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# Influence of Different Environmental Conditions on Cocoon Parameters and Their Effects on Reeling Performance of Bivoltine Hybrids of Silkworm, *Bombyx mori.* L.

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**Three newly authorized bivoltine silkworm hybrids namely, CSR2×CSR4 (productive single hybrid), (CSR6×CSR26)×(CSR2×CSR27) (Productive double hybrid) and CSR18×CSR19 (robust single hybrid) were chosen for the present study. These hybrids were subjected to different temperature and humidity treatments i.e., 25±1°C and RH 65±5% (control), 30±1°C, with combinations of low relative humidity (RH 65±5%) and high RH ( 85±5%) at different stages during rearing and spinning of silkworm larvae. The larvae of after 3rd moult were subjected to different thermal and humidity stress till the assessment of cocoon traits. The comparative rearing and reeling performance clearly indicated that the deleterious effect of high temperature and high RH was more pronounced for the majority of traits such as cocoon uniformity, cocoon weight, shell weight, shell percentage, reelability, filament length, raw silk percentage raw silk recovery denier and waste percentage on silk weight than other temperature and RH treatments and this effect was almost similar for all three silkworm hybrids studied. The present investigation clearly indicate that the deleterious effect of high temperature and high RH was more pronounced on rearing and spinning of silkworm larvae than other temperature and RH treatments and similar effect was noticed for all the three silkworm hybrids studied. The cocoon characters can be improved by providing ideal environmental conditions even during spinning stage of larvae affected with high temperature and RH. The study also suggest that high temperature and low humidity has greater effect during rearing stage than spinning stage.**

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## Introduction

Temperate zone has ideal temperature and humidity coupled with good quality leaf during favourable season for bivoltine sericulture. While in tropical countries, the prevailing climatic conditions are favourable predominantly for rearing of polyvoltine x bivoltine hybrids. Since sericulture helps in poverty alleviation, small-scale farming groups are attracted towards sericulture in these countries. Cocoon quality parameters play an important role on the quality of the raw silk reeled. The cocoon properties are defined by a large number of parameters, some of which important for the parent cocoons race maintenance some are important for cocoons reeling. For a reeling technologist, the technological parameters of the cocoon are significantly important, since they determine the quality, quantity and efficiency of the reeling process.

Significant variation in cocoon shape and cocoon size in hybrids results in variation in filament size as well as the quality of the reeled thread (Nakada, 1993). It is also mentioned that when reeling is carried out with irregular and non-uniform cocoons it results in thread breakage, hindrance due to slugs, poor reelability, poor cooking, decreased raw silk recovery, variation in raw silk denier and poor neatness (Takabayashi *et al.*, 1997). To obtain uniform filament size in auto and semiautomatic reeling units, cocoon size uniformity is very important (Mano, 1994). Extensive studies have been carried out on cocoon shape variation in parental silkworm breeds and their hybrids (Hirashi, 1912; Katsuki and Nagasawa, 1917; Hirabayashi, 1982; Gamo *et al.*; 1985; Nakada, 1989, 1993, 1994, 1998;

**Table 1.** Rearing and spinning environmental conditions at different stages of silkworm larvae

| Treatment No. | Rearing conditions | | Spinning conditions | |
|---|---|---|---|---|
| | Temperature (°C) | Relative humidity (%) | Temperature (°C) | Relative humidity (%) |
| T1 | 30 ± 1 throughout | 85 ± 5 | 30 ± 1 | 85 ± 5 |
| T2 | 30 ± 1 throughout | 85 ± 5 | 24~25 | 65 ± 5 |
| T3 | 30 ± 1 throughout | 50 ± 5 | 30 ± 1 | 50 ± 5 |
| T4 | 30 ± 1 throughout | 50 ± 5 | 24~25 | 65 ± 5 |
| T5 | 27~28 young age<br>24~25 late age | 85 ± 5<br>65 ± 5 | 30 ± 1 | 85 ± 5 |
| T6 | 27~28 young age<br>24~25 late age | 85 ± 5<br>65 ± 5 | 30 ± 1 | 50 ± 5 |
| T7 (Control) | 27~28 young age<br>24~25 late age | 85 ± 5<br>65 ± 5 | 24~25 | 65 ± 5 |

Ravindra Singh *et al.*, 1998).

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 of silkworm, as the silkworm is a poikilothermic (cold blooded insect) (Benchamin and Jolly, 1986). It is also known that the late age silkworms prefer relatively lower temperature than young age 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 are ample literature showing that good quality cocoons are produced within a temperature range of 22-27°C and above these levels makes the cocoon quality worse (Krishnaswami *et al.*, 1973). Limited information is available on the combined effect of different temperature and humidity on various cocoon characters and reeling parameters at different stages during rearing and spinning of silkworm larvae which in turn will provide valuable information to the technology developers who are engaged in the improvement of quality and quantity of silk acceptable to the level of international standard.

With an objective to understand the influence of different environmental condition on cocoon parameters and their effects on reeling performance, the present study was carried out at the Silkworm Breeding Laboratory of Central Sericultural Research and Training Institute, Mysore, India.

## Materials and Methods

In the present study, three popular and authorized bivoltine hybrids viz., CSR2 × CSR4 (productive single hybrid), (CSR2 × CSR27) × (CSR6 × CSR26) (productive double hybrid) and CSR18 × CSR19 (robust single hybrid) were utilized. The silkworm rearing was carried out in three replications following the standard method (Krishnaswami, 1978). After 3rd moult, the larvae were subjected to different environmental conditions in SERICATRON chamber with precise and automatic control facilities for uniform maintenance of temperature and relative humidity (Chuo Company, Japan). The details of the rearing and spinning environmental conditions at different stages of silkworm larvae were shown in Table 1.

The cocoons were harvested on 6th day and cocoon assessment was carried out by taking ten male and female live cocoons at random. The cocoon traits such as parameters like cocoon weight, shell weight, and shell percentage were recorded.

### Drying conditions

The cocoons were dried in a batch type hot air drier, following the temperature pattern of 115-100-85-70-55°C for a period of 5 hours. The degree of drying achieved was around 40%.

### Cocoon uniformity (size variability)

To assess the uniformity of the cocoon size, 50 cocoons are taken at random from each replication for all hybrids for all the seven temperature and RH treatments/environmental conditions. The cocoon length and breadth were measured using a vernier calipers specially designed for cocoon uniformity test. After measuring the length and breadth of the cocoons, ratio between length and breadth was calculated by using the following formula:

Cocoon length and width ratio = (Length/Breadth) × 100

The ratio obtained between length and breadth was taken and analyzed statistically for standard deviation (SD) and coefficient of variation (CV). The cocoons possessing less standard deviation (SD) and coefficient variation (CV) were considered uniform in cocoon shape.

### Cocoon cooking conditions

The dried cocoons were taken in a cage and then retted at 50°C for 1 minute in first pan of cooking. The retted cocoons were immediately treated at high permeation temperature of 90°C for 2 minutes duration in second pan of cooking followed by treatment at low permeation temperature of 60°C for 1 minutes duration in first pan of pan system of cooking. The cocoons were then cooked at 97°C for 2 minutes in second pan of cooking followed by adjustment treatment by pouring cold water in second pan it self thereby reducing the temperature gradually from 97 to 60°C. The total period of adjustment was thus 4 minutes and the cooking was carried in pan system of cooking. The cooked cocoons were then brushed manually at 80°C and then transferred to reeling basin for picking at 45°C.

### Reeling conditions

Reeling of cocoons were carried out on multiend reeling machine using 100 meters/minute reeling speed, 40°C reeling basin water temperature and 8 cm crosier length. The reeling parameters viz., reelability, filament length, raw silk %, raw silk recovery % denier and waste % on silk weight were recorded.

## Results

The effect of different temperature and humidity treatments on cocoon uniformity, cocoon characteristics and their reeling parameters of three popular and commercial bivoltine hybrids, CSR2 × CSR4, (CSR6 × CSR26) × (CSR2 × CSR27) were presented in Table 2 and 3. It could be observed that majority of cocoon characters viz., cocoon uniformity, cocoon weight, shell weight, shell percentage, reelability, filament length, raw silk percentage, raw silk recovery, denier and waste percentage of silk are adversely affected by different temperature and humidity treatments. The details are given below.

### Cocoon uniformity (size variability)

Minimum cocoon length of 2.61, 2.62, 2.47 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively, width of 1.52, 1.53 and 1.45 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively and more standard deviation of 21.85, 24.01 and 19.32 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum cocoon length of 3.65, 3.65, 3.34 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively, cocoon width of 2.16, 2.15 and 2.04 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively and less standard deviation of 7.28, 7.78 and 7.25 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. It was interesting to note that the effect of high temperature and high RH conditions (T1) was more pronounced for all

**Table 2.** Cocoon size variability (uniformity) in three bivoltine hybrids in different environmental conditions

| Treatment | Cocoon length (cm) | Cocoon width (cm) | (Length / Width) ×100 | SD | CV % |
|---|---|---|---|---|---|
| Hybrid : CSR2 × CSR4 | | | | | |
| T1 | 2.61 | 1.52 | 171.94 | 21.85 | 12.71 |
| T2 | 2.79 | 1.64 | 169.82 | 16.37 | 9.64 |
| T3 | 3.07 | 1.85 | 165.67 | 14.49 | 8.74 |
| T4 | 3.24 | 1.95 | 166.42 | 13.43 | 8.07 |
| T5 | 3.45 | 2.12 | 163.12 | 12.57 | 7.71 |
| T6 | 3.58 | 2.15 | 166.67 | 8.26 | 4.95 |
| T7 | 3.65 | 2.16 | 169.21 | 7.28 | 4.30 |
| CD at 5 % | 0.06 | 0.02 | 1.72 | | |
| Hybrid : (CSR6 × CSR26) × (CSR2 × CSR27) | | | | | |
| T1 | 2.62 | 1.53 | 171.80 | 24.01 | 13.97 |
| T2 | 2.86 | 1.62 | 176.24 | 16.21 | 9.20 |
| T3 | 3.06 | 1.88 | 162.76 | 14.69 | 9.02 |
| T4 | 3.29 | 1.93 | 170.79 | 13.68 | 8.01 |
| T5 | 3.47 | 2.10 | 164.97 | 12.66 | 7.67 |
| T6 | 3.60 | 2.14 | 168.12 | 8.47 | 5.04 |
| T7 | 3.65 | 2.15 | 169.97 | 7.78 | 4.57 |
| CD at 5% | 0.03 | 0.03 | 2.00 | | |
| Hybrid : CSR18 × CSR 19 | | | | | |
| T1 | 2.47 | 1.45 | 170.11 | 19.32 | 11.36 |
| T2 | 2.57 | 1.55 | 166.37 | 15.41 | 9.26 |
| T3 | 2.57 | 1.64 | 156.76 | 14.23 | 9.08 |
| T4 | 2.66 | 1.74 | 153.34 | 13.26 | 8.65 |
| T5 | 2.87 | 1.98 | 145.07 | 11.73 | 8.09 |
| T6 | 3.16 | 1.97 | 160.45 | 7.62 | 4.75 |
| T7 | 3.34 | 2.04 | 163.78 | 7.25 | 4.43 |
| CD at 5% | 0.04 | 0.04 | 4.77 | | |
| Hybrids (A) CD at 5% | 0.01 | 0.01 | 1.09 | | |
| Treatments (B) CD at 5% | 0.02 | 0.02 | 1.66 | | |
| (A × B) | | | | | |
| SE ± | 0.01 | 0.01 | 1.01 | | |
| CD at 5% | 0.04 | 0.03 | 2.87 | | |

**Table 3.** Cocoon characteristics and their reeling performance in three bivoltine hybrids in different environmental condition

| Treatment | Cocoon weight (g) | Shell weight (g) | Shell percentage (%) | Reelability (%) | Filament length (m) | Raw silk (%) | Raw silk recover (%) | Denier (d) | Waste on silk weight (%) |
|---|---|---|---|---|---|---|---|---|---|
| Hybrid : CSR2 × CSR4 | | | | | | | | | |
| T1 | 1.585 | 0.317 | 20.0 | 35.0 | 666 | 9.6 | 47.9 | 2.05 | 46.3 |
| T2 | 1.635 | 0.328 | 20.1 | 56.0 | 777 | 10.6 | 52.6 | 2.14 | 33.3 |
| T3 | 1.445 | 0.334 | 23.1 | 69.0 | 981 | 15.8 | 69.1 | 2.31 | 14.3 |
| T4 | 1.545 | 0.347 | 22.5 | 73.0 | 1037 | 16.2 | 73.5 | 2.34 | 13.5 |
| T5 | 1.927 | 0.427 | 22.2 | 51.0 | 831 | 10.0 | 44.9 | 2.51 | 34.8 |
| T6 | 1.845 | 0.450 | 24.4 | 86.5 | 1129 | 19.5 | 79.1 | 2.93 | 9.1 |
| T7 | 1.978 | 0.458 | 23.2 | 88.0 | 1181 | 19.7 | 84.8 | 3.10 | 7.6 |
| CD at 5% | 0.018 | 0.010 | 0.70 | 1.3 | 27 | 0.7 | 2.94 | 0.05 | 2.4 |
| Hybrid : (CSR6 × CSR26) × (CSR2 × CSR27) | | | | | | | | | |
| T1 | 1.715 | 0.347 | 20.2 | 35.5 | 694 | 9.2 | 45.5 | 2.04 | 43.2 |
| T2 | 1.760 | 0.360 | 20.4 | 55.0 | 799 | 10.0 | 49.2 | 2.23 | 31.4 |
| T3 | 1.633 | 0.375 | 23.0 | 66.5 | 1034 | 14.0 | 61.0 | 2.49 | 16.3 |
| T4 | 1.685 | 0.379 | 22.5 | 73.5 | 1098 | 14.7 | 65.2 | 2.55 | 13.3 |
| T5 | 1.930 | 0.420 | 21.8 | 53.0 | 848 | 12.2 | 55.8 | 2.56 | 33.4 |
| T6 | 1.876 | 0.450 | 24.0 | 85.0 | 1115 | 20.5 | 85.3 | 3.10 | 8.9 |
| T7 | 1.985 | 0.455 | 23.0 | 87.5 | 1245 | 20.2 | 87.8 | 3.18 | 7.1 |
| CD at 5% | 0.075 | 0.018 | 0.35 | 1.7 | 102 | 0.8 | 3.1 | 0.04 | 1.9 |
| Hybrid :CSR18 × CSR 19 | | | | | | | | | |
| T1 | 1.645 | 0.334 | 20.3 | 31.0 | 579 | 9.5 | 46.5 | 2.24 | 43.9 |
| T2 | 1.660 | 0.351 | 21.1 | 55.5 | 757 | 11.2 | 53.1 | 2.37 | 30.9 |
| T3 | 1.490 | 0.343 | 23.0 | 67.5 | 821 | 14.7 | 64.6 | 2.60 | 16.1 |
| T4 | 1.541 | 0.343 | 22.2 | 73.0 | 937 | 15.8 | 70.7 | 2.44 | 11.7 |
| T5 | 1.739 | 0.374 | 21.5 | 51.0 | 684 | 10.8 | 50.1 | 2.63 | 34.4 |
| T6 | 1.667 | 0.383 | 23.0 | 83.0 | 1088 | 18.0 | 78.1 | 2.69 | 11.0 |
| T7 | 1.859 | 0.398 | 21.4 | 87.5 | 1097 | 18.1 | 84.1 | 2.82 | 8.2 |
| CD at 5% | 0.039 | 0.01 | 0.48 | 1.6 | 12 | 0.34 | 1.94 | 0.14 | 1.1 |
| Hybrids (A) CD at 5% | 0.017 | 0.379 | 0.18 | 0.5 | 20 | 0.21 | - | 0.03 | - |
| Treatment (B) CD at 5% | 0.027 | 0.578 | 0.28 | 0.8 | 31 | 0.32 | 1.41 | 0.05 | 1.01 |
| (A × B) | | | | | | | | | |
| SE± | 0.02 | 0.35 | 0.17 | 0.49 | 18.61 | 0.20 | 0.85 | 0.03 | 0.62 |
| CD at 5% | 0.046 | 1.002 | 0.49 | 1.4 | 53 | 0.56 | 2.44 | 0.08 | 1.76 |

hybrids as evident from the higher values of standard deviation (SD) and coefficient variation (CV%) than other treatments. Marginal improvement in these characters was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). The results also indicate that high temperature and high RH (T5) has more effect on cocoon uniformity than high temperature and low humidity (T6) at spinning stage.

**Cocoon weight**

Cocoon weight was significantly altered by different environmental conditions. Minimum cocoon weight of 1.445, 1.633 and 1.541 g in CSR2×CSR4, (CSR6×CSR27)×( CSR2×CSR27) and CSR18 × CSR19 respectively was observed in high temperature and low RH (T3) than other treatments. Maximum cocoon weight of 1.978, 1.985 and 1.859 g in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and

CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. The effect of high temperature and low RH conditions (T3) was more effect for all hybrids than other treatments. Marginal improvement in cocoon weight was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and low RH (T6) has great effect on cocoon weight than high temperature and high RH (T5) at spinning stage.

**Shell weight**

Minimum shell weight of 0.317, 0.347 and 0.334 g in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum shell weight of 0.458, 0.455 and 0.397 g in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Marginal improvement in cocoon weight was observed when the spinning larvae were shifted to optimum conditions of temperature and RH. High temperature and high RH (T5) has more effect on shell weight than high temperature and low RH (T6) at spinning stage.

**Shell percentage**

Minimum shell percentage of 20.0, 20.2 and 20.3% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum shell percentage of 24.4, 24.0 and 23.0% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T6 when compared to other treatments. Marginal improvement in cocoon weight was observed when the spinning larvae were shifted to optimum conditions of temperature and RH. High temperature and high RH (T5) has great effect on shell percentage than high temperature and low RH (T6) at spinning stage.

**Reelability percentage**

Minimum reelability of 35.0, 35.5 and 31.0% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum reelabilty of 88.0, 87.5 and 87.5% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Significant improvement in reelability was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). The results also indicate that high temperature and high RH (T5) has great effect on reelability than high temperature and low RH (T6) at spinning stage.

**Filament length**

Filament length was significantly affected by different environmental conditions. Minimum filament length of 666, 694 and 579 m in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum filament length 1181, 1245 and 1097 m CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Significant improvement in filament length was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and high RH (T5) has grate effect on filament length than high temperature and low RH (T6) at spinning stage.

**Raw silk percentage**

The trait raw silk percentage ranged from 9.6 to 19.7 , 9.2 to 20.2 and 9.5 to 18.1 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively in different environmental conditions. Minimum raw silk of 9.6, 9.2 and 9.5% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum raw silk of 19.7, 20.2 and 18.1% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Marginal improvement in raw silk percentage was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and high RH (T5) has great effect on this trait than high temperature and low RH (T6) at spinning stage.

**Raw silk recovery**

Raw silk recovery was significantly affected by different environmental conditions. Minimum Raw silk recovery of 45.6 and 46.5% in (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments where as minimum raw silk recovery of 44.9% in CSR2 × CSR4 was recorded in T5. Maximum raw silk recovery of 84.8, 87.8 and 84.1% CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Significant improvement in raw silk recovery was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and high RH (T5) has great effect on filament length than high temperature and low RH (T6) at spinning stage.

**Denier**

Denier was significantly affected by different environmental conditions. Minimum Denier of 2.05, 2.04 and 2.24 d in (CSR6 × CSR27) × (CSR2 × CSR27) and CSR 18 × CSR19 respectively was observed in high temperature and high RH (T1) than other treatments. Maximum Denier of 3.10, 3.18 and 2.82 d in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T7 (control) when compared to other treatments. Denier was significantly increased when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and high RH (T5) has grate effect on denier than high temperature and low RH (T6) at spinning stage.

**Waste percentage on silk weight**

The waste percentage on silk weight ranged from 7.6 to 46.3, 7.1 to 43.2 and 8.2 to 43.9 in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively in different environmental conditions. Minimum waste percentage on silk weight of 7.6, 7.1 and 8.2% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was observed at optimum temperature and RH (T7 control) conditions than other treatments. Maximum waste percentage on silk weight of 46.3, 43.2 and 43.9% in CSR2 × CSR4, (CSR6 × CSR27) × (CSR2 × CSR27) and CSR18 × CSR19 respectively was recorded in T1 (high temperature and high RH conditions) when compared to other treatments. Significant reduction in waste percentage on silk weight was observed when the spinning larvae were shifted to optimum conditions of temperature and RH (T2 and T4). High temperature and high RH (T5) has more effect on this waste percentage on silk weight than high temperature and low RH (T6) at spinning stage.

Moreover, the effect of high temperature and high RH conditions (T1) was more pronounced for traits viz., cocoon uniformity, cocoon shell weight, cocoon shell percentage, reelability, filament length, raw silk percentage and waste percentage on silk weight for all hybrids than other treatments.

## Discussion

The variation in the size of silk filament depends mainly on the uniformity of the cocoons used and which in turn will ultimately determine the uniformity and the quality of the silk reeled. All the earlier studies carried out on cocoon shape variation in parental silkworm breeds and their hybrids (Hirashi, 1912; Katsuki and Nagasawa, 1917; Hirabayashi, 1982; Gamo *et al*., 1985; Nakada, 1989, 1993, 1994, 1998; Ravindra Singh *et al*., 1998) were based on the silkworm rearing conducted under the optimal conditions and so far no study had been carried out on the effect of combination of adverse environmental conditions such as high temperature and RH at various stages of silkworm rearing on cocoon shape variations , cocoon characteristics and their reeling performance. Suresh Kumar *et al*. (2003) indicated deleterious effect of high temperature and high humidity on the cocoon shape and size of all the pure races, foundation crosses, single hybrids and double hybrids.

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 summer months. This situation has led to the development of robust hybrids tolerant to high temperature (Datta *et al*., 1997). It was also observed 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). It is well established that the systematic evaluation is the most important aspect before identifying breeds/hybrids for commercial exploitation and various methods of hybrid evaluation are being practiced by silkworm breeders. Among the various methods employed for hybrid evaluation, the cocoon size uniformity is very important to obtain uniform filament size in automatic and semi automatic reeling units (Mano, 1994).

The results of the present study clearly indicated the effect of high temperature and high RH (T1) on the majority of characters such as cocoon uniformity, cocoon weight, shell weight, reelability, filament length, raw silk percentage raw silk recovery, denier and waste percentage of silk more effect than other temperature and RH treatments. Effect of high humidity on reeling characteristics could be attributed to the structural changes in the sericin. Akahane and Tsubochi (1994) have shown that a relation exists between water content of cocoon layers during the spinning stage and reelability of cocoons and recommended that water content of the cocoon layer should be below 20% in order to obtain good quality cocoons with better reelability. They have pointed out that more water content in the cocoon shell layers during cocoon spinning will reduce the reelability of cocoons. It is to be noted that when the humidity (of ambient conditions) is high during cocoon spinning, water present in the spinning solution, silkworm urine and faeces is evaporated slowly influencing the structure of sericin. This may reduce the solubility of sericin and increase the agglutination force between the cocoon filament and cocoon shell. This in turn would result in reduced sericin swelling and softening during cooking affecting the reelability. The low reelability will in turn affect all related parameters viz., filament length, raw silk percentage, raw silk recovery and waste percentage on silk weight. According to a Japanese investigation on impact of various factors during cocoon mounting on reeling performance, it is believed that the humidity and air flow during mounting has the maximum impact on reeling performance of cocoons than temperature and other conditions maintained during mounting (Wu, 1976a, b, c).

The present investigation clearly indicate that the deleterious effect of high temperature and high RH was more pronounced on rearing and spinning of silkworm larvae than other temperature and RH treatments and similar effect was noticed for all the three silkworm hybrids studied. The cocoon characters can be improved by providing ideal environmental conditions even during spinning stage of larvae affected with high temperature and RH. The study also suggest that high temperature and low humidity has greater effect during rearing stage than spinning stage.

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