ** Significant at 5% and 1% level respectively.

Specific Combining Ability (SCA)

Specific combining ability effects for 35 F1 hybrids have been presented in Table 6. None of hybrids expressed consistent SCA for all the traits. However, three hybrids viz., BL67 x NB4D2, BL67 x CSR5 and BL67 x CSR19 expressed significant positive SCA for four component traits and six hybrids viz., BL62 x CSR2, BL62 x CSR5, BL65 x CSR5 BL68 x NB4D2, BL69 x NB4D2 and BL24 x CSR2 expressed with respect to three component traits. Eleven hybrids did not exhibit any effects for all the six traits studied.

Hybrid Vigour

Manifestation of hybrid vigour in 35 F1 polyvoltine x

Table 7. Heterotic effects in poly x bi hybrids over mid parent value

Sl. No.	Hybrid/ Combination	Fecundity	Yield/ 10,000 larvae		Cocoon weight	Shell weight	Shell ratio
			By No.	By Wt.			
1	BL62 x NB4D2	-12.45	-4.46	6.68**	26.40**	28.99**	2.61*
2	BL62 x CSR2	-7.64	7.88**	7.81**	26.23**	15.90**	-7.67
3	BL62 x CSR5	-22.47	-0.03	8.66**	24.16**	28.78**	4.83**
4	BL62 x CSR18	-12.74	-0.06	40.95**	42.04**	51.65**	6.92**
5	BL62 x CSR19	-3.94	-8.03	24.32**	44.26**	51.35**	4.86**
6	BL65 x NB4D2	-3.75	-2.44	5.97**	17.72**	25.82**	7.16**
7	BL65 x CSR2	-10.74	-1.53	15.77*	30.34**	27.11**	-1.99
8	BL65 x CSR5	-12.71	-1.58	16.10**	31.69**	33.76**	2.32*
9	BL65 x CSR18	-2.25	-6.20	9.63**	27.55	40.64**	10.38**
10	BL65 x CSR19	2.19	-2.93	11.93**	35.42**	44.47**	6.58**
11	BL67 x NB4D2	10.71**	-5.14	11.95**	22.19**	35.05**	9.82**
12	BL67 x CSR2	-6.61	-2.58	28.17**	32.44**	25.22**	-5.27
13	BL67 x CSR5	14.66**	-0.85	13.35**	26.17**	37.21**	7.68**
14	BL67 x CSR18	1.21	1.93	15.63**	24.09**	44.62**	15.85**
15	BL67 x CSR19	8.62**	-9.97	19.26**	33.68**	44.64**	7.87**
16	BL68 x NB4D2	-4.51	-11.15	11.46**	28.06**	42.32**	11.20**
17	BL68 x CSR2	-7.82	-4.00	16.16**	19.14**	19.46**	-0.42
18	BL68 x CSR5	-7.69	-12.81	6.38**	24.16**	28.92**	3.83**
19	BL68 x CSR18	-9.64	-1.88	18.25**	26.50**	41.50**	10.08**
20	BL68 x CSR19	2.83	-7.45	7.81**	34.68**	36.82**	2.19
21	BL69 x NB4D2	-14.45	-4.53	3.51	17.09**	25.81**	8.21**
22	BL69 x CSR2	-7.46	-5.74	25.07**	27.42**	27.96**	1.50
23	BL69 x CSR5	-4.48	0.57	13.18**	27.08**	33.45**	6.50**
24	BL69 x CSR18	-3.52	-11.71	28.49**	33.50**	47.71**	10.82**
25	BL69 x CSR19	-6.89	-1.51	-0.84	39.53**	53.90**	13.64**
26	PM x NB4D2	-3.53	7.18**	44.75**	39.06**	50.47**	8.12**
27	PM x CSR2	-6.61	-0.86	24.95**	44.89**	37.90**	-1.25
28	PM x CSR5	-17.42	0.63	31.99**	43.30**	38.97**	1.03
29	PM x CSR18	-17.63	-8.13	20.95**	34.59**	47.36**	11.69**
30	PM x CSR19	-11.70	-3.31	34.43**	48.21**	57.81**	7.97**
31	BL24 x NB4D2	0.07	-7.48	6.98**	20.79**	19.35**	0.87
32	BL24 x CSR2	-5.98	-8.94	16.64**	31.75**	38.91**	7.85**
33	BL24 x CSR5	5.12	-11.20	3.89*	31.55**	21.28**	-5.27
34	BL24 x CSR18	-5.64	-13.86	8.21**	37.50**	41.06**	4.45**
35	BL24 x CSR19	5.93	-11.01	16.43**	30.21**	22.89**	-4.21

*, ** Significant at 5% and 1% level respectively.

bivoltine hybrids over mid parent value has been presented in Table 7. No single hybrid manifested significant hybrid vigour for all the six characters. Majority of the hybrids expressed significant hybrid vigour for cocoon yield /10,000 larvae by weight, cocoon weight and cocoon shell weight. However, four hybrids viz, BL67 x NB4D2, BL67 x CSR5, BL67 x CSR19 and PM x NB4D2 manifested significant hybrid vigour for five traits whereas 18 and 13 hybrids manifested for four and three traits respectively.

Discussion

Indian sericulture industry is predominantly polyvoltine oriented. The polyvoltine x bivoltine hybrids of silkworm are major source of silk production which contributes more than 95% of total silk produced in India. The silk produced from these hybrids are poor both in quantity and quality. In the present study, an attempt has been made to identify potential parents for future breeding programmes and superior hybrids with high quantitative traits for commercial exploitation. Perusal of the data revealed that great deal of variation exists among 35 hybrids studied. Analysis of variance computed for combining ability revealed that highly significant variances due to crosses, lines and line x testers observed except for cocoon weight among lines indicating the presence of both additive and non-additive gene actions for the expression of these traits and also establishing the existence of genotypic differences for all the traits. The non-significant differences observed among testers can be ascribed to their genetic uniformity and the same is reflected in the percent contribution of testers for different traits. Highly significant variances was observed ($p < 0.01$) for all the traits in line x testers can be attributed to the existence of high degree of divergence among lines. In the present study, percent contribution of lines are high for fecundity and shell ratio whereas line x tester contribution are more for cocoon yield/10,000 larvae both by number and weight, cocoon weight and shell weight. The results are in conformity with that of Razdan *et al.* (1994); Ravindra Singh *et al.* (2000) and Datta *et al.* (2001).

General combining ability effects of seven lines and five testers for six traits are presented in Table 4. It is clear from the data that the line BL67 expressed significant GCA for all the six traits followed by BL68 for four traits viz., fecundity, cocoon weight, shell weight and shell ratio indicating major role of additive gene action for the expression of these traits. Predominant role of additive gene action has been reported for fecundity (Jolly, 1983), total larval period and cocoon yield (Petkov *et al.*, 1975; Subba Rao and Sahai 1989; Sarkar *et al.*, 1991; Ravindra Singh *et al.*, 2001), cocoon weight, shell weight and shell ratio (Satenahalli *et al.*, 1989; Naseema Begum *et al.*, 1997). Among testers the breed CSR5 exhibited significant GCA effects for fecundity, cocoon yield/10,000 larvae by weight, cocoon weight, shell weight and shell ratio whereas CSR2 expressed for shell weight and shell ratio % only. On the contrary, Pershad *et al.* (1988) observed importance of both additive and non-additive gene actions in the inheritance of fecundity, larval span, pupal duration, cocoon yield, shell ratio and filament length while Kumar *et al.* (1994) reported importance of additive and non-additive gene actions for the expression of filament length and effective rate of rearing. Deviation of our results from the above workers may be due to variations in genetic architecture of silkworm breeds utilized in the present study. Different lines exhibited significant GCA effects for different traits. Based on the expression of GCA for different traits, lines can be utilized in the hybridisation programme depending upon specific objectives.

The superiority of F1 hybrids are judged by evaluating the specific combining ability and heterosis. Among 35 hybrids evaluated for six important traits, no single hybrid expressed consistent SCA for all the traits. However, three hybrids viz., BL67 x NB4D2, BL67 x CSR5 and BL67 x CSR19 expressed significant SCA for fecundity, cocoon weight, shell weight, shell ratio; yield/10,000 larvae both by number and weight, cocoon weight, shell weight; yield /10,000 larvae by weight, cocoon weight, shell weight and shell ratio respectively while six hybrids possessed significant SCA for three traits. Eleven hybrids did not show any SCA effects in desired direction. The present results are indicate the presence of non-additive, additive x additive and complimentary gene action for the expression of these traits as the parents involved are high x low, high x high and high x low GCA contributors. The hybrids involving one good general combiner and the other poor or medium combiner can yield desirable transgressive seggregants if the additive effects of one parent and complementary epistatic effects act in the same direction and maximise the desirable attributes (Ram *et al.*, 1986). Similar results were reported by Pershad *et al.* (1986), Bhargava *et al.* (1995), Kalpana and Sreerama Reddy (1998) and Datta *et al.* (2001).

It is clear from Table 7 that among 35 hybrids, no single hybris expressed consistent hybrid vigour for all the traits. Most of the hybrids showed significant hybrid vigour for cocoon yield/10,000 larvae by weight, cocoon weight and shell weight. Four hybrids expressed significant hybrid vigour for five traits and 18 hybrids for four traits. Three hybrids viz., BL67 x NB4D2, BL67 x CSR5 and BL67 x CSR19 expressed significant hybrid vigour for fecundity, cocoon yield/10,000 larvae by weight, cocoon weight, shell weight and shell ratio whereas PM x NB4D2 expressed for cocoon yield/10,000 larvae both by number and weight, cocoon weight, shell weight and shell ratio. Subba Rao and Sahai (1989) have reported significant hybrid vigour for cocoon yield, survival rate, cocoon weight, filament length and filament size in bivoltine hybrids. Recently, Raghavendra Rao *et al.* (2001) have found significant hybrid vigour for cocoon yield by weight, cocoon weight and shell weight in 135 polyvoltine x bivoltine hybrids. Expression of very high hybrid vigour for cocoon weight and shell weight was found between low yielding multivoltine and bivoltine breeds (Rama Mohana Rao *et al.*, 1998).

On the basis of the combining ability of lines, specific combining ability and hybrid vigour of 35 F1 hybrids between polyvoltine and bivoltine breeds for six quantitative traits, the genotype BL67 adjudicated as best followed by BL68. Three hybrids viz., BL67 x NB4D2, BL67 x CSR5 and BL67 x CSR19 have been identified as superior for yield and other contributing traits. These hybrids were evaluated in the laboratory for a period of one year. Based on their performance, the hybrids are submitted for Race Authorisation Test of Central Silk Board for commercial exploitation at farmers level to increase silk yield in India.

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