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# On the Breeding of "CSR18 × CSR19" - A Robust Bivoltine Hybrid of Silkworm, *Bombyx mori* L. for the Tropics

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**Earlier breeding experiments undertaken at Central Sericultural Research and Training Institute, Mysore, India since a decade had resulted in the development of many productive and qualitatively superior bivoltine hybrids. However, the hot climatic conditions of tropics prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids. This has necessitated breeding of compatible bivoltine hybrids for year-round rearing. Accordingly, the Japanese hybrid, B201 × BCS12 which was found to be tolerant to high temperature was used as breeding resource material. Following hybridization and selection rearing of silkworms was taken up in SERICATRON (Environmental chamber with precise and automatic control facilities for uniform maintenance of temperature and humidity) at high temperature of 36 ± 1°C and 85 ± 5% RH in fifth instar and the control batches at 25 ± 1°C and 65 ± 5% RH. Directional selection was resorted to the batches reared at 36 ± 1°C till $F_5$ keeping pupation rate as important selection criteria. From $F_5$ onwards the experiment was modified in such a way as to conduct normal rearing every alternate generation to regain the lost vitality due to continuous exposure to high temperature and high humidity stress. At $F_2$, Oval and dumb-bell cocoons were separated out and designated as CSR18 and CSR19, respectively. By utilizing these lines at $F_{12}$, the hybrid CSR18 × CSR19 was prepared and studied for the thermotolerance by subjecting to stress condition at high temperature of 36 ± 1°C and 85 ± 5% RH in fifth instar and the control batches at 25 ± 1°C and 65 ± 5% RH. The better performance of CSR18 × CSR19 (survival > 88%) at 36 ± 1°C clearly indicates the general superiority of CSR18 × CSR19 with regard to high temperature tolerance over the productive hybrids and CSR18 × CSR19 can perform well in varied agro-climatic conditions of the tropics with optimum qualitative and quantitative characteristics.**

**Key words**: *Bombyx mori* L., Bivoltine, Breeding, Robust hybrid, Thermotolerance

## Introduction

India is now on the threshold of vitalizing its sericulture industry with greater emphasis on improvement in quality rather than quantity. Raising of bivoltine silkworms have always faced with problems of marketing at remunerative prices. Farmers, thus felt that besides the hazards, the rearing of bivoltine hybrids is not economically viable and preferred to rear polyvoltine × bivoltine hybrids. Concerted efforts of research and development contributed to the increased raw silk production through the breeding of bivoltine breeds/hybrids. A few bivoltine hybrids such as CA2 × NB4D2 and CC1 × NB4D2 developed earlier (Datta, 1984) could not enhance the raw silk productivity at commercial level. Further, the tropical bivoltine hybrids mentioned above are not fully exploited for commercial production of silk due to non-availability of total package of practices for rearing. These hybrids were also found to be inconsistent in the expression of the commercial traits in different seasons of the year resulting in frequent crop losses (Sengupta, 1988). Keeping this in view, many productive and qualitatively superior bivoltine hybrids have been developed at CSRTI, Mysore by utilising Japanese commercial hybrids as breeding resource material (Basavaraja *et al.*, 1995; Datta *et al.*, 2000a, b). The potentiality of the new productive bivoltine hybrids will be realised only when optimum inputs to mulberry and good rearing

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management is assured and therefore, these hybrids have been recommended only for rearing during favourable months (August to February) in South India.

One of the main aims of the breeders is to recommend to farmers silkworm breeds that are stable under different environmental conditions and minimize the risk of falling below a certain yield level. Silkworm breeds which are reared over a series of environments exhibiting less variation are considered stable. However, the hot climatic conditions of tropics prevailing particularly in summer are not conducive to rear high yielding (productive) bivoltine hybrids. The low adaptability of these hybrids to the fluctuating environmental conditions of the tropical climate make them unsuitable for commercial exploitation throughout the year. Eventhough they are known for their productive merit, absence of genetic plasticity to buffer against the tropical environmental stresses acts as a constraint to tap full economic potential of these hybrids. Therefore, there is an urgent need for suitable robust bivoltine hybrids which can yield consistently good cocoon crop suiting the macro and micro environmental conditions and inferior management prevailing in the tropical conditions. Among the many factors that are attributed to poor performance of the bivoltine strains under tropical conditions, the most important one is that many quantitative characters such as viability and cocoon traits decline sharply when temperature increases over 28°C. Kato *et al.* (1989) in a series of experiments observed that, resistance to high temperature is a heritable character and it may be possible to breed silkworm races tolerant to high temperature.

Keeping in view of the above research findings, in a tropical country like India, it is very essential to develop bivoltine breeds/hybrids which can withstand the high temperature stress conditions. This has necessitated in the development of compatible hybrids for rearing throughout the year by utilizing Japanese thermotolerant hybrids as breeding resource material. This paper delineates the process involved in breeding successfully a bivoltine hybrid, CSR18 × CSR19, which can withstand the stress conditions of tropics like high temperature and high humidity.

## Materials and Methods

The Japanese bivoltine hybrid, B201 × BCS12 which was found to be tolerant to high temperature was used as breeding resource material and selection was effected by rearing silkworms at high temperature at 36 ± 1°C and 85 ± 5% of relative humidity (RH) in fifth instar and the control batches at 25 ± 1°C and 65 ± 5% RH. These two temperature schedules were chosen because in the former the silkworm grow luxuriously and yield to the maximum extent, whereas in the latter, growth, yield and various yield attributes such as pupation rate, cocoon weight, cocoon shell weight and cocoon shell ratio are affected adversely. According to the earlier studies in Japan it was observed that there are two phases during the fifth age larval duration *i.e.*, first two days as early phase and rest of the days till spinning as late phase (vulnerable to high temperature and high humidity conditions). Hence the thermal treatment at 36 ± 1°C temperature was effected to the 3$^{rd}$ day old larvae of fifth age for 6 hours daily till mounting, with relative humidity maintained above 85%.

The silkworm rearing was carried out following the standard method (Krishnaswami, 1978) till second day of 5$^{th}$ instar. Four hundred larvae per bed were counted and retained after third moult. On the third day of the 5$^{th}$ instar, 100 larvae were separated from each bed for the thermal treatment. The remaining larvae served as control at 25 ± 1°C and 65 ± 5% humidity. For the thermal exposure, the larvae were kept in plastic trays and reared in SERICATRON (Environmental chamber with precise and automatic control facilities for uniform maintenance of temperature and humidity) at 36 ± 1°C and RH 85 ± 5% from the third day of 5$^{th}$ instar and fed with fresh mulberry leaves twice a day. The thermal exposure was given every day for a duration of 6 hours till spinning. Spinning temperature was maintained at 25 ± 1°C and RH 65 ± 5%. Cocoon harvest was carried out on the 7$^{th}$ day and assessment was made on the subsequent day. The pupation rate was calculated as the number of healthy (live) pupae to the number of larvae reared at 25 ± 1°C and 36 ± 1°C, respectively.

### Selection and breeding methods

Directional selection was resorted to the rearing of silkworms at 36 ± 1°C till $F_5$ keeping pupation rate as important criteria. At $F_2$, the oval and dumb-bell cocoons were separated out and continued as separate lines designated as CSR18 (Oval) and CSR19 (dumb-bell). The larvae of both these lines were sex-limited for larval markings and spun creamish white cocoons. Owing to thermal effect in successive generations, it was observed after 5$^{th}$ generation that both qualitative and quantitative characters have declined. Hence, the experiment was modified in such a way that the normal rearing is conducted every alternate generation to regain the lost vitality. Mass rearing was conducted from $F_1$ to $F_6$ while cellular or individual batch rearing was conducted $F_7$ onwards. Further, directional selection was employed in the following 5 generations based on pupation rate and cocoon shape as selection criteria. Single cocoon assessment was carried out to select

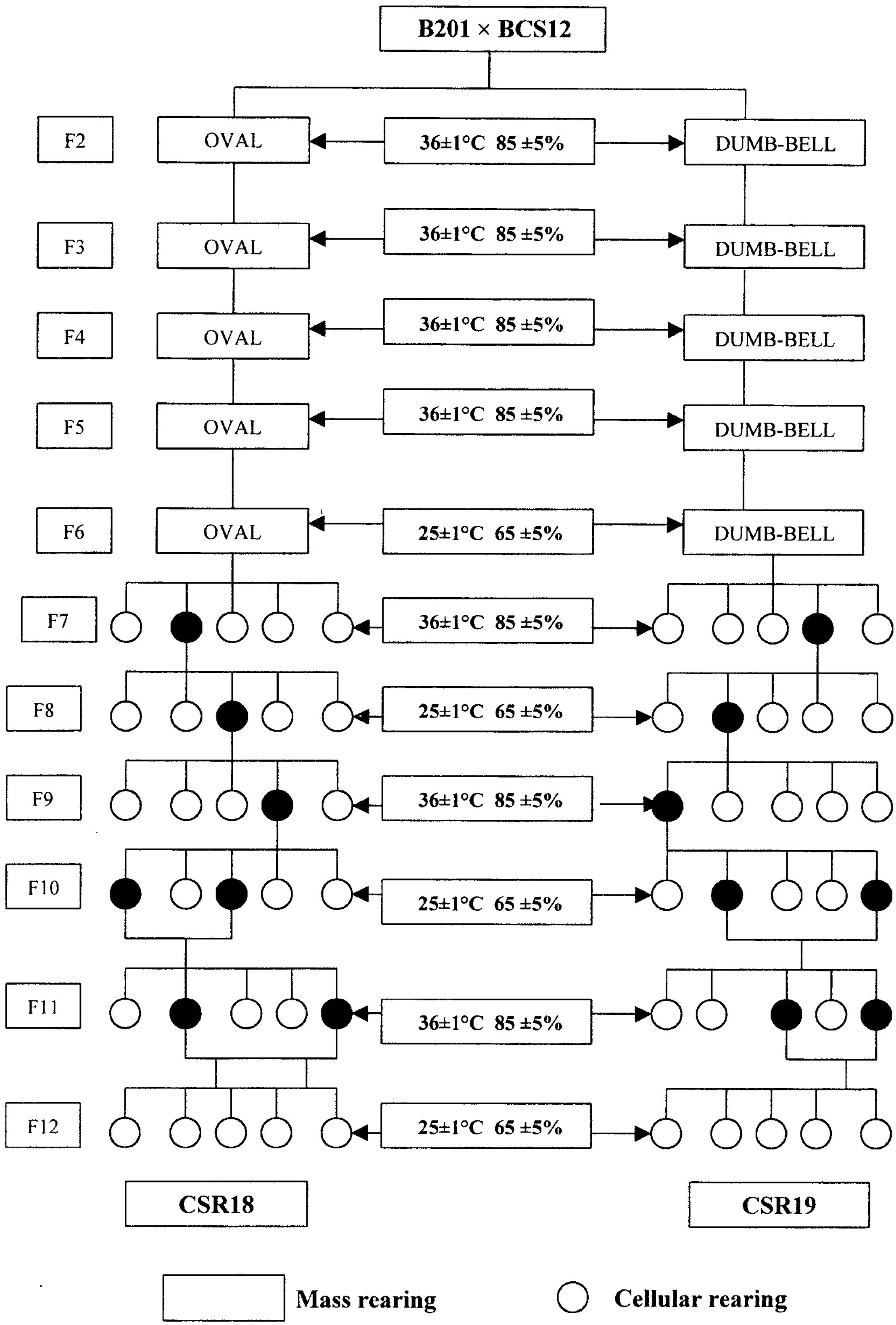


**Fig. 1.** Breeding Plan for CSR18 and CSR19.

the cocoons for continuation of progeny by maintaining the qualitative and quantitative characters at high profile.

The detail breeding plan of CSR18 and CSR19 is depicted in Fig. 1.

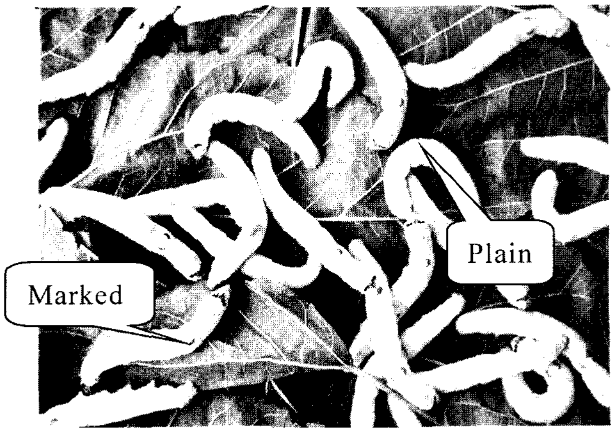


***Fig. 2.*** *Sex-limited larvae of CSR18×CSR19. Marked larvae* are females and plain larvae are males.

Though no positive selection response was noticed on survival rate when reared at high temperature followed by directional selection, progenetive lines performed remarkably superior in subsequent generations at room temperature conditions. By utilising these lines, hybrids were prepared and studied the thermotolerance by subjecting to stress condition as above because the genetic characters and high temperature tolerance are greatly aided by the phenomenon of heterosis. Since both parents are sex-limited in nature, the larvae of CSR18 × CSR19 are also sex-limited (Fig. 2).

## Results

The generation wise data of the breeding lines CSR18 and CSR19 both at high temperature (36 ± 1°C and 85 ± 5% RH) and room temperature (25 ± 1°C and 65 ± 5% RH) are presented in Tables 1 and 2, respectively. The mean values after fixation of the breeds and the percent improvement over control breeds KA and NB4D2 are presented in Table 3.

The perusal of data indicates that the survival percentage in respect of CSR18 at 36 ± 1°C and 85 ± 5% RH, ranged from 36.8 to 78.7% with a maximum of 78.7% recorded at $F_{11}$ and a minimum of 36.8% at $F_4$. However, at 25 ± 1°C and 65 ± 5% RH the survival percentage ranged from 87.7 to 94.6% with a maximum of 94.6% recorded at $F_{11}$ and the minimum of 87.7% at $F_5$. Similarly, for CSR19 the survival percentage at 36 ± 1°C and 85 ± 5% RH ranged from 43.0 to 79.8% with a maximum of 79.8% recorded at $F_{11}$ and a minimum of 43.0% at $F_4$, whereas at 25 ± 1°C and 65 ± 5% RH it ranged from 86.8 to 94.8% with a maximum of 94.8% recorded at $F_{12}$ and a minimum of 86.8% recorded at $F_3$ (Tables 1 and 2). The percent improvement of CSR18 over KA in respect of survival was (20.5%) and it was comparatively less for CSR19 over NB4D2 (4.3%).

At 36 ± 1°C and 85 ± 5% RH, the maximum cocoon yield/10,000 larvae for CSR18 was observed in $F_{11}$ (11.87 kg) and the least (4.75 kg) at $F_4$. Similarly, for CSR19 it was maximum in $F_{11}$ (10.53 kg) and the least (5.03 kg) in

**Table 1.** Generation wise mean performance of CSR18

| Generation | 36 ± 1°C and 85 ± 5% RH | | | | | 25 ± 1°C and 65 ± 5% RH | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) |
| $F_1$ | 46.0 | 5.23 | 1.25 | 29.0 | 23.2 | 96.0 | 19.6 | 2.02 | 46.1 | 22.9 |
| $F_2$ | 69.5 | 9.25 | 1.35 | 29.0 | 21.6 | 92.8 | 17.8 | 1.92 | 43.8 | 22.8 |
| $F_3$ | 76.5 | 10.20 | 1.35 | 27.8 | 20.6 | 92.7 | 17.2 | 1.86 | 41.5 | 22.3 |
| $F_4$ | 36.8 | 4.75 | 1.34 | 26.4 | 21.6 | 88.5 | 16.0 | 1.81 | 39.5 | 21.8 |
| $F_5$ | 69.7 | 10.05 | 1.48 | 30.3 | 20.4 | 87.7 | 16.2 | 1.85 | 39.7 | 21.4 |
| $F_6$ | -- | -- | -- | -- | -- | 90.3 | 16.4 | 1.81 | 38.5 | 21.3 |
| $F_7$ | 50.5 | 7.20 | 1.44 | 29.7 | 20.7 | 91.4 | 16.4 | 1.79 | 38.1 | 21.3 |
| $F_8$ | -- | -- | -- | -- | -- | 92.4 | 16.3 | 1.76 | 38.0 | 21.5 |
| $F_9$ | 58.6 | 7.31 | 1.33 | 26.8 | 20.2 | 92.7 | 16.2 | 1.75 | 38.1 | 21.8 |
| $F_{10}$ | -- | -- | -- | -- | -- | 93.4 | 16.3 | 1.74 | 38.0 | 21.8 |
| $F_{11}$ | 78.7 | 11.87 | 1.55 | 31.2 | 20.1 | 94.5 | 16.6 | 1.76 | 38.7 | 21.9 |
| $F_{12}$ | -- | -- | -- | -- | -- | 94.6 | 16.7 | 1.78 | 39.0 | 21.9 |
| Mean | 60.8 | 8.23 | 1.39 | 28.8 | 21.1 | 92.3 | 16.8 | 1.82 | 39.9 | 21.9 |
| SD | 15.24 | 2.52 | 0.01 | 1.68 | 1.04 | 2.45 | 1.01 | 0.08 | 2.6 | 0.53 |

**Table 2.** Generation wise mean performance of CSR19

| Generation | 36 ± 1°C and 85 ± 5% RH | | | | | 25 ± 1°C and 65 ± 5% RH | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) |
| $F_1$ | 67.5 | 9.20 | 1.39 | 31.1 | 22.6 | 96.0 | 19.6 | 2.02 | 46.1 | 22.9 |
| $F_2$ | 57.5 | 7.93 | 1.45 | 30.5 | 21.0 | 94.0 | 18.1 | 1.92 | 42.5 | 22.1 |
| $F_3$ | 65.3 | 8.13 | 1.27 | 26.8 | 21.1 | 86.8 | 16.4 | 1.89 | 41.0 | 21.7 |
| $F_4$ | 43.0 | 5.03 | 1.17 | 24.8 | 21.1 | 89.9 | 16.7 | 1.86 | 39.8 | 21.4 |
| $F_5$ | 65.7 | 7.33 | 1.20 | 24.5 | 20.4 | 90.1 | 16.7 | 1.85 | 39.5 | 21.4 |
| $F_6$ | -- | -- | -- | -- | -- | 90.4 | 15.8 | 1.75 | 36.9 | 21.1 |
| $F_7$ | 58.4 | 7.42 | 1.27 | 25.1 | 19.8 | 90.8 | 16.4 | 1.81 | 38.7 | 21.4 |
| $F_8$ | -- | -- | -- | -- | -- | 91.5 | 16.1 | 1.76 | 37.1 | 21.1 |
| $F_9$ | 62.7 | 7.90 | 1.26 | 25.0 | 19.8 | 92.8 | 15.9 | 1.76 | 37.5 | 21.3 |
| $F_{10}$ | -- | -- | -- | -- | -- | 93.4 | 16.1 | 1.75 | 37.2 | 21.3 |
| $F_{11}$ | 79.8 | 10.53 | 1.32 | 26.4 | 20.0 | 93.8 | 16.4 | 1.72 | 37.0 | 21.5 |
| $F_{12}$ | -- | -- | -- | -- | -- | 94.3 | 16.6 | 1.69 | 36.5 | 21.6 |
| MEAN | 62.5 | 7.93 | 1.29 | 26.8 | 20.7 | 92.0 | 16.7 | 1.82 | 39.2 | 21.6 |
| SD | 10.5 | 1.58 | 0.09 | 2.61 | 0.94 | 2.53 | 1.08 | 0.096 | 2.88 | 0.50 |

**Table 3.** Comparative mean values of CSR18 and CSR19 after stabilization

| Breed | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) | Raw silk (%) | Filament length (m) | Filament size (d) | Reelability (%) | Neatness (p) |
|---|---|---|---|---|---|---|---|---|---|---|
| CSR18 | 92.3 | 16.8 | 1.82 | 39.9 | 21.9 | 17.2 | 1112 | 2.68 | 82.0 | 90.7 |
| CSR19 | 92.0 | 16.7 | 1.82 | 39.2 | 21.6 | 17.0 | 964 | 2.91 | 83.0 | 90.0 |
| KA* | 76.6 | 15.1 | 1.96 | 33.4 | 19.4 | 15.1 | 878 | 2.98 | 78.0 | 89.6 |
| NB4D2* | 88.2 | 16.4 | 1.86 | 38.6 | 20.7 | 16.2 | 857 | 3.12 | 79.0 | 87.4 |
| Percent improvement | | | | | | | | | | |
| CSR18 vs KA | 20.5 | 11.3 | -7.1 | 19.5 | 12.9 | 13.9 | 26.7 | -10.1 | 5.1 | 1.2 |
| CSR19 vs NB4D2 | 4.3 | 1.8 | -2.2 | 1.6 | 4.3 | 4.9 | 12.5 | -6.7 | 5.1 | 3.0 |

* Control breeds.

$F_4$. At 25 ± 1°C and 65 ± 5% RH, the maximum for CSR18 was observed in $F_{12}$ (19.6 kg) and the least (16.0 kg) in $F_4$. But for CSR19 it was maximum in $F_1$ (19.6 kg) and the least (15.8 kg) in $F_6$ (Tables 1 and 2). The improvement of CSR18 over KA (11.3%) was more and it was comparatively less for CSR19 over NB4D2 (Table 3).

The maximum single cocoon weight in CSR18 was recorded at 36 ± 1°C and 85 ± 5% RH, in $F_{11}$ (1.55 g) and the least (1.25 g) in $F_1$. Similarly, for CSR19 it was maximum in $F_2$ (1.45 g) and the least (1.17 g) in $F_4$. At 25 ± 1°C and 65 ± 5% RH, the maximum for CSR18 was observed in $F_1$ (2.02 g) and the least (1.74 g) in $F_{10}$. While for CSR19 it was maximum in $F_1$ (2.02 g) and the least (1.69 g) in $F_{12}$ (Tables 1 and 2). The data indicated that there was no improvement in single cocoon weight in these breeds over the control breeds KA and NB4D2 (Table 3).

At 36 ± 1°C and 85 ± 5% RH, the maximum cocoon shell weight in CSR18 was recorded in $F_{11}$ (31.2 cg) and the least (26.4 cg) in $F_4$. Similarly, for CSR19 it was maximum in $F_2$ (31.1 cg) and the least (24.5 cg) in $F_5$. At 25 ± 1°C and 65 ± 5% RH, the maximum shell weight for CSR19 was observed in $F_1$ (46.1 cg) and the least (38.0 cg) in $F_8$ and $F_{10}$. But for CSR19 it was maximum in $F_1$ (46.1 cg) and the least (36.5 cg) in $F_{12}$ (Tables 1 and 2). The percent improvement of CSR18 over KA was more (12.9%) and it was comparatively less (4.3%) for CSR19 over NB4D2 (Table 3).

The maximum cocoon shell ratio in CSR18 was recorded in $F_1$ (22.6%) and the least (20.1%) at 36 ± 1°C and 85 ± 5% RH in $F_{11}$. Similarly, for CSR19 it was maximum in $F_2$ (22.6% and the least (19.8%) in $F_7$ and $F_9$. At 25 ± 1°C and 65 ± 5%, the maximum shell ratio for CSR18 was observed in $F_1$ (22.9%) and the least (21.3%) in $F_6$ and $F_7$, while in CSR19 it was least (21.1%) in $F_8$ and maximum (22.9%) in $F_1$ (Tables 1 and 2). The percent improvement in shell ratio of CSR18 over that of KA was (13.9%) and it was comparatively less (4.3%) for CSR19 over NB4D2 (Table 3).

It was also observed that the quality of cocoons produced under high temperature and high humidity conditions (36 ± 1°C and 85 ± 5% RH) had considerably reduced and reeling was not possible and hence the reeling parameters of batches reared under high temperature and high humidity could not be assessed. In both CSR18 and CSR19 all the post cocoon parameters related to breeding showed improvement over the control breeds except for the character, denier where it was less (Table 3).

The laboratory performance of the new hybrid is presented in Tables 4 and 5. At 36 ± 1°C and 85 ± 5% RH, the pupation rate was more (88.24%) for CSR18 × CSR19 than for the control hybrid, KA × NB4D2 (29.13%). Similarly, at 25 ± 1°C and 65 ± 5% RH, the highest pupation rate of 97.01% was recorded for CSR18 × CSR19 and the least of 91.86% was recorded for the control hybrid, KA × NB4D2. The percentage improvement in pupation rate of CSR18 × CSR19 over the control hybrid at 36 ± 1°C and 85 ± 5% RH was 203.1% whereas at 25 ± 1°C and 65 ± 5% RH, it was found very low (5.61%). At 36 ± 1°C and 85 ± 5% RH, the yield/10,000 larvae was the highest (12.8 kg) for CSR18 × CSR19 and the least (4.6 kg) was for KA × NB4D2. On the other hand, at 25 ± 1°C and 65 ± 5% RH, the yield/10,000 larvae was high (19.5 kg) for the control hybrid, KA × NB4D2 than CSR18 × CSR19 (18.2 kg). There was 178.3% improvement of this trait over KA × NB4D2 at 36 ± 1°C and 85 ± 5% RH and there was no improvement at 25 ± 1°C and 65 ± 5% RH.

At 36 ± 1°C and 85 ± 5% RH, the single cocoon weight was 1.50 g in KA × NB4D2 whereas 1.43 g in CSR18 × CSR19. Similarly, at 25 ± 1°C and 65 ± 5% RH also the cocoon weight was heavier (2.06 g) in KA × NB4D2 as compared to CSR18 × CSR19 (1.88 g). There was no percentage improvement of this trait at both the temperature treatments of CSR18 × CSR19 over KA × NB4D2. At 36 ± 1°C and 85 ± 5% RH, the cocoon shell weight was 29.7 cg in CSR18 × CSR19, but 27.6 cg in KA × NB4D2. On the other hand, at 25 ± 1°C and 65 ± 5% RH, the cocoon shell weight recorded for KA × NB4D2 was 42.0 cg as against 41.2 cg for CSR18 × CSR19. There was 7.6% improvement of this trait at 36 ± 1°C and 85 ± 5% RH over KA × NB4D2 and there was no improvement at 25 ± 1°C and 65 ± 5% RH. At 36 ± 1°C and 85 ± 5% RH, the cocoon shell ratio was 20.8% in CSR18 × CSR19, white it was 18.4% in KA × NB4D2. However, at 25 ± 1°C and 65 ± 5% RH also the cocoon shell ratio was higher (21.9%) in CSR18 × CSR19 than that in KA × NB4D2 (20.4%). The percentage improvement of CSR18 × CSR19 over KA × NB4D2 was 13.0% at 36 ± 1°C and 85 ± 5% and it was 7.4% at 25 ± 1°C and 65 ± 5% RH.

As mentioned earlier, like the parental breeds, reeling of cocoons of 36 ± 1°C and 85 ± 5% RH could not be done for the hybrids also and hence the reeling parameters were recorded only from the batches reared at 25 ± 1°C and 65 ± 5% RH. The raw silk recovery was 18.8% for CSR18

**Table 4.** Comparative performance of CSR18 × CSR19 at 25 ± 1°C and 65 ± 5% RH and 36 ± 1°C and 85 ± 5% RH (mean of 7 trials)

| | 36 ± 1°C | | | | | 25 ± 1°C | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hybrid | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) |
| CSR18 × CSR19 | 88.2 | 12.8 | 1.43 | 29.7 | 20.8 | 97.0 | 18.2 | 1.88 | 41.2 | 21.9 |
| KA × NB4D2 (C) | 29.1 | 4.6 | 1.50 | 27.6 | 18.4 | 91.9 | 19.5 | 2.06 | 42.0 | 20.4 |
| *t*-test | 9.18** | 6.82** | -0.87 | 0.92 | 2.76* | 4.99** | -1.50 | -2.28* | -0.47 | 9.05** |
| Percent improvement over control hybrids | | | | | | | | | | |
| CSR18 × CSR19 vs KA × NB4D2 | 203.1 | 178.3 | -4.7 | 7.6 | 13.0 | 5.5 | -6.7 | -8.7 | -1.9 | 7.4 |

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

**Table 5.** Laboratory performance of CSR18 × CSR19 (mean of 7 trials)

| Hybrid | Pupation rate (%) | Cocoon yield/ 10,000 larvae (kg) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) | Raw silk (%) | Filament length (m) | Filament size (d) | Reelability (%) | Neatness (p) |
|---|---|---|---|---|---|---|---|---|---|---|
| CSR18 × CSR19 | 97.0 | 18.2 | 1.88 | 41.2 | 21.9 | 18.8 | 1146 | 2.9 | 80.5 | 94.9 |
| KA × NB4D2 (C) | 91.9 | 19.5 | 2.06 | 42.0 | 20.4 | 16.9 | 1002 | 3.0 | 78.8 | 93.5 |
| t-test | 4.99** | -1.50 | -2.28* | -0.47 | 9.05** | 19.88** | 11.84** | -7.89** | 5.33** | 12.69** |
| Percent improvement over control hybrids | | | | | | | | | | |
| CSR18 × CSR19 vs KA × NB4D2 | 5.61 | -6.67 | -8.73 | -1.90 | 7.35 | 11.24 | 14.37 | -3.33 | 2.16 | 1.49 |

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

× CSR19 as against 16.9% recorded for KA × NB4D2 and the percentage improvement was 11.24% (Table 5).

The filament length was 1,146 m for CSR18 × CSR19 as against 1,002 m recorded for KA × NB4D2 and the percentage improvement was 14.37%. The denier was 2.9 as recorded for CSR18 × CSR19 against 3.0 by KA × NB4D2. The reelability was 80.5% recorded for CSR18 × CSR19 as against 78.8% recorded for KA × NB4D2 and the percentage improvement was 2.16%. The neatness was 94.9 points registered for CSR18 × CSR19 as against 93.5 points in KA × NB4D2 and the percentage improvement was 1.49% (Table 5).

After systematic evaluation at laboratory, CSR18 × CSR19 along with the control hybrid, KA × NB4D2 were tested at RSRSs of CSB. The performance is presented in Table 6. The perusal of the data indicates that CSR18 × CSR19 has recorded high pupation rate (91.88%) and cocoon shell ratio (21.6%) as compared to the pupation rate of 87.16% and cocoon shell ratio of 19.9% recorded for the control hybrid.

The comparative performance of CSR18 × CSR19 along with the productive hybrids, CSR2 × CSR4 and CSR2 × CSR5 indicated that the deleterious effect of high temperature and high humidity is highly pronounced in the productive hybrids than CSR18 × CSR19 (Fig. 3). Besides, the quality parameters of this hybrid were assessed by Central Silk Research and Training Institute (CSTRI), Bangalore and the silk was graded as 3A (Table 7).

**Table 6.** Performance of CSR18 × CSR19 at RSRSs (mean of 7 trials)

| Hybrid | Pupation rate (%) | Single cocoon weight (g) | Cocoon shell weight (cg) | Cocoon shell ratio (%) |
|---|---|---|---|---|
| CSR18 × CSR19 | 91.88 | 1.624 | 35.1 | 21.6 |
| KA × NB4D2 | 87.16 | 1.792 | 35.6 | 19.9 |
| *t*-test | 2.60* | -1.08 | -0.16 | 5.72 ** |

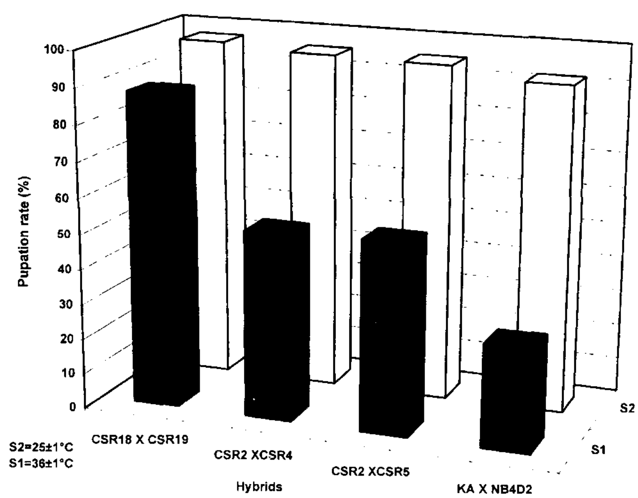


**Fig. 3.** Comparative performance of CSR18 × CSR19.

### Authorization test at different test centers

Based on the performance of this hybrid both at the laboratory and RSRS levels, it was subjected for race authorization test conceived and implemented by the Central Silk Board (CSB), Government of India during 1997. The hybrid, CSR18 × CSR19 was tested in 10 centres located at different regions in spring and autumn. The mean test results of this hybrid at all the test centres under race authorization test was given in Table 8. The overall performance indicate its superiority over the check values for

**Table 7.** Test reeling results of CSR18 × CSR19

| Sl. no. | Particulars | | Grade |
|---|---|---|---|
| I | Cocoon characteristics | | |
| 1 | Cocoon weight (g) | 1.938 | |
| 2 | Cocoon shell weight (g) | 0.413 | |
| 3 | Cocoon shell ratio (%) | 21.31 | |
| 4 | Average filament length (m) | 938 | |
| 5 | Non broken filament length (m) | 847 | |
| 6 | Single cocoon filament denier | 2.88 | |
| II | Reeling characteristics | | |
| 1 | Reelability (%) | 90.27 | |
| 2 | Renditta | 6.1 | |
| 3 | Raw silk recovery (%) | 76.93 | |
| 4 | Waste % on silk weight | 14.67 | |
| III | Quality characteristics | | Grade |
| 1 | Winding breaks/Hr/40 skeins | 8 | 3A |
| 2 | Average size | 21.4 | |
| 3 | Standard deviation | 1.34 | 3A |
| 4 | Maximum size deviation | 3.5 | 3A |
| 5 | Evenness variation VI | 80 | 4A |
| | VII | 0 | 4A |
| | VIII | 0 | 4A |
| 6 | Neatness (points) | 93 | 3A |
| 7 | Low neatness (%) | 90 | 4A |
| 8 | Cleanness (%) | 99 | 4A |
| 9 | Tenacity (g/denier) | 99 | 4A |
| 10 | Elongation (%) | 4.15 | 4A |
| 11 | Cohesion (strokes) | 77 | 4A |
| | Overall grade | | 3A |

(Sourc: Central Silk Technology Research Institute, Bangalore)

**Table 8.** Performance of CSR18 × CSR19 under race authorization test

| Sl. no. | Characters | CSR18 × CSR19 | Check value |
|---|---|---|---|
| 1 | Hatching ability (%) | 90 | 95 |
| 2 | Larval period (days) | 23.16 | 25 |
| 3 | Total missing larvae (%) | 6.21 | 9 |
| 4 | Pupation rate (%) | 91.1 | 90 |
| 5 | Cocoon yield/25,000 larvae (kg) | 4.08 | 3.7 |
| 6 | Good cocoon (%) | 95.0 | 90 |
| 7 | Double cocoon (%) | 1.02 | 9 |
| 8 | Cocoon/litre (no.) | 84 | 70 |
| 9 | Single cocoon weight (g) | 1.73 | 1.75 |
| 10 | Cocoom shell weight (cg) | 36.9 | 40 |
| 11 | Cocoom shell ratio (%) | 21.4 | 21 |
| 12 | Filament length (m) | 823 | 990 |
| 13 | Filament weight (cg) | 25.4 | 20 |
| 14 | Filament size (d) | 2.72 | 2.5 |
| 15 | Reelability (%) | 83.3 | 75 |
| 16 | Raw silk (%)(Based on wet base) | 33.6 | 35.7 |
| 17 | Boil off loss (%) | 20.6 | 27 |
| 18 | Neatness (%) | 95.0 | 85 |

The deta are mean of spring and autumn season of ten test centres during 1977.
(Source: Central Silk Borad, Bangalore)

11 out of the 18 characters tested.

## Discussion

Geneticists and breeders of all the sericultural countries have experienced the influence of environment during the process of breeding. The effect of temperature on silkworm was reported earlier by many scientists (Takeuchi *et al.*, 1964; Ohi and Yamashita, 1977; He and Oshiki, 1984; Suresh Kumar and Yamamoto, 1995). Ueda and Lizuka (1962) demonstrated that silkworms were more sensitive to temperature during the 4$^{th}$ and 5$^{th}$ stages. In India, Pillai and Krishanswami (1980, 1987) indicated the effect of exposure of silkworm larvae to high temperature in 5$^{th}$ instar and attributed the resultant low survival rate due to the low feeding activity of the silkworm resulting in the physiological imbalance and poor health of the larvae. Kato *et al.* (1989) in a series of experiments observed that the resistance to high temperature is a heritable character and it may be possible to breed silkworm races tolerant to high temperature. Accordingly, attempts were made to develop robust bivoltine hybrids tolerant to high temperature and high humidity conditions utilizing Japanese hybrids which are known to be tolerant to high temperature as breeding resource material and resulted in the development of robust bivoltine breeds wherein it was suggested that any study involving temperature as one of the environmental factors and viability followed by cocoon traits is a trend setter to provide basis to formulate appropriate selection strategies for required environments.

It is an established fact that the performance of an insect was improved by selection in the environment in which it is subsequently exploited. The performance of a race or a strain is a function of both the hereditary potential of its population and the extent to which such potential is permitted to be realised in the environment to which is exposed. The environment is dynamic and different environment bring about profound changes in the physical and biotic factors governing the expression of commercial characters in silkworm (Kobayashi *et al.*, 1986). The present study is also in concurrence with these observations that though no positive selection response was noticed on survival rate when reared at high temperature followed by directional selection, progenetive lines performed remarkably superior in subsequent generations at room temperature conditions.

The breeding experiments aimed at evolution of hardy bivoltine races for tropics by Maribashetty *et al.* (1998) indicated that genetic diversity, productivity and viability are complexly related, being influenced by the intrinsic and extrinsic factors. As opined by Barton (1986), nothing is known about the exact genetic basis of the quantitative characters except for measuring the variance of phenotypic and environmental components. Hence, it can be inferred that the stability in the performance of CSR18 × CSR19 exhibiting higher viability under the adverse environment could be due to the probable influence of large gene effects, varied multiple gene combinations, modifying effect, linkage, gene interaction, etc. or the combined effect of all of them.

The phenomenon of heterosis in CSR hybrids under high temperature conditions indicated that the better performance of CSR18 × CSR19 under high temperature and high humidity conditions is in concurrence with the earlier observations of Nagaraju *et al.* (1996) wherein it was emphasised that when both the parental strains and hybrids are raised in unfavourable conditions, the performance of the hybrids will be much superior to both the parents.

The superiority of CSR18 × CSR19 in comparison to productive CSR hybrids and the control hybrid, KA × NB4D2 could be attributed to the fact that the races performing well (surviving) in high temperature and high humidity yield better than the other breeds/hybrids in normal temperature and humidity conditions and it clearly indicates the genetical superiority of CSR18 × CSR19 over the productive hybrids when environment becomes hostile (Suresh Kumar *et al.*, 1999).

The performance of the CSR18 × CSR19 in comparison to other hybrids at 36 ± 1°C clearly indicates the general superiority of this robust hybrid over the productive hybrids and can perform well in the varied agro-climatic conditions of the tropics with optimum qualitative and quantitative characteristics. Accordingly, in 1998 after the Race Authorization Test, Central Silk Board has authorized the hybrid, CSR18 × CSR19 for commercial exploitation.

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