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Research Article

Evaluation of CSR Breeds for their Biology, Performance and Economic Importance of Silkworm, *Bombyx mori* L.

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Abstract

The classification and characterization of silkworm breeds are important for sericulture, which is supported by the constant development of new hybrids. In this study, 5 parental CSR breeds of *Bombyxi mori* L. from the germplasm bank of RSRS, Miran Sahib were evaluated regrading phenotypic and biological/economic parameters of CSR breeds. Observations on the different phenotypic and economic traits of silkworm, *Bombyx mori* L. were taken. The perusal of the data reveals that the fecundity was recorded from 365.00 (CSR - 18) to 460.67 (CSR - 5) and hatching per cent ranged from 93.87 (CSR 19) to 95.88 (CSR 2). The larval weight varied in the range of 34.94 to 40.86 g whereas, larval duration was observed in the range of 24.00 days to 26.22 days. The larval length recorded as on 6th day 7.76 cm (CSR - 19) to 8.26 cm (CSR - 2). Single cocoon weight 1.49 to 1.70 g. The highest single cocoon weight was CSR - 18 (1.70 g), Single shell weight 0.28 to 0.36 g. Maximum shell weight recorded in CSR - 18 (0.36 g), Shell percentage 18.86 per cent (CSR - 4) to 21.29 per cent (CSR - 19). Maximum yield CSR - 2 (15.23 Kg), was observed significantly superior compared to others. These findings will help the sericulturists in finding suitable breed for getting more economic returns from silkworm rearing. It is observed that CSR - 2 is having highest yield per 10, 000 larvae with shell ratio 20.06 (%).

Keywords: Fecundity; Larval Duration; Larval Length; Cocoon Yield; Shell Ratio; *Bombyx mori* L.

Hightlights

Five CSR breeds of *B. mori* has been evaluated and each one showed significant difference among them. However, the CSR- 2 revealed highest highest yield per 10, 000 larvae with shell ratio 20.06 (%).

Introduction

India is the second largest producer of mulberry raw silk in the country and largest silk consumers; it is also the world's largest importers of silk. As per the statistics available with Central silk board, more than 90% of the silk produced in the country is of multivoltines x bivoltine hybrid cocoons. The silk produced from such cocoons falling into the lower grades in the international grades for silk and cannot be suitable to use in the power looms especially for warp threads and they prefer imported silk for want of quality. Estimated demand of international quality silk in our country is around 6000 mt. It is a well-known fact that bivoltine silk excels in quality and productivity; it is inevitable to go in for large-scale production of bivoltine sericulture in the country. Elite bivoltine silkworm breeds are the basic and important input for the production of high-grade raw silk. Keeping in view of the demand for quality silk in the country an attempt made by Basavaraja., *et al.* [1]; Datta., *et al.* [2,3]; Datta., *et al.* [4,5]; Suresh Kumar., *et al.* [6,7]; Mal Reddy., *et al.* [8]; Dandin., *et al.* [9] led to the evolution of highly productive CSR bivoltine breeds which have potential to produce international grade silk.

Silkworm is the larvae of insects, which belongs to the order Lepidoptera experiencing complete metamorphosis. The mulberry silkworm *Bombyx mori* L. (Lepidoptera: Bombycidae) is a monophagous insect that feeds exclusively on mulberry foliage for its nutrition and produces the naturally protienous silk. Nutritional intake has direct impact on the overall genetic traits such as larval and cocoon weight, amount of silk production, pupation, and reproductive traits. Silkworms go through four stages of development- eggs, larva, pupa and adult. The silkworm larval life cycle is divided into five instars, separated by four molts. Four distinct stages of development completes one generation of the species. The total silkworm life cycle is completed in 56 - 62 days.

An extensive study is needed to improve existing strains for commercial purposes and to develop new strains through breeding programs aimed at improving silk productivity, adaptability to local environments, and disease resistance/tolerance capabilities [10,11]. Several studies related to the use of productivity markers [12,13] morphological dissimilarity [14-17] as indicators of the best strains for breeding.

Material and Methods

The investigation was carried out on five *B. mori* parental CSR breeds viz., CSR - 2, CSR - 4, CSR - 5, CSR - 18, CSR - 19 maintained at the RSRS, Jammu during spring, 2016 and were incubated for 9 - 12 days in a neat and clean, disinfected room at 80 - 85% humidity

and 24 - 25ºC temperature with 18 hrs light till pin head stage, at this stage black - boxing was done to ensure maximum hatching on exposure to bright light. The hatched larvae were reared separately under uniform laboratory conditions as described by Yokoyama [18] and Krishnaswami [19]. During the entire period of research, same micro-climate and feeding conditions were ensured as per the larval stage. The experiment analysed for phenotypic charateristics of egg, larvae and cocoon patterns (Table 1) and biological studies of larvae includes feeding duration (Table 2), hatching percentage, larval weight (Table 5) and total larval duration of different instars were studied, which reflects their variation among the breeds (Table 3) and cocoon characteristics of all breeds were recorded.

All the breeds were reared in three replications by following standard rearing techniques [19]. Three hundred larvae were retained after 2nd moult in each replication. The data pertaining to the morphology/phenotypic and biological parameters were recorded. During the entire period of research, same micro-climate and feeding conditions were ensured as per the larval stage.

At egg stage: Egg shape, egg colour, hatching percentage and average fecundity per female moth were studied.

At larval stage: Larval colour, markings, larval length and mean weight of 10 larvae on each day of V instar were studied and analyzed for different races.

The statistical analysis was done with the help of software SPSS and weight of larvae was measured with electronic balance.

At cocoon stage: Cocoon shape, cocoon colour, cocoon grain and economic characters of cocoon were noted.

Results and Discussion

Phenotypic Qualitative Parameters

- **Egg:** All the CSR breeds which are selected are ellipsoidal in shape, grey in color and shell color was recorded as white in CSR - 2, CSR - 4, CSR - 5 whereas CSR - 18 and CSR - 19 yellow in color (Table 1). Similar results were obtained by Anita., *et al* [20].
- **Larvae:** Color of newly hatched larvae was recorded as black and haemolymph color was transparent in all the breeds. The pattern of larvae was observed plain in CSR - 2, CSR - 4, CSR-5 and others it was recorded as plain-marked i.e. CSR - 18 and CSR - 19 (Table 1). The results were agreement with work done by Anita., *et al* [20].
- **Cocoon:** All the CSR breeds were distinctly white in color in CSR - 2, CSR - 4, CSR - 5 and others it was recorded as creemish i.e. CSR - 18 and CSR – 19 respectively. The shape of cocoon was dumbell and constricted (DC) in CSR - 4, CSR - 5, CSR - 19 and oval in CSR - 2 and CSR -18 respectively. The build and grain of among all the breeds was recorded hard and medium respectively (Table 1). Similar results were obtained by Anita., *et al* [20].

Breeds	Egg			Larvae			Cocoon			
	Shape	Shell Colour	Egg colour	Colour of Newly Hatched	Haemoly-mph Colour	Larval pattern	Colour	Shape	Build	Grains
CSR -2	E	W	G	B	T	P	W	O	H	M
CSR -4	E	W	G	B	T	P	W	DC	H	M
CSR -5	E	W	G	B	T	P	W	DC	H	M
CSR -18	E	Y	G	B	T	PM	C	O	H	M
CSR -19	E	Y	G	B	T	PM	C	DC	H	M

Table 1: Phenotypic qualitative characteristics of egg; larvae and cocoon parameters of CSR breeds.
Note: E: Ellipsoid; W: White; Y: Yellow; G: Grey; SS: Sand Stone; B: Black; T- Transparent; O: Oval; M: Medium; DC: Dumbell Constricted; H: Hard; P: Plain; M: Marked; C: Creemish

Biological parameters of larvae

Feeding duration

- **First instar:** The active period of feeding among all the breeds was recorded 3 days 5 h (Table 2).
- **Second instar:** 2 days 14 h were recorded as most active period of feeding among all the breeds (Table 2).
- **Third instar**: The active feeding period was recorded among all breeds was 3 days 16 h except in CSR - 5 i.e. 3 days 11 h respectively (Table 2).
- **Fourth instar:** The feeding period was observed among all breeds was varied 4 days 8 h was observed in CSR - 2, CSR - 4, CSR - 18 and CSR - 5 (4:41 h) and CSR - 19 (4:10 h) respectively (Table 2).
- **Fifth instar:** There is variation among breeds was recorded, 8 days 22 h more active feeding period was recorded in CSSR- 2 and less i.e. 6 days was observed in CSR - 4 respectively (Table 2).
- The total average feeding duration among all the breeds was more in CSR - 19 i.e. 21 days 22 h and less was recorded in CSR - 4 i.e. 19 days 19 h respectively (Table 2).

Larval duration

- **First instar:** The period among all the breeds was recorded as 4 days 5 h respectively (Table 3).
- **Second instar:** Three days 14 h were recorded as 2nd stage larval period among all the breeds (Table 3).
- **Third instar**: 4 days 16 h were recorded as 3rd stage larval period among all the breeds except in CSR - 5 i.e. 4 days 12 h (Table 3).
- **Fourth instar:** The larval period was observed 5 days 13 h among all the breeds except in CSR - 5 i.e. 6 days 18 h (Table 3).
- **Fifth instar:** There is variation among breeds, 7 days was recorded more in CSR - 5, CSR - 18, CSR - 19 and less i.e. 6 days was observed in CSR - 4 respectively (Table 3).

Race/Breed	Different stages (Days: h ± SD)					Total Avg. duration (Days: h)
	1st instar	2nd instar	3rd instar	4th instar	5th instar	
CSR -2	3:05 ± 0.00	2:14 ± 0.00	3:16 ± 0.00	4:08 ± 0.00	8:22 ± 0.52	20:14 ± 0.08
CSR -4	3:05 ± 0.00	2:14 ± 0.00	3:16 ± 0.00	4:08 ± 0.00	6:00 ± 0.00	19:19 ± 0.00
CSR -5	3:05 ± 0.00	2:14 ± 0.00	3:11 ± 0.09	4:41 ± 0.52	7:00 ± 0.00	21:16 ± 0.52
CSR -18	3:05 ± 0.00	2:14 ± 0.00	3:16 ± 0.00	4:08 ± 0.00	7:00 ± 0.00	20:19 ± 0.00
CSR -19	3:05 ± 0.00	2:14 ± 0.00	3:16 ± 0.00	4:10 ± 0.03	7:00 ± 0.00	21:22 ± 0.47

Table 2: Data showing feeding duration among different stages of CSR breeds during spring rearing (2016).

Races/breeds	Different stages (Days: h ± SD)					Total duration (Days : h)
	1st instar	2nd instar	3rd instar	4th instar	5th instar	
CSR -2	4:05 ± 0.00	3:14 ± 0.00	4:16 ± 0.00	5:13 ± 0.00	6:70 ± 0.52	24:70 ± 0.52
CSR -4	4:05 ± 0.00	3:14 ± 0.00	4:16 ± 0.00	5:13 ± 0.00	6:00 ± 0.00	24:00 ± 0.00
CSR -5	4:05 ± 0.00	3:14 ± 0.00	4:12 ± 0.07	6:18 ± 0.51	7:00 ± 0.00	25:00 ± 0.00
CSR -18	4:05 ± 0.00	3:14 ± 0.00	4:16 ± 0.00	5:13 ± 0.00	7:00 ± 0.00	25:00 ± 0.00
CSR -19	4:05 ± 0.00	3:14 ± 0.00	4:16 ± 0.00	5:13 ± 0.00	7:00 ± 0.00	25:00 ± 0.00

Table 3: Data showing larval duration among different stages of CSR breeds during spring rearing (2016).

Larval duration of total average among all the breeds was more in CSR - 2 i.e. 26 days twenty 2 h and less was recorded in CSR - 4 i.e. 24 days respectively (Table 5) and it was ranges from 24.00 - 26.22 days. The results were agreement with Krishnaswami [19] reported that the larval duration was longer in race M-5 (24.17), but it was non-agreement with results reported by Bothikar., *et al.* [21] the larvae reared on S -1635 recorded 19.66 days. Under ideal conditions it has been reported that the total larval duration is 25 - 30 days for selected JAM breeds (Raina, 2000). The results were justified with work done by Anita., *et al.* [20] reported similar results on JAM breeds, the larval duration which ranges between 23.22 - 26.16 days.

Larval length

The length of 5th instar larvae was recorded from first day to sixth day results revealed that there is significant differences were observed among all the breeds except in first day (Table 4). During first day the larval length ranges from 4.28 (CSR - 18) to 4.38 cm (CSR - 2), 2nd day it was ranges from 4.38 cm (CSR - 5) to 5.22 cm (CSR - 19), 3rd day ranges between 6.06 (CSR - 18) to 6.50 cm (CSR - 19), 4th day recorded as 6.40 cm (CSR - 5) to 7.42 cm (CSR - 2), 5th day it was ranges from 7.16 (CSR - 19) to 7.68 cm (CSR - 2) and 6th day recorded as 7.76 cm (CSR - 19) to 8.26 cm (CSR - 2) (Table 4). Similar results were recorded by 6.71 to 7.25 cm (Prabu., *et al.* 2011) and 6.12 to 7.05 cm [22]. The data shows that there is increase in larval length from day 1 to day 6 of 5th instar. The length of silkworm depends on amount of food it consumes. Length of larvae increases until larvae reaches its spinning state (6th day). When it reaches spinning stage the larvae reduce in size to one third of its normal length, it is the characteristic feature of a silkworm. This reduction in size increases pressure on silk glands to eject silk from the glands. Hence there is a sudden decrease in length on 6th day onwards. This decrease in length continues until pupal stage. The results also agreement with work done by Venugopal Reddy., *et al.* [23] revealed that the larval length varies from 5.00 to 7.43 cm.

Breeds	Days (5th instar)) (Length – Cm ± SD)					
	1	2	3	4	5	6
CSR -2	4.38 ± 0.08	4.60 ± 0.30	6.28 ± 0.15	7.42 ± 0.08	7.68 ± 0.08	8.26 ± 0.11
CSR -4	4.32 ± 0.13	4.56 ± 0.27	6.08 ± 0.24	7.06 ± 0.21	7.46 ± 0.11	7.98 ± 0.16
CSR -5	4.36 ± 0.13	4.38 ± 0.16	6.38 ± 0.19	6.40 ± 0.12	7.32 ± 0.15	7.78 ± 0.13
CSR -18	4.28 ± 0.08	5.20 ± 0.22	6.06 ± 0.21	6.72 ± 0.13	7.24 ± 0.11	7.80 ± 0.10
CSR -19	4.34 ± 0.05	5.22 ± 0.16	6.50 ± 0.16	6.44 ± 0.11	7.16 ± 0.17	7.76 ± 0.11
C.D. @ 1%	-	0.30	0.25	0.18	0.17	0.16
SE. m ±	0.04	0.10	0.08	0.06	0.05	0.05
C.V. (%)	2.35	4.82	3.06	2.02	1.74	1.59

Table 4: Data showing length of fifth instar larvae of CSR breeds during spring (2016).

Economic parameters

Nine economic traits of data pertaining to evaluation viz., hatching %, larval duration (h), larval weight (g), cocoon yield per 10,000 larvae by number, cocoon yield per 10,000 larvae by weight, pupation rate, cocoon weight, cocoon shell weight, and cocoon shell ratio of five breeds were presented in table 5. The perusal of the data reveals that the fecundity was recorded from 365.00 (CSR - 18) to 473.00 (CSR - 5) which shows statistically significant among all the breeds and hatching per cent ranged from 93.87 (CSR - 19) to 95.88 (CSR - 2) and showing statistically non-significant among all the breeds whereas larval duration shows statistically significant among all the breeds and recorded to a maximum of 26.22 (CSR - 2) and minimum of 24.00 (CSR - 4) whereas larval weight was recorded to a maximum of 40.86 g (CSR - 2) and minimum of 34.94 g (CSR - 5) showing statistically significant among all the breeds whereas pupation rate showing statistically non-significant among all the breeds and it was recorded as highest 91 per cent (CSR - 18) and less 89.00 per cent (CSR - 2) and pupal weight was ranges between 12.66g (CSR - 19) to 13.46g (CSR - 18) showing statistically non-significant among all the breeds. With regard to yield per 10,000 larvae by number, CSR - 18 was recorded the highest (9333.33) and lowest in CSR - 4 (9053.33). Yield per 10,000 larvae by weight (Kg), ranged to the maximum of 15.23 Kg in CSR - 2 and minimum of 10.88 Kg in CSR - 5 showing statistically significant among all the breeds with regard both by number and weight basis. The weight of cocoon found to the highest of 17.33g in CSR - 18 and lowest of 16.05g in CSR - 4 shows statistically non-significant among all the breeds. The cocoon weight ranged from the maximum of 1.70 g (CSR - 18) and minimum of 1.49 g (CSR - 4). The shell weight was maximum (0.36 g) in CSR - 18 and minimum in CSR - 4 (0.28 g) shows statistically significant among all the breeds with respect to both cocoon weight and shell weight. The shell ratio (%) shows statistically significant among all the breeds and was highest in CSR - 19 (21.29) and lowest in CSR - 4 (18.86) respectively.

Breeds	Fecundity by No.	Hatching (%)	Larval weight (g)	Larval duration (Days : h)	Pupal weight (g)	Pupation rate (%)	Yield/ 10000 Larvae		Weight of cocoon (g)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)
							No.	Wt. (Kg)				
CSR 2	424.33 (20.61)	95.88 (78.31)	40.86	24.70	12.85	89.00 (70.61)	9226.67 (96.06)	15.23	16.48	1.65	0.33	20.06 (26.58)
CSR 4	443.33 (21.07)	95.49 (77.70)	35.36	24.00	13.31	89.67 (71.25)	9053.33 (95.15)	12.36	16.05	1.49	0.28	18.86 (25.72)
CSR 5	473.00 (21.77)	95.28 (77.43)	34.94	25.00	13.29	90.33 (71.86)	9173.33 (95.78)	10.88	16.61	1.65	0.32	19.40 (26.11)
CSR 18	365.00 (19.12)	94.65 (76.66)	38.36	25.00	13.46	91.00 (72.53)	9333.33 (96.61)	14.37	17.33	1.70	0.36	20.97 (27.24)
CSR 19	440.00 (20.99)	93.87 (75.63)	39.48	25.00	12.66	90.33 (71.86)	9200.00 (95.92)	14.31	16.09	1.57	0.33	21.29 (27.46)
C.D. @ 1%	0.85	-	2.36	0.42	-	-	0.83	2.01	-	0.12	0.02	1.01
SE. m±	0.26	0.60	0.73	0.13	0.47	0.54	0.26	0.63	0.52	0.04	0.007	0.31
C.V. (%)	2.23	1.36	3.38	0.93	6.26	1.32	0.47	8.14	5.52	4.27	3.81	2.06

Table 5: Economic parameters of CSR breeds reared during spring (2016).

Average fecundity per moth was highest 522 in Jam 2 and lowest was 355 in Jam 18 reported by Anita., *et al.* [20] these results were non-agreement with our results. The lowest hatching percent (93.79%) was obtained in Jam 11 race and the highest (94.17%) was obtained in Jam 27 race, with a mean of 93.92 per cent in all studied races Anita., *et al* [20]. It was justified with our results, 93.87 (CSR - 19) to 95.88 (CSR - 2).

The larval weight was non-agreement with results reported by Bothikar., *et al.* [21] i.e. 40.54 g which were reared on S - 1635 and other breeds which on par with silkworm reared on variety M - 5 and breeds having larval weight ranges between 34.94 g (CSR - 5) to 40.86 g (CSR - 2). Similar results were recorded by Pakhale., *et al.* [24], the larval weight was ranges from 33.77 - 40.67 g.

The larval duration was non-agreement with results reported by Pakhale., *et al.* [24], the larval duration ranges from 21.04 - 22.28 days, our results shows that 24.00 - 26.22 days among the breeds.

The single cocoon weight was not justified with results reported by Bothikar., *et al.* [21] i.e. 1.86 g which were reared on S - 1635 and Rayer [25] and Chakravorty [26] reported the highest single cocoon weight on variety V- 1 and also not justified with results reported by Pakhale., *et al.* [24] single cocoon weight ranges from 1.76 - 1.86 g.

The single shell weight was non-agreement with Bothikar., *et al.* [21] report the silkworms which reared on S-1635 but it was similar results with variety M - 5 reported by Bothikar., *et al* [21]. Rayer [25] and Chakravorty [26] reported the highest single shell weight on variety V- 1 and also not justified with results reported by Pakhale., *et al.* [24] single cocoon weight ranges from 0.32 -0.36 g.

The cocoon shell percentage varies between 19.93 to 17.84 per cent reported by Bothikar., *et al.* [21] and it was agreement with our results the shell percentage varies between 18.86 - 21.29 per cent. Rayer [25] and Chakravorty [26] reported the cocoon shell percentage.

Cocoon yield per 10,000 larvae brushed varied in the range of 18.66 kg to 16.59 kg reported by Bothikar., *et al.* [21] and it was non-agreement with our results on S- 1635 but similar results which reared on variety M - 5, the yield varies between 9.97- 15.95 kg. Similar results reported by Rayer [25] and Chakravorty [26] reported the cocoon shell percentage.

Varietal differences for studied traits in *B. mori* has been reported by Ahsan., *et al.* [27], Li., *et al*. [11]; Furdui., *et al.* [28]. Similar studies on varietal diversity have also been sustained by the findings of Reza.,*et al.* [29], Mistri and Jayaswal [30]; Ahsan., *et al*. [31]; Umashankara and Subramanya [32]; Nezhad., et al. 2009; Nguku., *et al*. [33]; Nguku., *et al*. [34]; Zannata., *et al*. [35] and Pal and Moorthy [36].

Conclusion

The obtained data showed that there are highly significant differences among the breeds for all the studied characters. There is a high positive correlation between economic parameters among all the breeds studied. The differences in obtained results are due to the variability and genotype characters for each individual of every breed.

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