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Shyam Thore
M.Sc. student, Department of Agril. Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Chandrakant Latpate
Officer In charge, Sericulture Research Unit, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Dhananjay Mohod
Senior Research Assistant, Sericulture Research Unit, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Shriram Shinde
Ph.D. Scholar, Department of Agril. Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Shyam Thore
M.Sc. student, Department of Agril. Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Studies on evaluation and identification of bivoltine silkworm hybrids (*Bombyx mori* L.)

Shyam Thore, Chandrakant Latpate, Dhananjay Mohod and Shriram Shinde

Abstract
The experiment was conducted to evaluate and identify suitable hybrids with comparatively improved economic traits specific for climatic conditions of Marathwada region of Maharashtra at Sericulture Research Unit, V.N.M.K.V, Parbhani, during 2021-22, laid in Randomized Block Design with six treatments and four replications. It is generally done in comparison with the existing commercially accepted popular variety and aimed to select the better strains than the existing ones. During the study (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) recorded significantly highest hatching percent (98.16 percent), 10 mature larval weight (43.75 g), single cocoon weight (2.12 g), shell weight (0.45 g), filament length (1205 m), filament weight (0.381 g) and cocoon yield (19.70 kg) was found significantly superior over rest of hybrids. CSR_{50} x CSR_{51} had shown shortest larval duration (22.10 days), maximum shell percentage (21.84 percent) and highest moth emergence (98.25 percent). Silkworm hybrid FC_2 x FC_1 showed lowest denier value (2.61) while (S_8 x CSR_{16}) recorded minimum pupal duration (10.00 days).

Keywords: Silkworm, bivoltine, economic traits

1. Introduction
Sericulture being an agro based and industry is capable of providing employment to a larger section of people as a subsidiary occupation in rural areas (Trivedi and Sarkar, 2015) [14]. In India, main silk producing states are Kamataka, Jammu and Kashmir, Andhra Pradesh, Bihar, Madhya Pradesh, Tamil Nadu and West Bengal. It is also spreading in 12 non-traditional states including Maharashtra. Due to the horizontal expansion of sericulture in traditional and non-traditional areas, it has become necessary to use the silkworm hybrids suitable to particular zone. Sericultural advanced countries such as Japan and China have achieved a remarkable breakthrough in increasing the unit production of silk by evolving productive breeds/hybrids suitable to specific locations and agronomical practices (Yokoyama, 1979) [15]. In India, over 95 percent of the commercial raw silk is being produced from polylvoltine x bivoltine cross breed (Datta, 2000) [3]. The CSR &TI, Mysore and KSSRSsDI, Bangalore have developed new productive bivoltine hybrids *viz*, CSR_2 x CSR-$_4$, CSR_2 x CSR_5, CSR_4 x CSR_2, CSR_{18} X CSR_{19} and KSOl x NP_2 and NP_2 x KSOl, respectively. These hybrids showed a significant improvement in cocoon yield, raw silk recovery, filament length and renditta. There has been considerable deterioration in the breed characteristics and now it is high time for its replacement. The current situation demands establishment of new hybrids on the basis of both qualitative and quantitative characters. Mostly multi × bivoltine hybrids are reared in tropical areas of the country which do not meet the international standards, thus, there is great need and scope for improving the bivoltine sericulture of the country (Moorthy *et al*., 2007) [6]. From time to time, various bivoltine silkworm hybrids evolved by the southern states of the country have been recommended by 'Central Silk Board' for commercial exploitation (Rajalakshmi *et al*., 1998) [10]. The success of the sericulture business is completely depends upon the factors like silkworm races, quality of mulberry leaf and rearing, management since these factors decide the quality and quantity of good cocoon production. To increase cocoon production and to reduce labour cost, it is advisable to choose silkworm strain and mulberry variety which are suitable for particular set of condition. Therefore, it is most essential to conduct the studies on evaluation of different silkworm hybrids for particular region. Hence, the present study aims to evaluate the performance and better combinations of promising silkworm hybrids at Parbhai location.

2. Materials and Methods

Six popular bivoltine mulberry silkworm breeds namely; (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}), FC_1 x FC_2, FC_2 x FC_1, S_8 x CSR_{16}, CSR_{50} x CSR_{51}, and CSR_{16} x CSR_{17} were reared at Sericulture Research Unit, V.N.M.K.V, Parbhani under congenial laboratory conditions during the year 2021 (December) following standard package of practices of Krishnaswami (1978) [4].

The rearing house and all rearing appliances were disinfected with sanitech (CLO2) solution (500 ppm CLO2 +0.5% slaked lime) to make them free from pathogen before rearing. Paper Sheets of disease-free laying's of silkworm races were procured from Central Sericulture Research and Training Institute, Mysore and were incubated at 25+1 degree and 75+5% relative humidity. The egg sheet was sprayed out in a single layer in the rearing tray and covered with the paraffin wax coated paper in rearing stand and made the black boxes for each hybrids. The boxes kept under tray and covered with black cloth 48 hour before hatching and on the day of hatching should keep under light for uniform hatching. The newly hatched egg kept in different trays for easy feeding, newly hatched larvae of silkworm hybrids were fed with chopped pieces of fresh tender mulberry leaves harvested from the popular mulberry varieties *viz*; V-1 maintained at Mulberry Farm of Sericulture Research Unit. The feeding was given for four times in a day. The rearing trays were cleaned once after I^{st} moult and twice up to II^{nd} moult. The silkworm moults four times during its larval growth period. Its growth completed in five stages. The stage between two moults is called as "instar" and hence there are "five" instars in the life period of silkworm. During moulting the worms cease feeding and hence were not provided any food. Moulting is completed in 20 to 30 hrs. The duration of moult will be change as per the season, after the completion of each moult a bed disinfectant Vijeta @ 4 g/39 sq. feet was dusted to control the diseases and feeding was given after half an hour. Later on bed cleaning was undertaken. After the worms full development, the matured worms were identified, as they looked translucent with creamy colour. The matured worms ceased to eat, crawled towards periphery of the trays and tried to spin the cocoons, were handpicked and put on netrika for spinning cocoon. The worms spun the cocoons within 48 to 72hrs. The pupae remained inside.

During the rearing period, larvae and cocoons were assessed for different parameters *viz*; fecundity, hatching percentage, larval weight, larval duration, cocoon yield, cocoon weight, shell weight, pupal weight, shell ratio, denier, filament length, filament weight and moth emergence. The data pertaining to the above parameters was recorded replication-wise for all the treatments and subjected to statistical analysis. The characters studied and observational procedures adopted are given under the following headings.

2.1 Fecundity (no.)

The fecundity was calculated by taking the number of eggs laid by a single adult moth from each replication. The eggs number was counted individually and recorded.

2.2 Hatching (%)

The hatching % was calculated by deducting unhatched, unfertilized and dead eggs from the total number of eggs laid by a single adult female moth. It was calculated as,

$$\text{Hatching (\%)} = \frac{\text{No. of hatched eggs}}{\text{Total no. of eggs}} \times 100$$

2.3 Larval duration (days)

The total larval period measured by recording the period from hatching to the onset of spinning.

2.4 Larval weight (g)

The maximum larval weight was recorded by taking the weight of matured larvae just before the onset of spinning.

2.5 Single cocoon weight (g)

The cocoon weight recorded on 6^{th} day of spinning. The average of 10 cocoons were taken as single cocoon weight.

$$\text{Single cocoon weight (g)} = \frac{\text{Weight of 10 Cocoons}}{10}$$

2.6 Single shell weight (g)

The cocoon was cut at one end and shell weight will recorded after removing pupae.

$$\text{Single shell weight (g)} = \frac{\text{Weight of 10 shell}}{10}$$

2.7. Cocoon shell Ratio (%)

$$\text{Shell Ratio (\%)} = \frac{\text{Single shell weight}}{\text{Single cocoon weight}} \times 100$$

2.8 Cocoon yield / 10,000 larvae brushed by weight (kg)

This parameter was recorded as the average weight of cocoons harvested (kg) to that of larvae retained after third moult in each replication and converted for 10,000 larvae by following formulae:

$$\text{Cocoon yield (Kg)} = \frac{\text{Cocoon yield in kg}}{\text{No. of cocoons retained after}} \times 10000$$

2.9 Cocoon filament length (m)

Cocoon filament length was measured by reeling 10 cocoons in four replications with the help of epprovate.

2.10 Cocoon filament weight (g)

Cocoon filament weight was measured by reeling 10 cocoons in four replications with the help of electronic balance.

2.11 Denier

It is the term used to denote the thickness of silk filament and expressed in terms of ratio of weight of filament, to the filament length multiplied by 9000.

$$\text{Denier} = \frac{\text{Filament weight (g)}}{\text{Filament length (m)}} \times 9000$$

2.12 Pupal duration (days)
The total pupal period was measured by recording period from spinning to the emergence of moth.

3. Results and discussion
The present research findings revealed that bivoltine hybrid (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) registered the highest hatching percent (98.16 percent) over the rest of the hybrids followed by (S_8 x CSR_{16}) 97.30 percent, FC_1 x FC_2 97.30 percent as compared with check (CSR_{16} x CSR_{17}) (96.34 percent) which were at par with each other. FC_2 x FC_1 (95.26 percent) and CSR_{50} x CSR_{51} (95.00 percent) which were at par with each other and showed significantly lower hatching percent than control treatment (CSR_{16} x CSR_{17}) (Tables 1). Hatching percent in the hybrid CSR_{16} x CSR_{17} (96.19 percent) followed by CSR_{50} x CSR_{51} (92.52 percent) (Bobade *et al.*, 2019) [2]. The argument is well documented (Maske *et al.*, 2020) [5] and (Salunke, 2003) [11].
The weight of ten matured larvae (g) indicated that larval weight varied in the range of 41.23 to 43.75 g. The performance of bivoltine hybrid (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (43.75 g) and FC_1 x FC_2 (41.23. Hybrid FC_1 x FC_2 was observed significantly superior over rest of hybrids and recorded larval weight (41.23 g) followed by CSR_{50} x CSR_{51} (40.51 g) and FC_2 x FC_1 (40.25 g) which were at par with each other. Only hybrid S_8 x CSR_{16} (36.55 g) showed lower value than the control treatment CSR_{16} x CSR_{17} (39.20 g) (Tables 1). Weight of ten matured larvae was significantly superior in hybrids CSR_{16} x CSR_{17} (37.92 g) (Alam 2020, Pathan and Khan, 2018, Tekule *et al.*, 2018, Maske *et al.*, 2020) [1,9,13.5]. Maximum larval weight in FC_1 x FC_2 (37.37 g) which is similar with our findings (Alam 2020) [1].
The hybrid CSR_{50} x CSR_{51} had shown shortest larval duration (22.10 days) and found significantly superior over check. CSR_{16} x CSR_{17} shown larval duration (22.93 days) followed by S_8 x CSR_{16} (23.19 days) and (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (23.30 days) which were at par with each other. Only two hybrids FC_2 x FC_1 (25.40 days) and FC_1 x FC_2 (25.49 days) shown that non-significant larval duration than control check treatment CSR_{16} x CSR_{17} (22.93 days) (Tables 1). FC_1 x FC_2 (25 days) during winter season (Pathan and Khan, 2018) [9]. The larval duration of hybrid S_8 x CSR_{16} and CSR_{50} x CSR_{51} breeds are similar with findings (Bobade *et al.*, 2019, Maske *et al.*, 2020) [2, 5].
The single cocoon weight revealed that cocoon weight was recorded in the range of 1.20 g to 2.12 g. The significantly highest cocoon weight was observed in (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (2.12 g) over the rest of hybrids followed by FC_1 x FC_2 (1.92 g). FC_2 x FC_1 was recorded (1.70 g), hybrid CSR_{50} x CSR_{51} (1.38 g), CSR_{16} x CSR_{17} (1.31 g) and S_8 x CSR_{16} (1.20 g) which were at par with each other (Tables 1). Maximum single cocoon weight in FC_1 x FC_2 (1.793 g) and CSR_{50} x CSR_{51} (1.691 g) (Alam 2020) [1]. Maximum single cocoon weight of bivoltine hybrids S_8 x CSR_{16} was recorded about 1.176 g) (Maske *et al.*, 2020) [5].
The highest shell weight was recorded by the bivoltine hybrid (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (0.45 g) followed by FC_1 x FC_2 (0.41 g) which was at par with each other and shown superior performance over the check CSR_{16} x CSR_{17} (0.28 g). Among double hybrids, the two double hybrids FC_2 x FC_1 (0.35 g) and CSR_{50} x CSR_{51} (0.30 g) which was at par with each other and shown superior performance over the check hybrid CSR_{16} x CSR_{17} (0.28 g) which was at par with S_8 x CSR_{16} (0.26 g) (Tables 1). The hybrid CSR_{16} x CSR_{17} (0.312 g) highest singe shell weight than other hybrids (Bobade *et al.*, 2019) [2]. Single cocoon weight in bivoltine hybrids recorded FC_1 x FC_2 and CSR_{50} x CSR_{51} has shown superior single cocoon weight 0.395 g. and 0.353 g. respectively (Alam 2020) [1]. Hybrid S_8 x CSR_{16} recorded 0.248 g. and CSR_{50} x CSR_{51} 0.267 g. single cocoon weight under Marathwada condition (Maske *et al.*, 2020) [5].
Maximum shell percentage was recorded in CSR_{50} x CSR_{51} (21.84 percent) followed by (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (21.41 percent) and FC_1 x FC_2 (21.38 percent). Lowest shell percentage was recorded in S_8 x CSR_{16} (21.32 percent) and FC_2 x FC_1 (20.63 percent) hybrid than control CSR_{16} x CSR_{17} (21.36 percent) (Tables 1). Shell ratio of bivoltine hybrids recorded that maximum shell ratio in FC_1 x FC_2 (22.08 percent) and CSR_{50} x CSR_{51} (20.97 percent) (Alam 2020) [1] while, S_8 x CSR_{16} (21.12 percent) and CSR_{50} x CSR_{51} (22.96 percent) (Maske *et al.*, 2020) [5].
Hybrid (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) recorded significantly highest filament length (1205 m) followed by the hybrid FC_1 x FC_2 (1040 m). Two hybrids CSR_{50} x CSR_{51} (997.5 m) and FC_2 x FC_1 (972.5 m) which were shown at par results with other hybrid tested. Hybrid S_8 x CSR_{16} recorded lowest filament length (905) than check control treatment CSR_{16} x CSR_{17} (917.5 m) (Tables 1). Filament length of hybrid CSR_{16} x CSR_{17} (937.67 m) which was significant than other hybrids (Tekule *et al.*, 2020) [13]. Filament length in bivoltine hybrid CSR_{50} x CSR_{51} (938.33 m) (Munemanik *et al.*, 2018) [7]. Hybrid CSR_{16} x CSR_{17} recorded highest filament length (Paighan 2012, Shinde 2010) [8,12]. Maximum single cocoon weight in FC_1 x FC_2 (936 m) and CSR_{50} x CSR_{51} (770 m) (Alam 2020) [1]. S_8 x CSR_{16} (926.26 m) and CSR_{50} x CSR_{51} (956.67 m) (Maske *et al.*, 2020) [5].
The filament weight was varied from 0.282 to 0.381 g. The performance of (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (0.381 g) observed significantly highest than all other hybrids followed by CSR_{50} x CSR_{51} (0.332 g) and control treatment CSR_{16} x CSR_{17} (0.321 g) which were at par with each other. Hybrid FC_1 x FC_2 (0.307 g), S_8 x CSR_{16} (0.292 g) and FC_2 x FC_1 (0.282 g). Lower filament weight was shown by treatment CSR_{16} x CSR_{17} (0.321 g) (Tables 1). Highest filament weight of hybrid CSR_{16} x CSR_{17} (0.331 g) (Bobade *et al.*, 2019) [2]. Hybrid S_8 x CSR_{16} and CSR_{50} x CSR_{51} recorded 0.29 g and 0.306 g filament weight respectively (Maske *et al.*, 2020) [5].
Silkworm hybrid FC_2 x FC_1 (2.61) showed lowest denier value and found significantly superior followed by FC_1 x FC_2 (2.65), (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (2.84), S_8 x CSR_{16} (2.90) and CSR_{50} x CSR_{51} (3.00). The highest denier value was recorded in hybrid control treatment CSR_{16} x CSR_{17} (3.15) (Tables 1). Denier value recorded in hybrid CSR_{16} x CSR_{17} (3.13) (Bobade *et al.*, 2019) [2]. Hybrid S_8 x CSR_{16} (2.82) and CSR_{50} x CSR_{51} (2.88) denier value (Maske *et al.*, 2020) [5].
Cocoon yield/10,000 larvae brushed varies from 13.90 to 19.70 kg. Significantly highest cocoon yield was recorded by the hybrid (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (19.70 kg) which was superior over the rest of hybrids followed by FC_1 x FC_2 (18.90 kg) which were at par with each other. Hybrid FC_2 x FC_1 recorded (18.68 kg) cocoon yield/10,000 larvae brushed. CSR_{50}xCSR_{51} recorded (16.05 kg) followed by control treatment CSR_{16} x CSR_{17} (15.94 kg). Hybrids S_8 x CSR_{16} (13.90 kg) shown lowest yield than control hybrid CSR_{16} x CSR_{17} (15.94 kg) (Tables 1). CSR_{16} x CSR_{17} (16.59

kg) shown highest cocoon yield per 10,000 larvae (Bobade *et al.*, 2019) [2]. S_8 x CSR_{16} (13.829 kg) and CSR_{50} x CSR_{51} (14.826 kg) (Maske *et al.*, 2020) [5].

Pupal duration varies in the range of 10.00 to 11.75 days. Minimum pupal duration was observed in the hybrid (S_8 x CSR_{16}) (10.00 days) followed by (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (10.13 days), CSR_{16} x CSR_{17} (10.63 days) and FC_2 x FC_1 (11.25 days) which were at par with each other. Maximum pupal duration was observed in FC_1 x FC_2 (11.75 days) and CSR_{50} x CSR_{51} (10.88 days) which were non-significant compared to control treatment CSR_{16} x CSR_{17} (10.63 days)(Tables 1). Pupal duration in hybrid S_8 x CSR_{16} (10.38 days) and CSR_{50} x CSR_{51} (10.51 days) (Maske *et al.*, 2020) [5]. Hybrid CSR_{16} x CSR_{17} and CSR_{50} x CSR_{51} bivoltine silkworm hybrid recorded 09.45 days and 10.98 days pupal duration respectively [2]. 11.00 days pupal duration recoded by FC_1 x FC_2 during winter season (Pathan and Khan 2018) [9].

Moth emergence was varied in the range of 95.25 to 98.25 percent. Significantly highest moth emergence was recorded by the hybrid CSR_{50} x CSR_{51} (98.25 percent) which was superior over rest of hybrids followed by (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) (97.50 percent), S_8 x CSR_{16} (97.00 percent), CSR_{16} x CSR_{17} (96.00 percent), FC_1 x FC_2 (95.50 percent) and FC_2 x FC_1 (95.25 percent) which were at par with each other (Tables 1). All hybrids values for performance of moth emergence related to control treatment were non-significant. Similar findings regarding pupal duration in hybrid S_8 x CSR_{16} (94.75 percent), CSR_{50} x CSR_{51} (92.58 percent) and CSR_{16} x CSR_{17} (95.33 percent) (Maske *et al.*, 2020) [5].

Table 1: Mean performance of bivoltine silkworm hybrids for different biological and economic traits

Sr. No.	Treatments	Egg hatching (%)	10 mature larval weight (g)	Larval duration (Days)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Filament length (m)	Filament weight (g)	Denier	Pupal duration (Days)	Moth emergence (%)	Cocoon yield (kg) per 10,000 Larvae
1	(CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51})	98.16 (82.20)	43.75	23.30	2.120	0.450	21.41 (27.50)	1205.0	0.381	2.84	10.13	97.50 (81.12)	19.70
2	FC_1 x FC_2	97.26 (80.45)	41.23	25.49	1.925	0.410	21.38 (27.51)	1040.0	0.307	2.65	11.75	95.50 (77.81)	18.90
3	FC_2 x FC_1	95.26 (77.56)	40.25	25.40	1.695	0.348	20.63 (26.98)	972.5	0.282	2.61	11.25	95.25 (77.52)	18.68
4	S_8 x CSR_{16}	97.30 (80.64)	36.55	23.19	1.197	0.255	21.32 (27.47)	905.0	0.292	2.90	10.00	97.00 (80.38)	13.90
5	CSR_{50} x CSR_{51}	95.00 (77.07)	40.51	22.10	1.384	0.303	21.84 (27.80)	997.5	0.332	3.00	10.88	98.25 (82.57)	16.05
6	CSR_{16} x CSR_{17} (C)	96.34 (78.99)	39.20	22.93	1.310	0.278	21.36 (27.46)	917.5	0.321	3.15	10.63	96.00 (78.47)	15.94
	SE ±	0.707	0.46	0.25	0.074	0.015	0.842	13.174	0.018	0.292	0.30	1.196	0.287
	CD at 5%	2.150	1.399	0.749	0.224	0.046	2.469	40.071	0.054	0.864	N/S	N/A	0.873
	CV (%)	1.778	2.285	2.076	9.173	8.914	6.137	2.618	11.124	6.002	5.595	3.003	3.339

4. Conclusion

These research finding concluded that among all the eight treatment used for rearing (CSR_{16} x CSR_{17}) x (CSR_{50} x CSR_{51}) given the best results for economic traits. In aspect to larval duration and highest shell ratio CSR_{50} x CSR_{51} was found to outperform over all treatments.

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