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Performance of Newly Evolved Bivoltine Silkworm Hybrids of *Bombyx mori* with Reference to Hybrid Vigour

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In the present study, hybrid vigour in terms of heterosis and over dominance of newly evolved bivoltine hybrids and their reciprocals raised from the promising newly evolved bivoltine breeds were calculated for the important parameters like pupation, cocoon yield, cocoon weight, shell weight, shell ratio, raw silk percentage, filament length and neatness. Through there was no significant difference among the hybrids for the characters pupation, cocoon yield and cocoon weight, the magnitude of heterosis and over dominance were varied significantly for these characters. However, significant differences were observed between new hybrids and control hybrid for the characters like cocoon shell weight, cocoon shell ratio, filament length and raw silk percentage. The results indicate that majority of new hybrids have shown higher heterosis and over dominance than control hybrid. The data also indicate that highest mean heterosis of all new hybrids was recorded for cocoon yield followed by filament length. Whereas highest mean over dominance was recorded for cocoon yield followed by cocoon weight. Negative mean heterosis and over dominance were recorded for the trait cocoon shell ratio. Based on the results, the importance of three hybrids *viz*., CSR2 × CSR4, CSR2 × CSR5 and CSR3 × CSR6 and their reciprocals (CSR4 × CSR2, CSR5 × CSR2 and CSR6 × CSR3) which exhibited significant heterosis and over dominance, for commercial exploitation was discussed.

Key words: *Bombyx mori*, New bivoltine hybrids, Hybrid vigour, Heterosis, Over dominance

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Introduction

The superiority of the hybrids is judged by their cocoon yield and yield attributes as compared to their parents. The research work of Toyama in 1917 on the hybridization in silkworms in Japan was a landmark in the history of sericulture (Yokoyama, 1957). Later on many investigators reported the increased hybrid vigour in silkworms (Hirobe, 1957; Harada, 1961; Kobayashi *et al.*, 1968). Similar attempts were also made by several workers in India (Sengupta *et al.*, 1971; Subba Rao and Sahai, 1990).

During last decade quite a good number of promising bivoltine breeds/hybrids were evolved at Central Sericultural Research and Training Institute (Basavaraja *et al.*, 1995). The quantitative and qualitative characters of some of these newly evolved hybrids were well documented (Mano, 1994; Datta *et al.*, 2000a, b, 2001). In light of the above, the present study was undertaken to determine the hybrid vigour with reference to heterosis and over dominance of these newly evolved bivoltine hybrids and also to identify the promising combination for commercial exploitation.

Materials and Methods

Seven promising newly evolved bivoltine F_1 hybrids *viz.*, CSR1×CSR2, CSR2×CSR4, CSR2×CSR5, CSR10×CSR11, CSR12×CSR13 and CSR13×CSR5 and their reciprocals involving six newly evolved Chinese/oval type (CSR1, CSR2, CSR3, CSR10, CSR12 and CSR13) and four Japanese/dumbbell type (CSR4, CSR5, CSR6 and CSR11) bivoltine breeds, were selected. These hybrids were selected out of 161 hybrids studied on the basis of evaluation index (Mano, 1994). The selected hybrids and their reciprocals were reared in three replication of 300 larvae along with the control hybrids (KA×NB_4D_2 and NB_4D_2×KA) and parental breeds of all hybrids as per standard techniques (Krishnaswami, 1978). The desired temperature and humidity schedule were maintained through out the rearing period. The important parameters that govern silk quality and quantity such as pupation, cocoon yield, cocoon weight, shell weight, shell ratio, filament length, raw silk percentage and neatness were considered. Hybrid vigour is calculated in terms of heterosis and over dominance as follows,

$$\text{Heterosis} = \frac{\text{Hybrid value Mid parental value (MPV)}}{\text{Mid parental value (MPV)}} \times 100$$

$$\text{Over dominance} = \frac{\text{Hybrid value Better parental value (BPV)}}{\text{Better parental value (BPV)}} \times 100$$

Mean heterosis and over dominance were calculated for each character by taking into consideration of all new hybrids to assess which character shows maximum heterosis or over dominance.

Results and Discussion

The mean performance of parents and their hybrids, heterosis and over dominance are given in Table 1 to 4 respectively. The perusal of data for the trait pupation in parental breeds shows, the minimum and maximum pupation was recorded in CSR13 (81.2%) and CSR2 (93.0%) respectively. The maximum cocoon yield/10,000 larvae was recorded in CSR2 (18.0 kg), while minimum was observed in CSR3 (14.8 kg). The cocoon weight varied from 1.81 g (CSR3) to 2.07 g (CSR1). The maximum and minimum cocoon shell weight was recorded in CSR12 (49.0 cg) and CSR11 (37.8 cg) respectively. The cocoon shell ratio ranged from 19.4% (KA) to 25.1% (CSR12). The breed CSR12 recorded maximum filament length of 1260 m while KA recorded minimum of 831 m for the trait. The neatness ranged from 90.0 (KA) to 94.0 points (CSR11 and CSR13) (Table 2).

The highest pupation was recorded in CSR4×CSR2 (97.1%) as against KA×NB_4D_2 (92.6%). The cocoon yield ranged from 19.0 kg (CSR4×CSR1) to 21.5 kg (CSR4×CSR2). All the hybrids have recorded the cocoon weight of above 2.0 g. Highest shell weight (53.3 cg) and shell ratio (24.5%) was recorded for CSR6×CSR3 as against KA×NB_4D_2 (43.1 cg and 20.0%) respectively. The raw silk ranged from 16.9% (KA×NB_4D_2) to 21.2% (CSR6×CSR3). The hybrid CSR6×CSR3 has recorded highest filament length of 1315 m as against KA×NB_4D_2 (990 m). The neatness ranged from 91.0 (KA×NB_4D_2) to 95.8 (CSR4×CSR2). Though, there was not much significant difference between new hybrids and control hybrids (KA×NB_4D_2 and NB_4D_2×KA) for the traits pupation, cocoon yield and cocoon weight, significant difference ($p<0.05$) was noticed in respect of cocoon shell weight, cocoon shell ratio, raw silk percentage, filament length and neatness (Table 2).

As presented in the Table 3, most of the hybrids showed significant heterosis for the traits *viz*., pupation, cocoon weight, cocoon shell weight, filament length, raw silk percentage and neatness. Out of 14 new hybrids studied, sig-

Table 1. Performance of parental breeds (mean of 3 trials)

Sl no.	Breeds	Pupation (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg.)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Neatness (p)
1	CSR1	85.7	17.7	2.07	45.7	22.1	17.5	1195	92.5
2	CSR2	93.0	18.0	1.95	46.8	24.0	18.8	1048	90.5
3	CSR3	81.4	14.8	1.81	45.2	25.0	17.0	1148	89.0
4	CSR4	87.2	16.3	1.88	41.0	21.8	16.4	907	93.3
5	CSR5	81.3	15.0	1.89	44.0	23.3	17.4	888	93.3
6	CSR6	85.3	16.8	1.93	45.6	23.7	18.6	1108	93.8
7	CSR10	88.3	17.2	1.94	42.5	21.9	15.7	997	93.3
8	CSR11	92.0	16.9	1.82	37.8	20.8	17.0	837	94.0
9	CSR12	83.8	15.9	1.95	49.0	25.1	18.3	1260	92.9
10	CSR13	81.2	16.0	2.01	48.5	24.1	18.5	1240	94.0
11	KA (Control)	81.8	16.8	2.05	39.8	19.4	13.1	831	90.0
12	NB_4D_2 (Control)	92.0	17.9	1.93	41.1	21.3	15.2	975	91.0
	CD at 5%	8.2	1.97	0.08	2.6	1.05	1.2	52	3.6

Table 2. Performance of hybrids (mean of 3 trials)

Sl no.	Hybrid	Pupation (%)	Cocoon yield (kg)	Cocoon weight (g)	Shell weight (cg.)	Shell ratio (%)	Raw silk (%)	Filament length (m)	Neatness (p)
1	CSR1 × CSR4	94.9	20.3	2.09	44.1	21.1	17.8	1080	93.8
2	CSR4 × CSR1	91.1	19.0	2.11	44.7	21.1	18.1	1051	94.5
3	CSR2 × CSR4	94.9	20.7	2.17	49.1	22.7	19.8	1174	95.0
4	CSR4 × CSR2	97.1	21.5	2.22	51.0	23.0	19.3	1139	95.8
5	CSR2 × CSR5	96.7	20.5	2.16	51.3	23.8	20.2	1164	95.05
6	CSR5 × CSR2	96.6	20.6	2.15	52.1	24.2	20.3	1184	95.5
7	CSR3 × CSR6	95.3	20.1	2.12	52.0	24.5	20.8	1300	94.3
8	CSR6 × CSR3	94.7	20.6	2.18	53.3	24.5	21.2	1315	95.5
9	CSR10 × CSR11	94.8	20.6	2.12	45.3	21.4	18.4	1105	95.0
10	CSR11 × CSR10	93.9	20.	2.17	46.3	21.4	18.1	1095	94.2
11	CSR12 × CSR6	92.3	19.4	2.09	50.7	24.3	21.1	1273	93.7
12	CSR6 × CSR12	91.5	19.1	2.08	50.1	24.1	20.4	1285	93.8
13	CSR13 × CSR5	93.0	19.2	2.04	49.1	24.1	20.6	1247	95.0
14	CSR5 × CSR13	94.4	20.3	2.09	49.5	23.7	20.6	1216	95.2
15	KA × NB_4D_2 (C)	92.6	19.7	2.15	43.1	20.0	16.9	990	91.0
16	NB_4D_2 × KA (C)	93.5	19.7	2.18	43.9	20.1	17.3	1012	91.0
	CD at 5%	–	–	–	3.4	0.6	0.8	87	–

C, Control hybrid.

Table 3. Heterosis for eight economic traits in the hybrids (mean of 3 trials)

Sl no.	Hybrid	Pupation	Cocoon yield	Cocoon weight	Shell weight	Shell ratio	Raw silk	Filament length	Neatness	No. of traits
1	CSR1 × CSR4	9.76*	18.85*	6.03	1.73	–4.02	5.01	2.76	0.97	2
2	CSR4 × CSR1	5.34	11.46	6.89	3.11	–3.50	6.78	0.0	1.72*	1
3	CSR2 × CSR4	5.32	20.51*	13.05*	11.80*	–0.87	12.50*	20.10*	3.37*	5
4	CSR4 × CSR2	7.83	25.52*	15.93*	16.17*	0.44	9.66*	16.52*	4.24*	6
5	CSR2 × CSR5	10.97*	24.59*	12.30*	13.00*	0.42	11.60*	20.25*	3.92*	7
6	CSR5 × CSR2	10.90*	25.14*	12.19*	18.68*	2.11	12.15*	22.31*	3.92*	6
7	CSR3 × CSR6	14.31*	28.03*	13.77*	14.54*	0.41	16.85*	15.25	3.17*	6
8	CSR6 × CSR3	13.60*	30.98*	16.67*	15.40*	0.41	19.10*	16.58*	4.49*	6
9	CSR10 × CSR11	5.16	9.66	12.82*	12.83*	0.09	6.42	11.78	1.44*	3
10	CSR11 × CSR10	4.10	10.25	15.48*	15.32*	–0.06	5.20	10.58	0.59	2
11	CSR12 × CSR6	8.20	17.06*	7.09	5.92	–1.07	14.05*	7.52	0.48	2
12	CSR6 × CSR12	9.22	19.01*	7.76	7.19	–0.51	10.27*	8.50	0.37	2
13	CSR13 × CSR5	14.42*	22.09*	4.64	6.16	1.51	6.96	13.72	1.44*	3
14	CSR5 × CSR13	16.12*	21.06*	7.05	7.03	0.03	10.31*	11.37	1.66*	4
15	KA × NB_4D_2 (C)	6.49	13.61	8.04	6.55	–1.52	4.64	9.63	0.78	–
16	NB_4D_2 × KA(C)	7.52	13.50	9.55	8.53	–1.07	7.12	12.07	0.78	–
	CD at 5%	2.15	2.96	2.17	2.19	0.74	1.62	4.11	0.64	
	Mean heterosis	9.7	19.8	10.8	10.6	–0.33	10.5	12.7	1.9	

*, Significant at 5%.

#, Number of traits which showed significant herterosis.

C, Control hybrid.

nificant herterosis was recorded in 7 hybrids for the trait pupation, 11 hybrids for cocoon yield, 8 hybrids for cocoon weight, and 8 hybrids for cocoon shell weight. Similarly, significant herterosis was also estimated for reeling characters such as raw silk percentage (9 hybrids), filament length (5 hybrids) and neatness (10 hybrids). Highest degree of herterosis was noticed for the character pupation (16.12%) in CSR5×CSR13, where as CSR6×CSR3 showed highest heterosis for the character cocoon yield (30.98%), cocoon weight (16.67%), raw silk percentage (19.10%) and neatness (4.49%). The hybrid CSR5×CSR2 recorded highest heterosis for cocoon shell weight (18.68%) and filament length (22.31%). Majority of the hybrids have shown less heterosis or negative herterosis for the trait cocoon shell ratio.

Highest mean heterosis of 19.8% was registered for cocoon yield followed by filament length (12.7%), cocoon weight (10.8%), shell weight (10.6%), raw silk percentage (10.5%), pupation (9.7%) and neat ness (1.9%). Negative mean herterosis of 0.33% was recorded for the trait cocoon shell ratio (Fig. 1).

Significant over dominance for various characters *i.e.*, pupation (8 hybrids), cocoon yield (11 hybrids), cocoon weight (8 hybrids), shell weight (4 hybrids), raw silk percentage (10 hybrids), filament length (5 hybrids) and neatness (9 hybrids) was also recorded. Highest degree of over dominance (16.05%) was noticed for the character survival in CSR5×CSR13. The hybrid CSR6×CSR3 has recorded highest over dominance for the character cocoon yield (23.90%) and shell weight (16.89%). The hybrid CSR4×CSR2 showed significant over dominance for the character cocoon weight (13.90%) and neatness (2.68%). Negative over dominance was observed for the character for majority of the hybrids (Table 4).

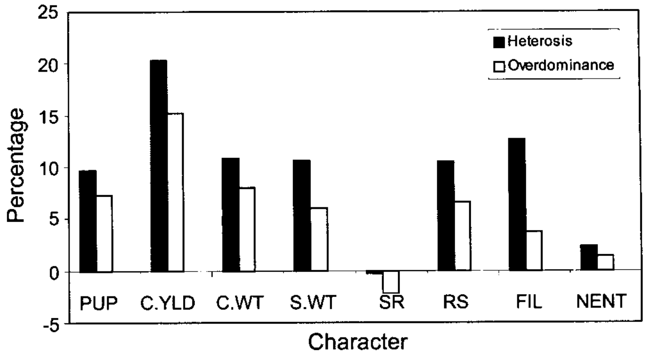

Fig. 1. Mean heterosis and overdominance in new Bivoltine hybrids. PUP pupation, C.YLD cocoon yield, C.WT cocoon weight, SR-shell ratio %, RS raw silk percentage and FIL filament length NEAT neatness.

Table 4. Overdominance (%) for eight economic traits in the hybrids

Sl no.	Hybrid	Pupation	Cocoon yield	Cocoon weight	Shell weight	Shell ratio	Raw silk	Filament length	Neatness	No. of traits
1	CSR1 × CSR4	8.81*	14.18*	1.26	−3.50	−4.70	1.71	−9.62	0.53	2
2	CSR4 × CSR1	4.43*	7.07	2.08	−2.19	−4.18	3.43*	−12.05	1.29*	3
3	CSR2 × CSR4	2.07	15.05*	11.08*	4.91	−5.42	5.32*	12.02*	1.82*	5
4	CSR4 × CSR2	4.50	19.83*	13.90*	8.92	−4.17	2.66	8.68	2.68*	3
5	CSR2 × CSR5	4.03	14.20*	10.57*	9.62*	−0.83	7.45*	11.07*	2.36*	6
6	CSR5 × CSR2	3.97	14.70*	10.47*	11.32*	0.83	7.98*	12.98*	2.36*	6
7	CSR3 × CSR6	11.74*	20.48*	10.29*	14.00*	−0.20	11.83*	13.32*	0.53	6
8	CSR6 × CSR3	11.05*	23.26*	13.09*	16.89*	−0.20	13.98*	14.53*	1.81*	7
9	CSR10 × CSR11	3.05	8.74	9.24*	6.59	−2.42	2.35	2.81	1.06*	2
10	CSR11 × CSR10	2.01	9.32	11.82*	8.94	−2.57	1.18	1.71	0.21	1
11	CSR12 × CSR6	7.27*	14.02*	6.29	2.24	−3.81	13.44*	1.03	0.00	3
12	CSR6 × CSR12	8.28*	15.91*	6.96	3.47	−3.26	9.68*	1.98	−0.11	3
13	CSR13 × CSR5	14.35*	18.11*	1.49	1.24	−0.25	3.78*	−2.42	1.06*	4
14	CSR5 × CSR13	16.05*	17.11*	3.83	2.06	−1.70	7.03*	−4.44	1.28*	4
15	KA × NB_4D_2 (C)	0.60	9.89	4.83	4.87	−5.91	−1.74	1.54	0.55	–
16	NB_4D_2 × KA(C)	1.58	9.78	6.29	6.81	−5.49	0.58	3.79	0.55	–
	CD at 5%	2.78	2.62	1.98	2.56	1.34	2.42	3.78	0.42	
	Mean overdominance	7.3	15.2	8.0	6.0	−2.3	6.6	4.2	1.2	

*, Significant at 5%.
#, Number of traits which showed significant herterosis.
C, Control hybrid.

Highest mean over dominance of 15.2% was recorded for the character cocoon yield followed by cocoon weight (8.0%), pupation (7.3%), raw silk percentage (6.6%), shell weight (6.0%), filament length (4.2%) and neatness (1.2%). Negative mean over dominance of 2.3% was recorded for the trait cocoon shell ratio (Fig. 1).

Kobayashi *et al.* (1968) observed the occurrence of heterosis was most prominent for the cocoon weight and cocoon shell weight, moderate amount of heterosis for pupation and low degree for cocoon shell ratio. Manifestation of maximum heterosis for cocoon yield as compared to other characters has been reported. However, the level of heterosis recorded for different traits by different investigators is not consistent. Subba Rao and Sahai (1990) showed the significantly highest level of heterosis in bivoltine hybrids for cocoon yield (14.25%), followed by cocoon weight (3.89%) and denier (3.08%). Similarly, Nagaraju (1996) showed the highest heterosis in multivoltine×bivoltine for larval weight (13.93%) followed by pupation (12.7%) and cocoon weight (8.7%). Such wide differences in the manifestation of heterosis suggest that the parental breeds involved in hybrids differ in their genetic makeup, as reflected in differences in quantitative traits such as cocoon weight, cocoon shell weight, shell ratio, filament length *etc.* (Yokoyama, 1957; Gamo and Hirabayashi, 1983).

In the present study, high level of heterosis was recorded for cocoon yield followed by filament length, cocoon weight, shell weight, raw silk percentage and pupation. Whereas, high level of over dominance was recorded for cocoon yield followed by cocoon weight and pupation. The hybrids CSR2×CSR4, CSR2×CSR5, CSR3×CSR6 and their reciprocals have exhibited significant heterosis and over dominance for 5 to 7 characters out of 8 studied. Based on these results, the importance of theses hybrids as potential productive hybrids for commercial exploitation was realized.

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