Int. J. Indust. Entomol. Vol. 6, No. 2, 2003, pp. 171~178

International Journal of
Industrial Entomology

Evolution and Identification of Thermo-Tolerant Hybrids in the Silkworm, *Bombyx mori* L.

A. Naseema Begum*, M. Rekha, H. K. Basavaraja and M. M. Ahsan[1]
Central Sericultural Research and Training Institute, Mysore-570 008, India.
[1]Central Sericultural Research and Training Institute, Pampore J & K, India.

(Received 16 January 2003; Accepted 8 May 2003)

Four thermo-tolerant lines of silkworm, *Bombyx mori* (L.) *viz.*, A HT, B HT (Chinese type) and F HT, G HT (Japanese type) were evolved by utilizing the breeding resource material (identified from initial screening at a temperature of 31 ± 1°C and relative humidity 85 ± 5%) through conventional breeding. These tolerant lines were crossed with productive breeds and forty four hybrids were evaluated on eight economic traits by the Multiple Trait Evaluation Index Method. Ten hybrids were short-listed based on the average evaluation index value larger than 50 for eight economic traits studied. The identified ten hybrids recorded higher index values (> 50) for most of the traits studied. Single hybrid G × CSR12 indicated average index value larger than 50 for six traits *viz.*, pupation number (58), cocoon weight (67), shell weight (65), average filament length (74), raw silk % (69), reelability % (51) except for shell ratio % (41). The standard deviation of the cocoons in the above hybrid was 8.41 in the hybrid cocoon length and width measurement. However, two selected hybrids *viz.*, A × CSR5 and G × CSR13 recorded average index value larger than 50 for all the traits *viz.*, pupation number (57, 60), cocoon weight (50, 54), shell weight (56, 57), shell ratio percentage (59, 53), average filament length (55, 60), raw silk percentage (63, 67) and reelability percentage (53, 53). The standard deviation of the cocoons in the two selected hybrids *viz.*, A × CSR5 and G × CSR13 was 8.41 and 8.06 respectively in the cocoon length and width measurement.

Key words: *Bombyx mori* L., Multiple trait evaluation index method, Thermo-tolerant lines

Introduction

India being a tropical country is characterized by high temperature, scanty rainfall, low quality mulberry leaf, poor management practices and rampant disease incidence in the silkworm resulting in crop losses by the farmers. For rearing bivoltine silkworm in the fluctuating high temperature conditions, there is a need to evolve high temperature tolerant silkworm breeds. Sericultural research over the years in India has resulted in the increase in raw silk production. But the quality of the silk is poor and not internationally recognized. Even though bivoltine silkworm breeds with high productivity and qualitatively superior hybrids have been evolved and being commercially exploited for silk, they are identified only for rearing during favourable season (August - February) in Southern India (Basavaraja *et al.*, 1995). In the sericulturally advanced countries like China and Japan, the influence of environment during breeding of silkworm has been studied. In China, high silk yielding silkworm breeds have been developed for rearing in spring season (Hourong *et al.*, 1996; Wang 1997). Silkworm breeds have also been developed for rearing during summer-autumn season at a temperature of 28 – 30°C and humidity 85 – 90% (He *et al.*, 1989; Sohn *et al.*, 1987; Yang, 1998). In Japan, the effect of high temperature on survival of the silkworm larvae have been studied (He and Oshiki, 1984). Based on the environmental stress factor in the rearing of bivoltine silkworm in the tropical country and to meet the farmer requirements, an attempt was made for the development of thermo-tolerant breeds/hybrids by utilising the germplasm stock maintained at Central Sericultural Research and Training Institute, Mysore, as breeding resource material.

Materials and Methods

Eight foundation crosses of bivoltine silkworm breeds

---

*To whom correspondence should be addressed.
Central Sericultural Research and Training Institute, Mysore-570 008, India. Tel: 091-0821-362406; E-mail: naseemcsrti@yahoo.com

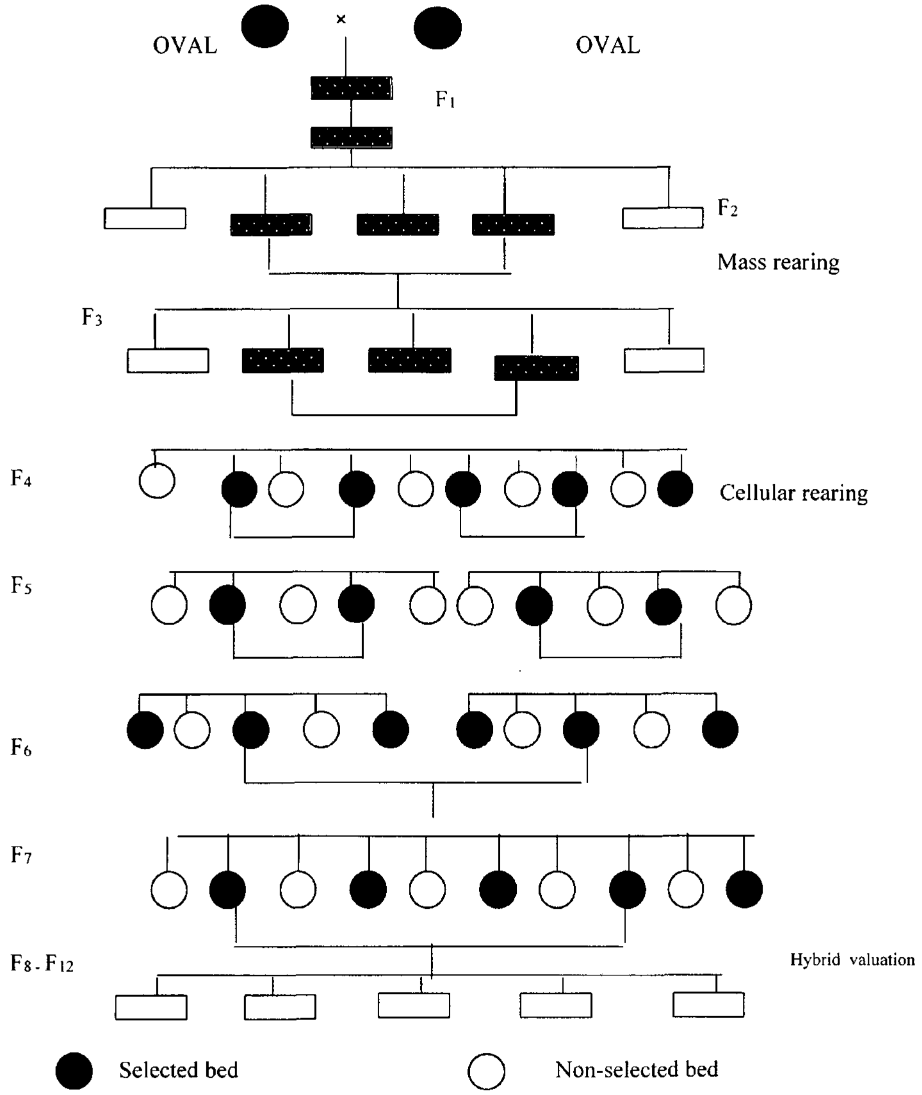

Fig. 1. Breeding plan of new thermo-tolerant silkworm breed.

viz., 1) C3 × A (A), 2) A × Tokai (B), 3) A × C3 (C), 4) Tokai × C124 (D), 5) 935A × 916A1 (E), 6) 916A2 × 912B2 (F), 7) 916A1 × 2001) were utilized as initial parents for the evolution of thermo-tolerant breeds. Eight breeding lines were initiated and breeding progressed by the conventional breeding procedure (Fig. 1). Breeding was carried throughout at a temperature of 31 ± 1°C and relative humidity 85 ± 5% in Sericatron (Naseema *et al.*, 2001). Sericatron is a thermo-statically controlled chamber where the required temperature and humidity are controlled.

Breeding procedure

Mass rearing was carried out from $F_1 - F_3$ generation. Composite layings consisting of about 2000 eggs from 25 disease free laying were prepared and brushed in five plastic trays measuring 60 × 40 × 7.5 cm. After 3rd ecdysis, larvae were counted and ten replications of 100 larvae per replication were retained. After the harvesting of cocoons, they were divided into three parts. One part was utilized for general cocoon assessment (n = 20). Second part for reeling (n = 30) and the third part for the seed preparation (n = 50). The cocoons were cut and number of live pupae were recorded. Out of the ten replications, the beds where highest number of live pupae survived were recorded and selected. All the live pupae were pooled for preparation of disease free laying. The eggs prepared were reared both at high and normal temperature (Krishnaswami, 1978).

Cellular rearing was carried out from $F_4 - F_7$ generation. After F_3 generation, the selected beds were maintained as families. In each line, ten families were maintained. Inbreeding coupled with stabilization selec-

Table 1. Rearing performance of the silkworm hybrids at 31 ± 1°C and RH 85 ± 5%

Sl.	Hybrid	5th age larval period (hrs)	Pupation no.	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Average filament length (m)	Raw silk (%)	Reelability (%)
1	A × CSR4	138	5600	1.624	0.333	20.63	756.00	12.60	88.80
2	A × CSR5	140	9233	1.573	0.325	20.77	855.00	13.50	85.60
3	A × CSR6	138	8733	1.565	0.317	20.30	788.00	11.50	77.30
4	A × B9	140	6633	1.614	0.336	20.99	684.00	10.70	86.00
5	A × B61	140	9567	1.651	0.329	20.02	825.00	10.80	85.40
6	A × B25	140	7400	1.549	0.309	20.00	831.00	11.00	85.90
7	A × 935A	140	9700	1.620	0.336	20.78	734.00	11.90	76.40
8	A × 935E	138	7433	1.640	0.334	20.40	770.00	11.40	87.30
9	A × J2	138	9200	1.523	0.309	20.37	942.00	12.00	80.60
10	B × CSR4	142	9033	1.503	0.305	20.34	737.00	12.50	82.70
11	B × CSR5	142	9233	1.540	0.312	20.40	874.00	14.10	80.40
12	B × CSR6	150	9433	1.556	0.319	20.54	800.00	12.60	83.10
13	B × B9	138	8900	1.471	0.308	20.99	685.00	11.10	85.00
14	B × B61	142	8967	1.527	0.319	21.00	862.00	10.50	87.50
15	B × B25	144	9633	1.561	0.315	20.23	699.00	12.00	88.00
16	B × 935A	142	9033	1.551	0.310	20.03	722.00	11.20	87.10
17	B × 935E	138	8467	1.570	0.315	20.29	723.00	11.00	86.00
18	B × J2	138	6233	1.586	0.316	20.07	842.00	10.90	77.20
19	F × A63	138	8033	1.487	0.313	21.23	781.00	11.00	87.00
20	F × A70	140	9300	1.531	0.313	20.59	868.00	11.40	85.60
21	F × CSR2	138	4967	1.577	0.322	20.54	705.00	11.30	75.00
22	F × CSR3	138	6900	1.541	0.317	20.65	748.00	11.60	82.90
23	F × CSR12	148	5633	1.500	0.308	20.61	738.00	12.80	83.30
24	F × CSR13	142	8433	1.609	0.321	20.22	795.00	12.80	87.70
25	F × A	140	6467	1.474	0.314	21.36	826.00	12.00	77.00
26	F × C1	138	8133	1.626	0.326	20.11	855.00	10.90	85.20
27	F × C3	138	8167	1.686	0.344	20.57	917.00	11.00	82.80
28	F × A1	138	9633	1.501	0.309	20.70	846.00	12.50	67.70
29	F × A3	142	5000	1.569	0.319	20.38	846.00	11.30	87.80
30	A × F	140	9733	1.672	0.338	20.28	877.00	11.80	86.30
31	B × F	144	9533	1.568	0.321	20.59	789.00	14.00	90.00
32	G × A63	138	8633	1.620	0.314	19.44	819.00	11.00	91.00
33	G × A70	138	9233	1.558	0.316	20.39	876.00	15.50	88.90
34	G × CSR2	138	8467	1.583	0.324	20.67	743.00	11.70	79.30
35	G × CSR3	138	6433	1.630	0.334	20.61	958.00	12.90	81.00
36	G × CSR12	138	9400	1.669	0.334	20.14	1012.00	14.30	84.80
37	G × CSR13	138	9700	1.596	0.327	20.57	892.00	14.00	85.50
38	G × A	138	8233	1.502	0.307	20.52	625.00	11.00	86.00
39	G × C1	138	9667	1.587	0.313	20.13	819.00	13.10	73.70
40	G × C3	140	9133	1.527	0.315	20.63	716.00	10.80	87.40
41	G × A1	138	9433	1.615	0.321	20.28	903.00	11.60	90.00
42	G × A3	140	7933	1.574	0.309	19.79	909.00	14.00	87.00
43	A × G	140	9367	1.669	0.332	20.07	840.00	11.60	74.40
44	B × G	140	9200	1.511	0.313	20.79	917.00	12.40	83.10

Table 2. Evaluation Index values of the silkworm hybrids

Sl.	Hybrid	5th age larval period	Pupation no.	Cocoon weight	Shell weight	Shell ratio %	Average filament length	Raw silk %	Reelability %	Average E. I.
1	A × CSR4	42.95	29.84	59.29	63.09	54.96	43.17	54.82	59.39	52.08
2	A × CSR5	50.52	56.52	50.06	55.78	58.60	55.14	62.53	52.99	55.94
3	A × CSR6	42.95	52.85	48.55	46.94	45.77	47.04	45.41	36.39	46.14
4	A × B9	50.52	37.43	57.36	66.49	64.63	34.47	38.56	53.79	50.39
5	A × B61	50.52	58.97	64.09	59.18	38.05	51.51	39.42	52.59	51.97
6	A × B25	50.52	43.06	45.60	38.78	37.61	52.24	41.13	53.59	44.57
7	A × 935A	50.52	59.95	58.51	66.49	59.06	40.51	48.83	34.59	52.56
8	A × 935E	42.95	43.30	62.19	64.79	48.55	44.86	44.55	56.39	52.09
9	A × J2	42.95	56.27	41.04	39.46	47.57	65.66	49.69	42.99	48.95
10	B × CSR4	58.09	55.05	37.39	35.21	46.96	40.88	53.97	47.19	45.23
11	B × CSR5	58.09	56.52	43.97	41.67	49.01	57.44	67.66	42.59	51.26
12	B × CSR6	88.36	57.99	47.02	49.66	52.35	48.49	54.82	47.99	51.19
13	B × B9	42.95	54.07	31.51	37.59	64.57	34.59	41.99	51.79	45.16
14	B × B61	58.09	54.56	41.68	48.98	65.09	55.99	36.85	56.79	51.42
15	B × B25	65.65	59.46	47.80	44.90	43.87	36.28	49.69	57.79	48.54
16	B × 935A	58.09	55.05	46.11	39.97	38.33	39.06	42.84	55.99	45.34
17	B × 935E	42.95	50.89	49.52	45.24	45.57	39.18	41.13	53.79	46.47
18	B × J2	42.95	34.49	52.30	46.43	39.50	53.57	40.28	36.19	43.25
19	F × A63	42.95	47.71	34.47	43.54	71.14	46.19	41.13	55.79	48.57
20	F × A70	50.52	57.01	42.46	43.37	53.71	56.71	44.55	52.99	50.11
21	F × CSR2	42.95	25.19	50.79	52.55	52.26	37.01	43.70	31.79	41.90
22	F × CSR3	42.95	39.39	44.30	46.77	55.32	42.20	46.27	47.59	45.98
23	F × CSR12	80.79	30.08	36.85	37.59	54.28	41.00	56.53	48.39	43.53
24	F × CSR13	58.09	50.65	56.49	50.85	43.70	47.89	56.53	57.19	51.90
25	F × A	50.52	36.20	32.18	44.39	74.75	51.63	49.69	35.79	46.38
26	F × C1	42.95	48.44	59.63	56.29	40.49	55.14	40.28	52.19	50.35
27	F × C3	42.95	48.69	70.45	74.47	53.25	62.64	41.13	47.39	56.86
28	F × A1	42.95	59.46	36.97	39.46	56.62	54.05	53.97	17.19	45.39
29	F × A3	58.09	25.43	49.28	48.81	47.99	54.05	43.70	57.39	46.66
30	A × F	50.52	60.19	67.86	68.19	45.18	57.80	47.98	54.39	57.37
31	B × F	65.65	58.72	49.19	51.53	52.79	47.16	66.80	61.79	55.43
32	G × A63	42.95	52.11	58.54	43.88	22.10	50.79	41.13	63.79	47.48
33	G × A70	42.95	56.52	47.23	45.75	48.26	57.68	79.64	59.59	56.38
34	G × CSR2	42.95	50.89	51.78	54.42	55.79	41.60	47.12	40.39	48.86
35	G × CSR3	42.95	35.96	60.32	64.45	54.28	67.59	57.39	43.79	54.82
36	G × CSR12	42.95	57.74	67.38	64.96	41.30	74.12	69.37	51.39	60.89
37	G × CSR13	42.95	59.95	54.26	57.48	53.24	59.61	66.80	52.79	57.73
38	G × A	42.95	49.18	37.21	36.57	51.74	27.33	41.13	53.79	42.42
39	G × C1	42.95	59.70	52.60	43.20	41.04	50.79	59.10	69.18	53.66
40	G × C3	50.52	55.79	41.77	45.58	54.94	38.34	39.42	56.59	47.49
41	G × A1	42.95	57.99	57.66	51.19	45.30	60.94	46.27	61.79	54.45
42	G × A3	50.52	46.97	50.15	39.12	31.76	61.67	66.80	55.79	50.32
43	A × G	50.52	57.50	67.35	62.07	39.45	53.33	46.27	30.59	50.93
44	B × G	50.52	56.27	38.84	43.03	59.28	62.64	53.11	47.99	51.59

tion was carried out for attaining homozygosity of the lines. Directional selection for pupation was adopted for selection of lines. At the end of F_7 generation, the lines which showed similar quantitative traits were pooled, short-listed and four lines *viz.*, two oval lines (A HT, B HT) and two dumb-bell lines (F HT, G HT) were evolved. From F_8 to F_{11} generation stabilization of the lines for the target characters *viz.*, pupation rate and shell ratio were carried out.

The evaluation of the lines was carried out at F_{12} generation. Hybrids were prepared by making crosses with the thermo-tolerant lines and productive breeds. Forty four hybrids were prepared and evaluated at a temperature of 31 ± 1°C and RH 85 ± 5%. The observations were recorded for the following parameters: 1. 5th age period 2. Pupation number 3. Cocoon weight 4. Shell weight 5. Shell ratio % 6. Average filament length 7. Raw silk percentage and 8. Reelability percentage. The data were analysed using Multiple Trait Evaluation Index method (Mano *et al.,* 1993).

A total number of 500 cocoons were selected from each hybrid and reeling was carried out in the multi-end reeling machine at Central Sericultural Research and Training Institute, Mysore, to study the reeling parameters *viz.*, average filament length, raw silk percentage and reelability percentage. One hundred cocoons were randomly selected from ten hybrids for the measurement of cocoon length, cocoon width and for the determination of length/width ratio in each hybrid. Length and width of the cocoons were measured using vernier calipers. Cocoon shape variation was determined by uniformity test based on standard deviation (Mano, 1993). The cocoon length/width ratio, its standard deviation and coefficient of variation of each cocoon were considered for cocoon uniformity test. Hybrids showing standard deviation less than eight were considered uniform in cocoon shape in silkworm hybrids.

Results

For each of the eight traits under study, mean value, standard deviation and evaluation index (E. I.) values for the forty four hybrids were calculated (Table 1, 2). The average evaluation index value for each of the hybrid was derived from the individual evaluation index values (E. I.) (Table 2). Different crosses evaluated at temperature of 31 ± 1°C and RH 85 ± 5% indicated higher mean values for different economic traits than the control hybrid. A × F showed higher values for survival number (9733) and cocoon weight (1.672 g), F × C3 for shell weight (0.344 g), F × A for shell ratio % (21.36), G × CSR12 for average filament length (1012 m), G × A70 for raw silk percentage (15.5), G × A1 for reelability percentage (90.0), (Table 2), B × G for cocoon uniformity CV % (2.08) (Table 3).

Similarly different hybrids indicated higher average index values for different traits.The hybrids A × F, A × 935A, G × CSR13 and G × C1 exhibited higher E. I. values for survival number (60). F × C3 for cocoon weight, shell weight (70,74); F × A for shell ratio percentage (75); G × CSR12 for average filament length (74); G × A70 for raw silk percentage (80) and G × A1 for reelability percentage (62) (Table 2).

Ten hybrids were short-listed based on average index value > 50 for most of the traits (Table 3). The hybrid G × CSR12 exhibited average EI value > 50 for six traits *viz.*, pupation number (58), cocoon weight (67), shell weight (65), average filament length (74), raw silk percentage (69), reelability percentage (52) except shell ratio percentage (41). Two hybrids A × CSR5 and G × CSR13 recorded average index value larger than 50 for all the traits studied *viz.*, pupation number (56,60), cocoon weight (50,54), shell weight (56,57), shell ratio % (59,53), average filament length (55,60), raw silk percentage (63, 67) and reelability percentage (54,54). The standard deviation of the cocoons were 8.06 and 8.41 respectively in the cocoon uniformity test.

The standard deviation of cocoons in the ten hybrids ranged from 8.06 to 10.65 (Table 3). However, in the three hybrids A × CSR5, G × CSR12 and G × CSR13 the standard deviation of the cocoons was 8.41, 8.41 and 8.06 respectively.

Discussion

In China, bivoltine silkworm breeds/hybrids have been evolved for rearing during spring, summer and autumn seasons. Thermo-tolerant, disease resistant, fluoride resistant silkworm breeds have been evolved for rearing during summer-autumn season by Sohn *et al.* (1987), Shao *et al.* (1987, 1990), Murakami (1989), He *et al.* (1989, 1990), Shao (1989), He *et al.* (1991), Krishna Rao *et al.* (1996), Yang (1998), Zhang *et al.* (1994). In the present study pure breeds were evolved and hybrids were developed at 31 ± 1°C and RH 85 ± 5% for rearing in farmers conditions during summer.

Lin and Huang (1998) studied the effect of high temperature on egg hatching. The male eggs hatched normally while the female eggs scarcely hatched. They concluded that temperature tolerance is controlled by a major gene located in Z chromosome which shows recessive sex-limited inheritance. Japanese scientists Shirota (1992) and Tazima and Ohnuma (1995) during breeding of thermo-

Table 3. Rearing performance of the selected ten silkworm hybrids at 31 ± 1°C (Selected on the basis of average E. I. value >50)

Sl. no.	Hybrid	Pupation number	Cocoon wt.(g)	Shell wt. (g)	Shell ratio (%)	AFL (m)$^+$	Raw silk (%)	Reelability (%)	Avg. E. I.	5th age (hrs)	SD	CV %
1.*	A × CSR5	9233 (56.52)	1.573 (50.06)	0.325 (55.78)	20.77 (58.60)	855 (55.14)	13.5 (62.53)	85.6 (52.99)	56	140 (51)	8.41	4.66
2.	A × F	9733 (60.19)	1.672 (67.86)	0.338 (68.19)	20.28 (45.18)	877 (57.80)	11.80 (47.98)	86.30 (54.39)	57	140 (51)	8.06	5.28
3.	A × B61	9567 (58.97)	1.651 (64.09)	0.329 (59.18)	20.02 (38.05)	825 (51.51)	10.80 (39.42)	85.40 (52.59)	52	140 (51)	9.41	5.25
4.	A × 935 A	9700 (59.95)	1.620 (58.51)	0.336 (66.49)	20.78 (59.06)	734 (40.51)	11.90 (48.83)	76.40 (34.59)	53	140 (51)	8.93	5.59
5.	B × G	9200 (56.27)	1.511 (38.84)	0.313 (43.03)	20.79 (59.28)	917 (62.64)	12.40 (53.11)	83.10 (47.99)	52	140 (51)	8.84	2.08
6.	A × G	9367 (57.50)	1.669 (67.35)	0.332 (62.07)	20.07 (39.45)	840 (53.33)	11.60 (46.27)	74.40 (30.59)	51	140 (51)	9.25	5.44
7.	B × F	9533 (58.72)	1.568 (49.19)	0.321 (51.53)	20.59 (52.79)	789 (47.16)	14.00 (66.80)	90.00 (61.79)	55	144 (43)	10.65	6.27
8.**	G × CSR12	9400 (57.74)	1.669 (67.38)	0.334 (64.96)	20.14 (41.30)	1012 (74.12)	14.30 (69.37)	84.80 (51.39)	61	138 (43)	8.41	5.43
9.*	G × CSR13	9700 (59.95)	1.596 (54.26)	0.327 (57.48)	20.57 (53.24)	892 (59.61)	14.00 (66.80)	85.50 (52.79)	58	138 (43)	8.06	5.04
10.	G × A1	9433 (57.99)	1.615 (57.66)	0.321 (51.19)	20.28 (45.30)	903 (60.94)	11.60 (46.27)	90.00 (61.79)	55	138 (43)	8.77	5.38
	KA × NB_4D_2	6900	1.521	0.313	20.6	612	10.4	72.1		138	8.84	5.30

+indicates Average filament length. The values in the parenthesis indicates the E. I. values.
*Hybrids where the average E. I. value exceeded 50 in all the 7 characters.
**Hybrids where the average E. I. value exceeded 50 in 6 characters.

tolerant strains confirmed that the thermo-tolerance in silkworm is genetically heritable based on pupation rate of silkworm reared under high temperature during 5th instars. They also concluded that the performance of an insect is improved by selection in the environment in which it is exploited. Suresh Kumar and Yamamoto (2001) while studying the effect of higher temperature (35 ± 1°C) on the pure races as well as on the F_1 hybrids between polyvoltine and bivoltine silkworm races indicated that the hybrids are more tolerant than the pure races and there was maternal effect regarding temperature tolerance. This was evident from higher survival in the hybrids than in the pure race. This was also evident from the better performance of these hybrids where the female parent used was more tolerant than pure races. In the present study the performance of all the ten hybrids was better as compared to the control hybrid KA × NB_4D_2. The better performance may be due to the maternal effect of thermo-tolerance, which is inherited in the hybrids (thermo-tolerant × productive breed). These results are in conformity with the observations of Suresh Kumar and Yamamoto (2001). The authors reported that the better performance of the hybrids was pronounced due to the polyvoltine female parent, which was tolerant as pure race. The tolerant nature of the polyvoltine female tolerant parent is pronounced in the high temperature than at the room temperature.

Geneticists and breeders of all sericulturally advanced countries have established the effect of environment during the breeding process. The effect of temperature on silkworm has been reported by many workers (Huang *et al.,* 1979; He and Oshiki, 1984) observed that the resistance to high temperature is a heritable character and it may be possible to breed silkworm races tolerant to higher temperature. Cocoon uniformity is one of the important parameters in the evolution and evaluation of hybrids for silk production (Mano, 1993; Nakada, 1994). Cocoon shape variation in the parental and in the hybrid silkworm have been reported (Katsuki and Nagasawa,1917; Hirabayashi, 1982; Gamo *et al.,* 1985; Nakada, 1994). In the present study the hybrids were evaluated to study their uniformity in cocoon shape. The standard deviation of the hybrid cocoons ranged from 8.06 to 10.65 and the hybrids where the standard deviation was around 8 were considered to be uniform in cocoon shape. The hybrid B × G was found to be comparatively more uniform in cocoon shape showing very low CV % (2.08) even though SD was

8.84. Out of the ten hybrids, in three hybrids *viz.*, A × CSR5, G × CSR12 and G × CSR13 the standard deviation was 8.41, 8.41 and 8.06, respectively. This study is also in concurrence with the earlier workers based on higher survival of the hybrids and the hybrid cocoon uniformity through their low standard deviation values (Mano, 1994; Ravindra Singh *et al.*, 1998). Cocoons with uniform shape helps to get uniform filament size in automatic and semi-automatic reeling machine (Mano, 1994). Studies on cocoon variability is useful to identify suitable parents/hybrids for breeding.

However, two selected hybrids *viz.*, A × CSR5 and G × CSR13 recorded average index value larger than 50 for all the traits *viz.*, pupation number (57,60), cocoon weight (50,54), shell weight (56,57), shell ratio % (59,53), average filament length (55,60), raw silk % (63,67) and reelability % (53,53). The standard deviation of the cocoons in the two selected hybrids *viz.*, A × CSR5 and G × CSR13 was 8.41 and 8.06 respectively in the cocoon length and width measurement.

The selected ten hybrids will be subjected to three different temperature treatments (25 ± 1°C, 31 ± 1°C, 36 ± 1°C) and the most tolerant hybrids at 36 ± 1°C will be selected for commercial exploitation.

References

Basavaraja, H. K., S. Nirmal Kumar, N. Suresh Kumar, N. Mal Reddy, Kshama Giridhar, M. M. Ahsan and R. K. Datta (1995) New productive bivoltine hybrids. *Indian Silk.* **34**, 5-9.

Gamo, T., S. Saito, Y. Otsuki, T. Hirobe and T. Tazima. (1985) Estimation of combining ability and genetic analysis by diallel crosses between regional races of the silkworm (2). Shape and size of cocoon. *Tech. Bull. Seric. Exp. Stn.* **126**, 121-135.

He, S. M., X. Yan, Y. Mi and L. Xia. (1989) Breeding of a new silkworm variety "Feng I" × "54A" for summer - autumn rearing. *Sci. Seri.* **15**, 79-87.

He, S. M., L. Z. Xia, X. Y. Yan, D. Miy, Z. H. Lin and S.Y. Pan. (1990) The breeding of the silkworm varieties "57 A. 57 B", "24.46" and their hybrids for both spring and autumn rearing. *Canye Kexue* **16**, 15-20.

He, Y., Y. H. Sima, D. X. Jiang and P. Dai. (1991) Breeding of the silkworm varieties for summer and autumn rearing "Xuhua","Qiuxing"and their hybrids. *Canye Kexue* **17**, 200-207.

Hirabayashi, T. (1982) Influence of difference of cocoon shape in pure strains to that of hybrids. *Canye Kexue* **121**, 27-36.

Hourong, X., H. Chen, M. L. Zheng, Z. Zhengiong and L. Sheng. (1996) Breeding of spring use silkworm varieties lian Hua and Tian Dou and the preparation of their (F_1 hybrid) *Canye Kexue* **22**, 150-154.

He, Y. and T. Oshiki (1984) Study on cross breeding of a robust silkworm race for summer and autumn rearing at low latitude area in China. *J. Seric. Sci. Jpn.* **53**, 320-324.

Huang, P. J., J. H. Chen, D. H. Hong and C. N. Chen (1979) Preliminary study on the inheritance of tolerance to high temperature in some silkworm strains. *J. Agric. Assoc. China* **105**, 23-29.

Krishna Rao, S., M. L. Shivamallu and Venkataramu (1996) Evaluation of bivoltine silkworm races for high temperature tolerance. Seric Sci facing 21st Cent Int Symp Seric Sci Hangzhou China, Oct 6-10, p 90.

Krishnaswami, S. (1978) New technology of silkworm rearing. Bulletin No.2 Central Silk Board, Bangalore, Ministry of Industry, Government of India.

Lin, J. and Z. Huang (1998) Studies on inheritence of sex-linked temperature sensitivity of silkworm, *Bombyx mori* L. *Canye Kexue* **24**, 100-103.

Mano, Y., S. Nirmal Kumar, H. K. Basavaraja, N. Mal Reddy and R. K Datta (1993) A New method to select promising silkworm breeds/combinations. *Indian Silk* **31**, 53.

Murakami, A. (1989) Genetic studies on tropical races of silkworm, *Bombyx mori* with special reference to cross breeding strategy between tropical and temperate races 2. Multivoltine strains in Japan and their origin *JARQ 23*, 123-129.

Nakada, T. (1994) On the cocoon shape measurement and its statistical analysis in the silkworm, *Bombyx mori* L. *Indian J. Seric.* **33**, 100-102.

Naseema Begum, A., H. K. Basavaraja., M. Rekha, M. M. Ahsan and R. K. Datta (2001) Identification of breeding resource material for the development of thermo - tolerant breeds in the silkworm, *Bombyx mori* L. *Int. J. Indust. Entomol.* **2**, 111-117.

Ravindra Singh., G. V. Kalpana, P. Sudhakara Rao and M. M. Ahsan.(1998) Studies on cocoon shapes in different crosses of the mulberry silkworm, *Bombyx mori* L. *Indian J. Seric.* **37**, 85-88.

Shao, Y. H. (1989) Breeding of Lantian Baiyun, new summer-autumn silkworm variety. *Sci. Seric.* **15**,125-129.

Shao, Y. H., W. B. Li, J. Q. Xia and J. R. Cao (1987) The breeding of the mulberry silkworm varieties, "Xinhang" and "Keming" for summer-autumn rearing. *Canye Kexue* **13**, 15-20.

Shao, Y. H., W. B. Li, J. Q. Xia and J. R.Cao (1990) Breeding of a new silkworm variety "Fangshan" "Xing.ming" for autumn rearing. *Canye Kexue* **16**, 74-79.

Shirota, T. (1992) Selection of healthy silkworm strain through high temperature rearing of fifth instar larvae. *Rep. Silk Sci. Res. Inst.* **40**, 33-40.

Sohn. K. W., K. M. Kim, K. W. Hong, K. S. Ryu, S. R. Choi, K.Y. M. Kim, S. P. Lee and Y. H. Kwon (1987). Breeding of Daesongjam, a sex-limited larval marking and high yielding silkworm variety for summer-autumn rearing. *Res. Rep. Rural Dev. Adm.* **29**, 54-60.

Suresh Kumar, N., T. Yamamoto, H. K. Basavaraja and R. K. Datta (2001) Studies on the Effect of high temperature on F_1

hybrids between polyvoltine and bivoltine silkworm races of *Bombyx mori* L. *Int. J. Indust. Entomol.* **2**, 123-127.

Suresh Kumar, N., H. K. Basavaraja, N. Mal Reddy and R. K. Datta (2002) On the breeding of "CSR18 CSR19"- A robust bivoltine hybrid of silkworm, *Bombyx mori* L. for the tropics. *Int. J. Indust. Entomol.* **2**, 153-162.

Tazima, Y. and A. Ohnuma (1995) Preliminary experiments on the breeding procedure for synthesizing a high temperature resistant commercial strain of the silkworm, *Bombyx mori* L. *Rep. Silk. Sci. Res. Inst.* **43**, 16-17.

Wang, Z. E. (1997) Breeding of the spring rearing silkworm varieties Su (213), Chun (628) and their quaternary hybrid Su.zhen Chun. guang. *Canye Kexue* **23**, 14-19.

Yang, M. (1998) The report of the newly improved silkworm race Fangcao Chen.xing for summer-autumn rearing. *Canye Kexue* **24**, 1-5.

Zhang, P. Z., P. JI, X. H. Shen and X. H Chen (1994) Breeding of variety Qiufeng Baiyu for summer-autumn rearing. *Canye Kexue* **20**, 17 -25.