Int. J. Indust. Entomol. Vol. 6, No. 2, 2003, pp. 197~202

[Note]

International Journal of
Industrial Entomology

Effect of High Temperature and High Humidity on the Quantitative Traits of Parents, Foundation Crosses, Single and Double Hybrids of Bivoltine Silkworm, *Bombyx mori* L.

N. Suresh Kumar*, H. K. Basavaraja, N. Mal Reddy and S. B. Dandin

Central Sericultural Research and Training Institute, Mysore-570 008, India.

(Received 28 December 2002; Accepted 24 March 2003)

The hot climatic conditions prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids throughout the year. In order to select efficiently the breeds with high temperature tolerance, it is very important to analyze critically the impact of high temperature on many silk yielding attributes of silkworm races. Keeping the above in view, the present study was undertaken to determine the effect of high temperature (36 ± 1°C) and high humidity (80 ± 5% Relative Humidity) on the rearing performance of pure races, foundation crosses, single hybrids and double hybrids of bivoltine silkworm, *Bombyx mori* L. The robust bivoltine breeds, CSR18, CSR19, 8HT and 5HT, eight foundation crosses, eight single hybrids and eight double hybrids involving these breeds were chosen as materials in this study.

Key words: *Bombyx mori*, Bivoltine silkworm, High temperature, High humidity, Parents, Foundation cross, Single hybrids, Double hybrids

Introduction

The success of sericulture industry depends upon several factors, of which the impact of the environmental factors such as biotic and abiotic factors is of vital importance. Among the abiotic factors, temperature plays a major role on growth and productivity in silkworm, as the silkworm is a poikilothermic insect (Benchamin and Jolly, 1986). It is known that the late age silkworm prefers relatively lower temperature than young age (Krishnaswami, 1994) and fluctuation of temperature during different stages of larval development was found to be more favourable for growth and development of larvae than constant temperature. There is ample literature showing that good quality cocoons are produced within a temperature range of 22 – 27°C and above this level makes the cocoon quality worse (Krishnaswami *et al.*, 1973). However, multivoltine races reared in tropical countries are known to tolerate slightly higher temperature. It is also true with cross breeds which have been evolved specially for tropical climate.

In order to introduce bivoltine races in a tropical country like India, it is necessary to have stability in cocoon crop under high temperature environments. One of the important stresses faced in a tropical country is the high temperature environment not congenial to bivoltine rearing. Many productive and qualitatively superior bivoltine hybrids have been developed at CSRTI, Mysore by utilizing Japanese commercial hybrids as breeding resource material (Basavaraja *et al.*, 1995). However, the hot climatic conditions prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids throughout the year. This has led to the development of compatible bivoltine hybrids for rearing throughout the year by utilizing Japanese thermotolerant hybrids as breeding resource material (Datta, *et al.*, 2001) and suggested that any study involving temperature as one of the environmental factors and viability as a trend setter to provide basis to formulate appropriate selection policies for required environments.

While studying the performance of robust and productive bivoltine hybrids under two temperature conditions, Suresh Kumar *et al.* (1999) indicated that the deleterious effect of high temperature was more pronounced in productive hybrids than the robust hybrids. Studies on the effect of high temperature on F_1 hybrids between poly-

*To whom correspondence should be addressed.
Central Sericultural Research and Training Institute, Mysore-570 008, India. Tel: 091-0821-362419; Fax: 091-0821-362845; E-mail: nairsuresh_in@yahoo.com

voltine and bivoltine (Suresh Kumar *et al.,* 2001) indicated that there was maternal effect regarding temperature tolerance as evident from the better performance of those hybrids where the female parent used was more tolerant as pure race.

As such it becomes a difficult task to breed such bivoltine silkworm breeds, which are suitable to high temperature environments. In order to select efficiently the breeds with high temperature tolerance, it is very important to analyze critically the influence of high temperature on many silk yielding attributes of silkworm races.

Materials and Methods

Four thermotolerant pure breeds namely CSR18, 8HT (ovals), CSR19 and 5HT (dumbbells) and utilising these pure breeds eight single hybrids, four foundation crosses (two ovals and two dumbbells) and eight double hybrids were selected as materials for the study.

Parents: CSR18, CSR19, 8HT, 5HT
F1 hybrids: CSR18 × CSR19, CSR19 × CSR18, 8HT × 5HT, 5HT × 8HT, CSR18 × 5HT, 5HT × CSR18, CSR19 × 8HT, 8HT × CSR19
Foundation crosses: CSR18 × 8HT (Oval), 8HT × CSR18 (Oval), CSR19 × 5HT (Dumbbell), 5HT × CSR19 (Dumbbell)
Double hybrids: (CSR18 × 8HT) × (CSR19 × 5HT) (DH1), (CSR18 × 8HT) × (5HT × CSR19) (DH2), (8 HT × CSR18) × (CSR19 × 5HT) (DH3), (8HT × CSR18) × (5HT × CSR19) (DH4), (CSR19 × 5HT) × (CSR18 × 8HT) (DH5), (CSR19 × 5HT) × (8HT × CSR18) (DH6), (5HT × CSR19) × (CSR18 × 8HT) (DH7), (5HT × CSR19) × (8HT × CSR18) (DH8)

Test temperature

All the breeds were subjected to two temperature and humidity schedules *i.e.,* 25 ± 1°C and 65 ± 5% RH and 36 ± 1°C and 85 ± 5% RH. These two temperatures were chosen because in the former, the silkworms grow luxuriously and yield to maximum extent, whereas in the later, growth, yield and various yield attributes such as pupation rate, cocoon weight, cocoon shell weight and shell weight are affected adversely. According to the earlier studies in Japan (Kato *et al.,* 1989) 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 (vulnerable to high temperature and high humidity conditions). Hence the thermal treatment at 36 ± 1°C temperature was effected to the 3rd day old larvae of fifth age for 6 hrs daily till mounting, with relative humidity maintained above 85% (Suresh Kumar *et al.,* 1999, 2002).

Silkworm rearing

The silkworm rearing was carried out in three replications following the standard method (Krishnaswami, 1978) till second day of 5th instar. Four hundred larvae per replications were counted and retained after third moult. On the third day of the 5th 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 (artificially designed rearing chamber) at 36 ± 1°C and RH 85 ± 5% from the third day of 5th instar and fed with fresh mulberry leaves twice a day. The thermal exposure was given every day for a duration of 6 hrs till spinning. Spinning temperature was maintained at 25 ± 1°C and RH 65 ± 5%. Cocoon harvest was carried out on the 7th day and assessment was made on the subsequent day. The survival rate was calculated as the number of healthy (live) pupae to the number of larvae treated both at 25 ± 1°C and 36 ± 1°C, respectively. Various parameters such as pupation rate, cocoon weight, cocoon shell weight and cocoon shell ratio % were calculated for the batches reared at 25 ± 1°C and 65 ± 5% RH and 36 ± 1°C and 85 ± 5% RH.

Results

Rearing performance was estimated under two temperature schedules of 25 ± 1°C (65 ± 5% RH) and 36 ± 1°C (85 ± 5% RH) in four robust bivoltine breeds (CSR18, CSR19, 8HT and 5HT), four foundation crosses, eight single hybrids and eight double hybrids of *Bombyx mori* L.

Rearing performance

The rearing performance, based on pupation rate and cocoon characters such as cocoon weight, cocoon shell weight and cocoon shell ratio of three trials was evaluated under two temperature schedules of 25 ± 1°C (65 ± 5% RH) and 36 ± 1°C (85 ± 5% RH). Since the three trials of rearing were conducted under controlled environmental conditions, no variation on the performance between trials were noticed. The results of the pure breeds in comparison to their foundation crosses and the single hybrids in comparison to double hybrids are discussed based on the mean of three trials which are presented in Table 1 and 2. The data was statistically analysed by employing Analysis of Variance (ANOVA). Perusal of the data clearly indicates that the deleterious effect of high temperature was so pronounced on the rearing performance for all the pure breeds, foundation crosses, single hybrids and double hybrids considered for this study.

Table 1. Comparative performance of parents and foundation crosses at two temperature treatments

Breed	25 ± 1°C and 65 ± 5% RH					36 ± 1°C and 85 ± 5% RH				
	Pupation rate (%)	Yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon shell ratio (%)	Pupation rate (%)	Yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon shell ratio (%)
Parent										
CSR18	92.8	16.8	1.81	38.9	21.5	82.7	12.1	1.47	30.3	20.3
CSR19	94.6	15.9	1.68	35.1	20.9	79.3	9.4	1.20	23.4	19.5
8HT	90.7	17.6	1.89	42.6	22.8	71.3	11.4	1.47	30.3	20.6
5HT	89.9	16.9	1.90	42.8	22.5	79.3	10.2	1.34	25.4	19.0
Foundation cross										
CSR18 × 8HT	92.6	17.8	1.91	42.2	22.1	81.0	12.9	1.54	33.1	21.5
8HT × CSR18	91.6	18.0	1.92	44.6	23.2	75.7	12.2	1.58	32.7	20.7
CSR19 × 5HT	94.3	18.1	1.92	41.8	21.8	78.3	10.6	1.41	28.0	19.8
5HT × CSR19	93.9	18.3	1.94	44.0	22.7	73.3	10.2	1.35	25.5	18.9
CD at 5%										
For breeds	NS	1.26	0.73	1.56	0.48					
For Temperature.	3.52	0.63	0.37	0.78	0.24					
Breed × Temperature	NS	NS	0.10	2.21	0.67					

Table 2. Comparative performance of single hybrids and double hybrids at two temperature treatments

Breed	25 ± 1°C and 65 ± 5% RH					36 ± 1°C and 85 ± 5% RH				
	Pupation rate (%)	Yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon shell ratio (%)	Pupation rate (%)	Yield/ 10000 larvae (kg)	Cocoon weight (g)	Cocoon shell weight (cg)	Cocoon shell ratio (%)
Single hybrids										
CSR18 × CSR19	98.0	19.7	2.01	44.1	22.0	92.3	18.1	1.90	38.2	20.1
CSR19 × CSR18	98.6	20.2	2.03	43.3	21.8	95.0	17.9	1.87	38.1	20.4
8HT × 5HT	94.8	20.1	2.04	47.7	23.3	86.7	15.8	1.83	38.6	21.1
5HT × 8HT	92.2	19.3	2.09	46.1	22.0	83.0	15.3	1.88	38.9	20.6
CSR18 × 5HT	97.5	20.6	2.12	46.3	22.2	89.7	16.9	1.86	38.8	21.0
5HT × CSR18	95.3	20.3	2.13	47.9	22.4	86.0	16.5	1.91	39.6	20.7
CSR19 × 5HT	97.6	19.2	1.97	44.1	22.4	93.7	16.6	1.76	37.6	21.3
5HT × CSR19	95.1	19.1	2.00	46.5	23.2	85.0	14.7	1.71	36.0	21.0
Double hybrids										
DH1	97.1	20.1	2.04	46.5	22.8	94.0	16.4	1.75	37.0	21.1
DH2	96.7	20.2	2.09	45.5	21.8	92.0	16.5	1.78	37.6	20.1
DH3	93.9	20.0	2.12	46.6	22.0	84.3	15.0	1.72	34.7	20.2
DH4	96.5	20.2	2.08	47.2	22.7	66.3	11.8	1.76	33.9	19.2
DH5	96.4	19.8	2.01	43.9	21.8	85.3	15.2	1.77	35.5	20.0
DH6	97.8	21.0	2.15	47.6	22.1	92.7	16.2	1.73	36.4	21.0
DH7	98.3	20.9	2.12	47.4	22.4	94.0	17.7	1.85	39.8	21.7
DH8	98.5	21.0	2.12	47.6	22.4	74.0	12.6	1.71	35.4	20.6
CD at 5%										
For breeds	4.38	1.09	0.07	1.51	0.60					
For Temperature	1.55	0.39	0.25	0.53	0.21					
Breed × Temperature	6.20	1.55	0.10	2.13	0.85					

Pupation rate: The pupation rate among pure breeds at 36 ± 1°C ranged from 71.3 to 82.7% with the highest of 82.7% recorded for CSR18 and the lowest of 71.3% recorded for 8HT. On the other hand, at 25 ± 1°C, it ranged from 89.9% to 94.6% with the highest of 94.6% recorded for CSR19 and the lowest of 89.9% recorded for 5HT. Among the foundation crosses, the pupation rate at 36 ± 1°C ranged from 73.3 to 81.0% with the highest of 81.0% recorded for CSR18 × 8HT and the lowest of 73.3% recorded for 5HT × CSR19. At 25 ± 1°C, the pupation rate ranged from 91.6 to 94.3% with the highest of 94.3% recorded for CSR19 × 5HT and the lowest of 91.6% recorded for 8HT × CSR18 (Table 1).

The pupation rate among single hybrids at 36 ± 1°C ranged from 83.0 to 95.0% with the highest of 95.0% recorded for CSR19 × CSR18 and the lowest of 83.0% recorded for 5HT × 8HT. On the other hand, at 25 ± 1°C, it ranged from 92.2 to 98.6% with the highest of 98.6% recorded for CSR19 × CSR18 and the lowest of 92.2% recorded for 5HT × 8HT. Among the double hybrids, the pupation rate at 36 ± 1°C ranged from 74.0 to 94.0% with the highest of 94.0% recorded for DH1 and DH2 and the lowest of 74.0% recorded for DH8. At 25 ± 1°C, the pupation rate ranged from 93.9 to 98.5% with the highest of 98.5% recorded for DH8 and the lowest of 93.9% recorded for DH3 (Table 2).

Yield/10000 larvae: The yield/10000 larvae among pure breeds at 36 ± 1° ranged from 9.4 to 12.1 kg with the highest of 12.1 kg recorded for CSR18 and the lowest of 9.4 kg recorded for 8HT. On the other hand, at 25 ± 1°C, it ranged from 15.9 to 16.9 kg with the highest of 16.9 kg recorded for 5HT and the lowest of 15.9 kg recorded for CSR19. Among the foundation crosses, the yield/10000 larvae at 36 ± 1°C ranged from 10.2 to 12.9 kg with the highest of 12.9 kg recorded for CSR18 × 8HT and the lowest of 10.2 kg recorded for 5HT × CSR19. At 25 ± 1°C, the yield/10000 larvae ranged from 17.8 to 18.3 kg with the highest of 18.3 kg recorded for 5HT × CSR19 and the lowest of 17.8 kg recorded for CSR18 × 8HT (Table 1).

The yield/10000 larvae among single hybrids at 36 ± 1°C ranged from 14.7 to 18.1 kg with the highest of 18.1 kg recorded for CSR18 × CSR19 and the lowest of 14.7 kg recorded for 8HT × CSR19. On the other hand, at 25 ± 1°C, it ranged from 19.1 to 20.6 kg with the highest of 20.6 kg recorded for CSR18 × 5HT and the lowest of 19.1 kg recorded for 8HT × CSR19. Among the double hybrids, the yield/10000 larvae at 36 ± 1°C ranged from 11.8 to 17.7 kg with the highest of 17.7 kg recorded for DH7 and the lowest of 11.8 kg recorded for DH4. At 25 ± 1°C, the yield/10000 larvae ranged from 19.8 to 21.0 kg with the highest of 21.0 kg recorded for DH6 and DH8 and the lowest of 19.8 kg recorded for DH5 (Table 2).

Cocoon weight: The cocoon weight among pure breeds at 36 ± 1°C ranged from 1.20 to 1.47 g with the highest of 1.47 g recorded for CSR18 and 8HT and the lowest of 1.20 g recorded for CSR19. On the other hand, at 25 ± 1°C, it ranged from 1.68 to 1.90 g with the highest of 1.90 g recorded for 5HT and the lowest of 1.68 g recorded for CSR19. Among the foundation crosses, the cocoon weight at 36 ± 1°C ranged from 1.35 to 1.58 g with the highest of 1.58 g recorded for 8HT × CSR18 and the lowest of 1.35 g recorded for 5HT × CSR19. At 25 ± 1°C, the cocoon weight ranged from 1.91 to 1.94 g with the highest of 1.94 g recorded for 5HT × CSR19 and the lowest of 1.91 g recorded for CSR18 × 8HT (Table 1).

The cocoon weight among single hybrids at 36 ± 1°C ranged from 1.71 to 1.91 g with the highest of 1.91 g recorded for 5HT × CSR18 and the lowest of 1.71 g recorded for 8HT × CSR19. On the other hand, at 25 ± 1°C, it ranged from 1.97 to 2.13 g with the highest of 2.13 g recorded for 5HT × CSR18 and the lowest of 1.97 g recorded for CSR19 × 8HT. Among the double hybrids, the cocoon weight at 36 ± 1°C ranged from 1.71 to 1.85 g with the highest of 1.85 g recorded for DH7 and the lowest of 1.71 g recorded for DH8. At 25 ± 1°C, the cocoon weight ranged from 2.01 to 2.15 g with the highest of 2.15 g recorded for DH6 and the lowest of 2.01 g recorded for DH5 (Table 2).

Cocoon shell weight: The cocoon shell weight among pure breeds at 36 ± 1°C ranged from 23.4 to 30.3 cg with the highest of 30.3 cg recorded for CSR18 and 8HT and the lowest of 23.4 cg recorded for CSR19. On the other hand, at 25 ± 1°C, it ranged from 35.1 to 42.8 cg with the highest of 42.8 cg recorded for 5HT and the lowest of 35.1 cg recorded for CSR19. Among the foundation crosses, the cocoon shell weight at 36 ± 1°C ranged from 25.5 to 33.1 cg with the highest of 33.1 cg recorded for CSR18 × 8HT and the lowest of 25.5 cg recorded for 5HT × CSR19. At 25 ± 1°C, the cocoon shell weight ranged from 41.8 to 44.6 cg with the highest of 44.6 cg recorded for 8HT × CSR18 and the lowest of 41.8 cg recorded for CSR19 × 5HT (Table 1).

The cocoon shell weight of single hybrids at 36 ± 1°C ranged from 36.0 to 39.6 cg with the highest of 39.6 cg recorded for 5HT × CSR18 and the lowest of 36.0 cg recorded for 8HT × CSR19. On the other hand, at 25 ± 1°C, it ranged from 43.3 to 47.9 cg with the highest of 47.9 cg recorded for 5HT × CSR18 and the lowest of 43.3 cg recorded for CSR19 × CSR18. Among the double hybrids, the cocoon shell weight at 36 ± 1°C ranged from 33.9 to 39.8 cg with the highest of 39.8 cg recorded for DH7 and the lowest of 33.9 cg recorded for DH4. At 25 ± 1°C, the cocoon shell weight ranged from 43.9 to 47.6 cg with the highest of 47.6 cg recorded for DH6 and DH8 and the lowest of 43.9 cg recorded for DH5 (Table 2).

Cocoon shell ratio: The cocoon shell ratio among pure breeds at 36 ± 1°C ranged from 19.0 to 20.6% with the highest of 20.6% recorded for 8HT and the lowest of 19.0% recorded for 5HT. On the other hand, at 25 ± 1°C, it ranged from 20.9 to 22.8% with the highest of 22.8% recorded for 8HT and the lowest of 20.9% recorded for CSR19. Among the foundation crosses, the cocoon shell ratio at 36 ± 1°C ranged from 18.9 to 21.5% with the highest of 21.5% recorded for CSR18 × 8HT and the lowest of 18.9% recorded for 5HT × CSR19. At 25 ± 1°C, the cocoon shell ratio ranged from 21.8 to 23.2% with the highest of 23.2% recorded for 8HT × CSR18 and the lowest of 21.8% recorded for CSR19 × 5HT (Table 1).

The cocoon shell ratio of single hybrids at 36 ± 1°C ranged from 20.1 to 21.3% with the highest of 21.3% recorded for CSR19 × 8HT and the lowest of 20.1% recorded for CSR18 × CSR19. On the other hand, at 25 ± 1°C, it ranged from 21.8 to 23.3% with the highest of 23.3 % recorded for 8HT × 5HT and the lowest of 21.8% recorded for CSR19 × CSR18. Among the double hybrids, the cocoon shell ratio at 36 ± 1°C ranged from 19.2 to 21.7% with the highest of 21.7% recorded for DH7 and the lowest of 19.2% recorded for DH4. At 25 ± 1°C, the cocoon shell ratio ranged from 21.8 to 22.8% with the highest of 22.8% recorded for DH1 and the lowest of 21.8% recorded for DH2 and DH5 (Table 2).

Discussion

Silkworm breeds which are reared over a series of environments exhibiting less variation are considered stable. One of the main aims of the breeders is to recommend to farmers that are stable under different environmental conditions. In India, indigenous races are well adapted to fluctuating tropical climatic conditions characterized by high temperature, but they are poor in productivity. Keeping this in view, efforts over a decade to improve the quality of raw silk has resulted in the development of many productive and qualitatively superior bivoltine hybrids (Basavaraja *et al.*, 1995). These hybrids have been recommended to rear during favourable months and their unsuitability to rear during hot climatic condition prevailing, particularly in months. This situation has led to the development of robust hybrids tolerant to high temperature (Suresh Kumar *et al.*, 2002). It was also reported that the lines selected at high temperature and high humidity perform better than the lines selected at normal temperature. When both parental strains and hybrids are raised in unfavourable environmental conditions, performance of hybrids will be much superior to both the parental strains (Nagaraju *et al.*, 1996).

The higher survival of the hybrids than the pure races and the foundation crosses under high temperature conditions noticed in the present study is in concurrence with the earlier observations of Kato *et al.* (1989), Suresh Kumar *et al.* (1999, 2001) and Datta *et al.* (2001). Besides, the yield/10000 larvae, cocoon weight, shell weight and shell ratio were also low in the high temperature treated batches when compared to the batches reared under normal condition.

Hybridisation coupled with selection has been exploited as an important tool by many silkworm breeders for the improvement of silkworm for their maximum gains. Whatever may be the hybrid vigour shown by the hybrids or parent, it may not give anticipated yield and cocoon characters in adverse environmental conditions. Environmental factors especially temperature and relative humidity play a very important role in the life cycle of silkworm. The results of the present study clearly indicated the deleterious effect of high temperature and high humidity on the rearing performance on all the pure races, foundation crosses, single hybrids and double hybrids and also suggest 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 policies for required environments.

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.

Benchamin, K. V. and M. S. Jolly (1986) Principles of silkworm rearing; in *Proceedings of Seminar on Problems and Prospects of Sericulture.* Mahalingam, S. (ed.), pp. 63-108, Vellore, India.

Datta, R. K., N. Suresh Kumar, H. K. Basavaraja, C. M. Kishor Kumar and N. Mal Reddy (2001) "CSR18 × CSR19" A robust bivoltine hybrid for all season rearing in the tropics. *Indian Silk* **39**, 5-7.

Kato, M., K. Nagayasu, O. Ninagi, W. Hara and A.Watanabe (1989) Study on resistance of the silkworm *Bombyx mori* to high temperature. Proc. of the 6th International Congr. of SABRAO (II), pp. 953-956.

KrishnaswamI, S. (1978) New technology of silkworm rearing. *CSRTI Bulletin* **2**, 1-24.

Krishanswami, S., M. N.Narasimhanna, S. K. Suryanarayana and S. Kumararaj (1973) Silkworm rearing Bulletin 15/2, FAO Agricultural Services, United Nations Organizations.

Krishnaswami, S. (1994) A practical guide to mulberry silk cocoon production in Tropics. Srramula Sericulture Consultants, Bangalore, India.

Nagaraju, J., S. Raje Urs and R. K. Datta (1996) Cross breeding and heterosis in the silkworm, *Bombyx mori*. *Sericologia* **36**, 1-20.

Suresh Kumar, N., C. M. Kishor Kumar, H. K. Basavaraja, N. Mal Reddy, M. Ramesh Babu and R. K. Datta (1999) Comparative performance of robust and productive bivoltine hybrids of *Bombyx mori* L. under high temperature conditions. *Sericologia* **39**, 567-571.

Suresh Kumar, N., T. Yamamoto, H. K. Basavaraja and R. K. Datta (2001) Studies on the effect of high temperature on F1 hybrids between polyvoltine and bivoltine silkworm races of *Bombyx mori* L. *Int. J. Indust. Entomol.* **2**, 123-127.

Suresh Kumar, N., H. K. Basavaraja, C. M. Kishor Kumar, 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.* **5**, 153-162.