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Evaluation of bivoltine mulberry silkworm *Bombyx mori* L breeds suitable for temperate region of Jammu and Kashmir, India

Bharath Kumar Neelaboina, Shivkumar, Mir Nisar Ahmad and MK Ghosh

Abstract
The present study was undertaken to evaluate the performance of eleven bivoltine silkworm, *Bombyx mori* L, breeds (CSR2, CSR6, CSR27, CSR26, CSR50, PAM114, PAM117, APS4, APS5, SK6 and SK7) of different origin under temperate climatic conditions during spring, summer and autumn, 2018 at Central Sericultural Research and Training Institute, Pampore, Jammu and Kashmir. The rearing was carried out under uniformed laboratory condition by adopting the standard method. These eleven breeds were evaluated for their performance in eight metric traits viz., fecundity (No.), hatching (%), yield per 10,000 larvae by number and by weight (kg), single cocoon weight (g), single shell weight (g), shell ratio (%) and pupation rate (%). The performance of breeds varied from season to season since they originated from different progenitors. The data generated was analyzed statistically and subjected to multiple trait Evaluation index (E.I). On the basis of the evaluation index values ranking CSR2, CSR26, CSR27, CSR50, PAM114 and PAM117 performed well in all the three seasons with E.I values above 50. Two breeds APS5 and CSR6 recorded E.I values below 50 in all the three seasons. APS4 has performed well in only spring season whereas SK6 and SK7 recorded E.I values above 50 in summer and autumn only. Based on their performance in all the three seasons, these parental breeds will be utilized for development of foundation crosses which will be further shortlisted for the development of bivoltine silkworm double hybrids suitable to temperate region of J&K as an alternate for ruling CSR double hybrid.

Keywords: Silkworm, parental breeds, temperate, evaluation index

1. Introduction
Mulberry belonging to family Moraceae is primarily cultivated for the rearing of silkworms and its contribution towards successful rearing is 38.2%. The common silkworm *Bombyx mori* Linnaeus (Lepidoptera: Bombycidae) spins valuable silk fibre, making it one of the most beneficial insect to mankind and is becoming an attractive multifunctional material for both textile and non-textile uses [19]. The practice of sericulture consist of two major activities *viz*., cultivation of mulberry plants for producing healthy leaf to the silkworm larvae and the rearing of silkworm larvae to produce the quality cocoons, which is the raw material for the silk reeling industry [2,3]. With the re-orientation of silkworm breeding approaches aimed at sustainability and increased qualitative silk production, unstinted and coordinated efforts by various silkworm breeders in the country [1, 15] resulted in the development of many bivoltine silkworm breeds and hybrids over the last few decades. Systematic breeding approaches adapted by various silkworm breeders in different sericulturally advanced countries [6, 12] have contributed to produce silkworm (*Bombyx mori* L.) genotypes of desirable constitution and improvement of several quantitative and qualitative traits of economic value. Till date limited number of silkworm breeds / hybrids has been developed for the spring season under temperate climatic conditions of Kashmir [8, 18] Whereas, during summer 10-15 percent farmers take up sericulture in temperate regions of Kashmir [16] few attempts have also been made for the identification of hybrids for summer or autumn season [7, 10, 13]. It is also need of the hour to develop silkworm breeds/ hybrids withstanding the climate change [4].
Hence, the present study aims to evaluate the performance of breeds in all the three seasons at CSR&TI, Pampore to develop the foundation crosses which will be shortlisted for the development of bivoltine silkworm double hybrids suitable for Kashmir valley.

2. Materials and Methods

The present investigation was carried out at Central Sericultural Research and Training Institute, Pampore, Jammu & Kashmir (J&K) during spring, summer and autumn, 2018 to study the performance of eleven silkworm, *Bombyx mori* L, breeds (CSR2, CSR6, CSR27, CSR26, CSR50, PAM114, PAM117, APS4, APS5, SK6 and SK7) of different origin under temperate climatic conditions. Eleven silkworm genotypes {CSR2, CSR6, CSR27, CSR26 and CSR50 [CSR&TI, Mysore] PAM114 and PAM117 [CSR&TI, Pampore] APS4 and APS5 [APSSRDI, Hindupur] SK6 and SK7 [CSR&TI, Berhampore]} procured from different Institutes were reared during spring (May-June), summer (July-August) and autumn (August- September), 2018 at Central Sericultural Research and Training Institute, Central Silk Board, Pampore, Kashmir. The characteristics of the parental breeds are presented in Table: 1. The standard rearing techniques were followed [9]. The important quantitative and qualitative traits *viz*., fecundity, hatching percentage, yield per 10,000 larvae by weight, single cocoon weight, single shell weight, shell ratio and pupation rate were recorded in all the eleven silkworm breeds during spring, summer and autumn, 2018. All the breeds were reared following completely randomised design with three replications each and 250 larvae were maintained in each replication after the 3rd moult. At the end of 5th instar, the spinning larvae were collected manually and mounted in plastic collapsible mountages. The evaluation index value was calculated for all the eight traits studied. The evaluation index (EI) was calculated as per the below mentioned procedure [11].

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where, A = Value obtained for a particular trait in a particular breed
B = Mean value of a particular trait of all the breeds
C = Standard deviation of a particular trait of all the breeds
10 = Standard unit
50 = Fixed value

The index value obtained for all the traits was combined and the average EI values were obtained. The EI value fixed for the selection of a line is 50 or >50. The line, which scored above the limit, is considered to possess greater economic value.

3. Results and Discussion

The present research findings revealed that seven breeds *viz*., CSR2 (55.20), CSR26 (51.40), CSR27 (57.55), CSR50 (50.80), PAM114 (55.74), PAM117 (57.48) and APS4 (50.42) were performed well in the spring season except CSR6 (41.20), APS5 (44.46), SK6 (40.88) and SK7 (43.00) (Table: 3). During summer season except CSR6 (38.86), APS4 (45.50) and APS5 (48.24) remaining breeds *viz.*, CSR2 (55.49), CSR26 (53.30), CSR27 (50.56), CSR50 (52.39), PAM114 (50.42) PAM117 (54.47), SK6 (50.13) and SK7 (50.11) shown E.I above 50 (Table:5).

In autumn CSR2 (51.72), CSR26 (52.67), CSR27 (52.22), CSR50 (51.88), PAM114 (50.83) PAM117 (57.96), SK6 (50.45) and SK7 (50.64) recorded E.I above 50 except CSR6 (38.82), APS4 (46.21) and APS5 (44.86) (Table: 7). Since these breeds originated from different parts of the country, the performance of these breeds varies from season to season indicating the degree of variability in genetic potential. The performance of eleven breeds during spring, summer and autumn 2018 is depicted in Table: 2, 4 &6. CSR breeds from Mysore and PAM breeds from Pampore performed well in all the three seasons except CSR6 which didn't performed well in all the three seasons. APS4 is the only breed from Hindupur which performed well in spring only whereas SK breeds from Berhampore recorded E.I value above 50 during summer and autumn, 2018. Mean Evaluation index values of all the parental breeds during spring, summer and autumn, 2018 is depicted in Table: 8.

Success of any breeding programme is dependent on the degree of genetic variability of the available genetic resources. Building heterotic combinations will be the key factor for success of breeding programmes. Results of various economic parameters showed significant difference among the breeds which revealed their genetic potential as well as variability of the breeds. These breeds have immense potentiality as breeding material as they displayed adequate variability for economic traits. Higher the variability more is the scope for obtaining a higher amount of heterotic potential and also more variability is expected to surface in segregating generations of such crosses [5, 17]. Similar studies based on evaluation index values had also been conducted by [13, 14].

Table 1: Characteristic features of the eleven silkworm parental breeds

S. No.	Breeds	Larval Marking	Cocoon Colour	Cocoon Shape	S. No.	Breeds	Larval Marking	Cocoon Colour	Cocoon Shape
1	CSR2	Plain	White	Oval	7	PAM117	Plain	White	Constricted
2	CSR6	Marked	White	Constricted	8	APS4	Plain	White	Constricted
3	CSR26	Marked	White	Constricted	9	APS5	Plain	White	Oval
4	CSR27	Plain	White	Oval	10	SK6	Plain	White	Constricted
5	CSR50	Plain	White	Oval	11	SK7	Plain	White	Constricted
6	PAM114	Plain	White	Oval					

Table 2: Rearing performance of the eleven silkworm parental breeds during spring, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)
				By No.	By Wt. (kg)				
1	CSR-2	521	94.26	9740	15.08	1.71	0.38	22.22	92.00
2	CSR-6	446	79.86	9320	14.60	1.74	0.37	21.26	90.00
3	CSR-26	513	92.28	9640	14.94	1.72	0.36	20.93	93.00
4	CSR-27	573	97.07	9600	14.72	1.70	0.38	22.35	95.00
5	CSR-50	538	96.08	9680	14.96	1.59	0.33	20.75	94.00
6	Pam-114	526	95.41	9740	15.34	1.74	0.36	20.69	95.00

7	Pam-117	514	94.01	9760	15.57	1.76	0.37	21.02	96.00
8	APS-4	534	95.43	9670	14.52	1.56	0.33	21.15	95.00
9	APS-5	496	95.02	9640	13.48	1.57	0.31	19.75	95.00
10	SK-6	428	93.66	9640	13.63	1.58	0.31	19.62	93.00
11	SK-7	514	94.98	9640	13.53	1.57	0.31	19.75	92.00
	Avg.	509	93.46	9643	14.58	1.66	0.35	20.86	93.64
	SD	41	4.69	119	0.73	0.08	0.03	0.92	1.80

Table 3: Evaluation index values of eleven silkworm parental breeds during spring, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Mean E.I
				By No.	By Wt. (kg)					
1	CSR-2	52.93	51.71	58.15	56.85	56.25	60.00	64.81	40.89	55.20
2	CSR-6	34.63	21.00	22.86	50.27	60.00	56.67	54.40	29.78	41.20
3	CSR-26	50.98	47.48	49.75	54.93	57.50	53.33	50.76	46.44	51.40
4	CSR-27	65.61	57.70	46.39	51.92	55.00	60.00	66.23	57.56	57.55
5	CSR-50	57.07	55.59	53.11	55.21	41.25	43.33	48.86	52.00	50.80
6	Pam-114	54.15	54.16	58.15	60.41	60.00	53.33	48.15	57.56	55.74
7	Pam-117	51.22	51.17	59.83	63.56	62.50	56.67	51.77	63.11	57.48
8	APS-4	56.10	54.20	52.27	49.18	37.50	43.33	53.19	57.56	50.42
9	APS-5	46.83	53.33	49.75	34.93	38.75	36.67	37.88	57.56	44.46
10	SK-6	30.24	50.43	49.75	36.99	40.00	36.67	36.52	46.44	40.88
11	SK-7	51.22	53.24	49.75	35.62	38.75	36.67	37.88	40.89	43.00

Table 4: Rearing performance of the eleven silkworm parental breeds during summer, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)
				By No.	By Wt.(kg)				
1	CSR-2	507	94.51	9360	14.86	1.78	0.38	21.35	92.50
2	CSR-6	415	94.48	8900	12.66	1.63	0.35	21.23	84.50
3	CSR-26	447	92.23	9480	15.55	1.83	0.39	21.04	93.00
4	CSR-27	532	94.38	9380	13.98	1.68	0.35	20.83	91.50
5	CSR-50	519	91.77	9400	14.60	1.80	0.38	21.11	92.50
6	Pam-114	512	93.45	9620	14.46	1.69	0.34	20.12	94.50
7	Pam-117	513	93.65	9640	14.44	1.69	0.36	21.36	94.00
8	APS-4	519	94.77	9260	13.72	1.57	0.32	20.45	91.00
9	APS-5	512	94.90	9460	14.09	1.60	0.33	20.31	92.50
10	SK-6	553	95.75	9530	14.32	1.57	0.32	20.13	93.00
11	SK-7	527	94.32	9560	15.17	1.55	0.32	20.32	94.00
	Avg.	505	94.02	9417	14.35	1.67	0.35	20.75	92.09
	SD	40	1.17	207	0.77	0.10	0.03	0.49	2.73

Table 5: Evaluation index values of eleven silkworm parental breeds during summer, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Mean E.I
				By No.	By Wt.(kg)					
1	CSR-2	50.55	54.15	47.25	57.30	61.00	60.00	62.21	51.50	55.49
2	CSR-6	27.38	53.89	25.02	28.74	45.50	48.33	59.81	22.20	38.86
3	CSR-26	35.58	34.66	53.04	66.24	66.00	61.67	55.88	53.33	53.30
4	CSR-27	56.83	53.08	48.21	45.84	51.00	50.00	51.70	47.84	50.56
5	CSR-50	53.50	30.73	49.18	53.83	63.00	60.00	57.37	51.50	52.39
6	Pam-114	51.73	45.13	59.81	52.06	52.00	46.67	37.11	58.83	50.42
7	Pam-117	51.90	46.84	60.77	51.85	51.50	53.33	62.55	57.00	54.47
8	APS-4	53.48	56.37	42.42	42.40	39.50	40.00	43.82	46.01	45.50
9	APS-5	51.78	57.52	52.08	47.30	43.00	41.67	41.07	51.50	48.24
10	SK-6	62.10	64.74	55.46	50.26	39.50	38.33	37.30	53.33	50.13
11	SK-7	55.50	52.56	56.91	61.30	38.00	38.33	41.28	57.00	50.11

Table 6: Rearing performance of the eleven silkworm parental breeds during autumn, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)
				By No.	By Wt.(kg)				
1	CSR-2	524	93.72	9200	13.26	1.64	0.35	21.10	90.50
2	CSR-6	517	94.34	8780	10.96	1.45	0.31	21.44	84.00
3	CSR-26	533	94.96	9140	13.39	1.66	0.33	20.07	89.50
4	CSR-27	523	94.12	9360	13.41	1.63	0.33	20.58	92.00
5	CSR-50	536	94.90	9340	12.58	1.54	0.32	20.82	91.00
6	Pam-114	522	94.20	9640	13.14	1.55	0.31	20.16	94.50
7	Pam-117	541	95.35	9600	13.36	1.58	0.32	20.46	95.00
8	APS-4	520	94.67	9360	13.47	1.52	0.30	19.43	91.50
9	APS-5	505	94.55	9440	13.63	1.50	0.30	19.64	91.50
10	SK-6	529	94.44	9560	13.46	1.50	0.31	20.34	92.50
11	SK-7	521	95.55	9400	13.42	1.51	0.31	20.21	91.50
	Avg.	524	94.62	9347	13.10	1.55	0.32	20.39	91.23
	SD	10	0.54	244	0.76	0.07	0.02	0.59	2.88

Table 7: Evaluation index values of eleven silkworm parental breeds during autumn, 2018

S. No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Mean E.I
				By No.	By Wt.(kg)					
1	CSR-2	49.70	33.24	43.98	52.14	62.50	62.75	62.02	47.47	51.72
2	CSR-6	42.60	44.81	26.76	21.80	36.14	45.75	67.77	24.90	38.82
3	CSR-26	58.60	56.20	41.52	53.76	66.00	56.75	44.51	43.99	52.67
4	CSR-27	48.50	40.74	50.53	54.06	60.71	57.25	53.30	52.67	52.22
5	CSR-50	61.70	55.19	49.71	43.21	48.50	50.25	57.26	49.20	51.88
6	Pam-114	48.10	42.22	62.01	50.56	50.00	46.25	46.12	61.35	50.83
7	Pam-117	66.50	63.52	60.37	53.40	54.14	51.50	51.12	63.09	57.96
8	APS-4	45.80	50.93	50.53	54.80	45.43	37.50	33.79	50.94	46.21
9	APS-5	30.70	48.61	53.81	56.91	43.14	37.50	37.30	50.94	44.86
10	SK-6	54.60	46.67	58.73	54.74	42.79	42.50	49.15	54.41	50.45
11	SK-7	47.00	67.22	52.17	54.14	44.14	42.50	46.98	50.94	50.64

Table 8: Mean Evaluation index values of eleven silkworm parental breeds during spring, summer and autumn 2018

Breeds / Seasons	CSR-2	CSR-6	CSR-26	CSR-27	CSR-50	Pam-114	Pam-117	APS-4	APS-5	SK-6	SK-7
Spring	55.20	41.20	51.40	57.55	50.80	55.74	57.48	50.42	44.46	40.88	43.00
Summer	55.49	38.86	53.30	50.56	52.39	50.42	54.47	45.50	48.24	50.13	50.11
Autumn	51.72	38.82	52.67	52.22	51.88	50.83	57.96	46.21	44.86	50.45	50.64

4. Conclusion

The eleven parental breeds utilised for the present study performed well during Spring (CSR2, CSR26, CSR27, CSR50, PAM114, PAM117 and APS4), summer (CSR2, CSR26, CSR27, CSR50, PAM114, PAM117, SK6 and SK7) and autumn (CSR2, CSR26, CSR27, CSR50, PAM114, PAM117, SK6 and SK7), 2018. The variation in the performance of these breeds during three different seasons indicates the degree of genetic variability. The identified parental breeds will be utilised for breeding programmes to develop foundation crosses which will be further shortlisted to develop sustainable bivoltine silkworm double hybrids suitable to temperate region of J&K as an alternate for ruling CSR double hybrid.

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