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Evaluation of Elite Bivoltine Silkworm (*Bombyx mori* L.) Foundation Crosses Suitable for Temperate Region of Jammu & Kashmir

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A B S T R A C T

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 24 bivoltine silkworm, *Bombyx mori* L, foundation crosses (12 Oval & 12 Constricted) under temperate climatic conditions. The rearing was carried out under uniformed laboratory condition by adopting standard method. These 24 bivoltine silkworm foundation crosses (FC) 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 foundation crosses varied from season to season since the parental races involved in these foundation crosses have different origin with specific characteristics. The data generated was analyzed statistically and subjected to multiple trait Evaluation index. On the basis of the evaluation index (E.I) values ranking constricted FC's *viz*., SK-6 × SK-7, Pam-117 × APS-4 and Pam-117 × SK-7 performed well in all the three seasons with E.I above 50 and SK-7 × Pam-117 performed well in autumn season only. In case of Oval FC's *viz.*, CSR-27 × Pam-114 & CSR-50 × Pam-114 along with their reciprocals performed well and recorded E.I above 50 in all the three seasons whereas CSR-27 × CSR-50 & APS-5 × Pam-114 recorded E.I above 50 in spring and summer only. CSR-50 × APS-5 and its reciprocal were found superior in performance only in autumn season. Based on their performance in all the three seasons, these foundation crosses will be utilized for the development of bivoltine silkworm double hybrid suitable to temperate region of J&K as an alternate for ruling CSR double hybrid.

Introduction

Mulberry belonging to family Moraceae is primarily cultivated for rearing of silkworms and its contribution towards successful rearing is 38.2% (Miyashita, 1986). 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 Tsukada (2005). The practice of sericulture consist of two major activities *viz*., cultivation of mulberry plants for producing healthy leaf for feeding 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 (Bharath Kumar *et al.,* 2017; Bharath Kumar *et al.,* 2018a). 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 (Basavaraja *et al.,* 1995) resulted in the development of many bivoltine silkworm breeds and hybrids over the last few decades. Till date limited number of silkworm breeds / hybrids has been developed for the spring season under temperate climatic conditions of Kashmir (Trag *et al.,* 1992) Whereas, during summer 10-15 percent farmers take up sericulture in temperate regions of Kashmir (Sahaf *et al.,* 2016) few attempts have also been made for identification of hybrids for summer or autumn season (Farooq *et al.,* 2006; Malik *et al.,* 2009 and Nisar *et al.,* 2013). It is also need of hour to develop silkworm breeds/ hybrids withstanding the climate change (Bharath Kumar *et al.,* 2018b).

In a single hybrid, hybrid vigour between two genetically distant parents has the potential for better productivity, but the double hybrids involving four parental breeds of diverse characteristics (disease tolerance, high productivity *etc*.) ensure the sustainability and better financial returns to the farmer. The flexibility in genetic constitution within the population and polygenic expression of several economic characteristics in silkworm double hybrids is more stable than the single hybrids under sub-optimal conditions. The temperate conditions of Jammu & Kashmir demand the silkworm breeds/hybrids which possess disease tolerance coupled with high productivity. The bivoltine double hybrids have better genetic plasticity to buffer against adverse climatic conditions resulting in crop stability (Basavaraja *et al.,* 2006). The development of sustainable silkworm double hybrids characterized for disease tolerance and high productivity would provide better opportunities for the up liftment of socio economic conditions of farmers in North West India

Hence, the present study aims to evaluate the performance of 24 foundation crosses in all the three seasons at CSR&TI, Pampore to develop the bivoltine silkworm double hybrid suitable for Kashmir valley.

Materials and Methods

Twenty four bivoltine silkworm foundation crosses (12 Oval and 12 Constricted) 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 standard rearing techniques were followed Krishnaswamy (1978). 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 24 bivoltine silkworm foundation crosses during spring, summer and autumn, 2018. All the foundation crosses were reared following completely randomised design with three replications each and 250 larvae were maintained in each replication after 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 (Mano *et al.,* 1993).

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

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.

Results and Discussion

The present research findings revealed that six constricted foundation crosses *viz*., APS-4 × SK-7, SK-6 × APS-4, SK-6 × Pam-117, SK-6 × SK-7, Pam-117 × APS-4 and Pam-117 × SK-7 performed well over the control FC1 (CSR6×CSR26) in the spring season (Table 1) with E.I values 51.57, 50.31, 52.94, 55.41, 55.77 and 61.32 (Table 2) respectively along with six oval foundation crosses *viz*., CSR-27 × CSR-50 (55.37), CSR-27 × Pam-114 (54.93), CSR-50 × Pam-114 (52.91), Pam-114 × CSR-27 (56.26), Pam-114 × CSR-50 (56.60) and APS-5 × Pam-114 (53.65) (Table 3 and 4). Among the constricted foundation crosses SK-6 × SK-7, Pam-117 × APS-4 and Pam-117 × SK-7 performed well in the summer season with E.I values 59.13, 58.72, and 59.66 (Table 5 and 6) whereas in case of oval foundation crosses CSR-27 × CSR-50 (51.15), CSR-27 × Pam-114 (53.18), CSR-50 × Pam-114 (55.38), Pam-114 × CSR-27 (57.50), Pam-114 × CSR-50 (56.51) and APS-5 × Pam-114 (56.44) performed well over the control FC2 (CSR2×CSR27) in summer 2018 (Table 7 and 8). In autumn season SK-6 × SK-7, Pam-117 × APS-4, Pam-117 × SK-7 and SK-7 × Pam-117 excelled over the other constricted foundation crosses with E.I values 57.34, 55.55, 60.82 and 53.40 respectively (Table 9 and 10) along with oval foundation crosses *viz*., CSR-27 × Pam-114 (53.33), CSR-50 × Pam-114 (61.72), CSR-50 × APS-5 (52.46), Pam-114 × CSR-27 (61.62), Pam-114 × CSR-50 (54.04) and APS-5 × CSR-50 (53.95) (Table 11 and 12).

Three constricted FC *viz*., SK-6 × SK-7, Pam-117 × APS-4 and Pam-117 × SK-7 performed well in spring, summer and autumn, 2018 whereas APS-4 × SK-7, SK-6 × APS-4 and SK-6 × Pam-117 observed with E.I values above 50 only in spring season. Among the constricted foundation crosses SK-7 × Pam-117 excelled in only autumn season, 2018. In case of oval foundation crosses CSR-27 × Pam-114, CSR-50 × Pam-114, Pam-114 × CSR-27 and Pam-114 × CSR-50 performed well in spring, summer and autumn, 2018 whereas CSR-27 × CSR-50 and APS-5 × Pam-114 recorded E.I values above 50 in spring and summer, 2018. Among the oval foundation crosses CSR-50 × APS-5 and its reciprocal performed well in autumn only. Similar studies were conducted by Moorthy *et al.*, (2011) for identification of suitable bivoltine foundation cross for sustainable silkworm seed crop in tropics and found that D6 (P) N x SK4C shown higher cocoon yield of 12.8kg/10000 larvae with 91% pupation compared to 9.8kg cocoon yield/10000 larvae with 67% pupation in control, NB18 x P5.

Success of any breeding programme is dependent on the degree of genetic variability of the available genetic resources and the selection of suitable and genetically diverse parental breeds to build heterotic combinations. Higher the variability more is the scope for obtaining higher amount of heterotic potential and also more variability is expected to surface in segregating generations of such crosses (Shabir Ahmad Bhat *et al.*, 2018). Similar studies based on evaluation index values had also been conducted by Quadir *et al.*, (2000), Suresh Kumar *et al.*, (2006) and Nisar *et al.*, (2013).

Table.1 Rearing performance of the constricted foundation crosses during spring, 2018

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)				
APS-4 × SK-6	521	95.67	9580	13.4	1.57	0.31	19.75	88.00
APS-4 × Pam-117	532	96.44	9720	12.6	1.46	0.28	19.18	89.00
APS-4 × SK-7	554	96.26	9480	14.7	1.72	0.31	18.02	90.00
SK-6 × APS-4	570	96.08	9560	13.3	1.56	0.31	19.87	89.00
SK-6 × Pam-117	543	96.72	9600	14.6	1.69	0.32	18.93	88.00
SK-6 × SK-7	541	96.88	9680	13.7	1.59	0.32	20.13	92.00
Pam-117 × APS-4	501	95.21	9700	14.5	1.66	0.34	20.48	92.00
Pam-117 × SK-6	574	95.16	9480	12.7	1.51	0.29	19.21	89.00
Pam-117 × SK-7	565	94.55	9600	15.4	1.77	0.38	21.47	91.00
SK-7 × APS-4	559	95.03	9360	13.8	1.64	0.30	18.29	88.00
SK-7 × SK-6	515	94.97	9540	13.1	1.54	0.30	19.48	91.00
SK-7 × Pam-117	475	92.75	9600	13.5	1.57	0.30	19.11	92.00
FC-1	449	95.50	9387	13.63	1.62	0.33	20.37	93.00
Average	531	95.48	9561	13.75	1.61	0.31	19.56	90.15
SD	38	1.09	111	0.82	0.09	0.03	0.93	1.77

Table.2 Evaluation index values of the constricted foundation crosses during spring, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
APS-4 × SK-6	47.37	51.74	51.71	46.22	45.56	50.00	51.99	40.00	48.07
APS-4 × Pam-117	50.26	58.81	64.32	35.85	33.33	40.00	45.89	45.00	46.68
APS-4 × SK-7	56.05	57.16	42.70	60.98	62.22	50.00	33.48	50.00	51.57
SK-6 × APS-4	60.26	55.50	49.91	44.02	44.44	50.00	53.35	45.00	50.31
SK-6 × Pam-117	53.16	61.38	53.51	60.00	58.89	53.33	43.28	40.00	52.94
SK-6 × SK-7	52.63	62.84	60.72	49.88	47.78	53.33	56.08	60.00	55.41
Pam-117 × APS-4	42.11	47.52	62.52	58.54	55.56	60.00	59.91	60.00	55.77
Pam-117 × SK-6	61.32	47.06	42.70	36.79	38.89	43.33	46.19	45.00	45.16
Pam-117 × SK-7	58.95	41.47	53.51	70.02	67.78	73.33	70.53	55.00	61.32
SK-7 × APS-4	57.37	45.87	31.89	50.00	53.33	46.67	36.37	40.00	45.19
SK-7 × SK-6	45.79	45.32	48.11	41.98	42.22	46.67	49.15	55.00	46.78
SK-7 × Pam-117	35.26	24.95	53.51	46.61	45.56	46.67	45.14	60.00	44.71
FC-1	28.42	50.18	34.32	48.63	51.11	56.67	58.71	65.00	49.13

Table.3 Rearing Performance of the oval foundation crosses during spring, 2018

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)				
CSR-27 × CSR-50	492	94.30	9700	15.04	1.72	0.37	21.51	94.00
CSR-27 × Pam-114	487	94.63	9780	15.12	1.71	0.36	21.05	94.00
CSR-27 × APS-5	476	88.02	9620	14.03	1.63	0.34	20.86	91.00
CSR-50 × CSR-27	479	91.23	9740	14.23	1.63	0.34	20.86	95.00
CSR-50 × Pam-114	510	92.32	9660	15.11	1.73	0.37	21.39	92.00
CSR-50 × APS-5	578	97.25	9500	13.93	1.64	0.34	20.73	91.00
Pam-114 × CSR-27	569	94.22	9680	15.29	1.75	0.37	21.14	92.00
Pam-114 × CSR-50	524	93.12	9600	15.87	1.82	0.38	20.88	93.00
Pam-114 × APS-5	535	94.54	9480	13.57	1.60	0.30	18.75	90.00
APS-5 × CSR-27	512	96.24	9440	14.50	1.71	0.34	19.88	90.00
APS-5 × CSR-50	526	93.30	9600	14.48	1.68	0.34	20.24	92.00
APS-5 × Pam-114	561	94.24	9640	15.61	1.79	0.36	20.11	91.00
FC2	597	96.27	9507	15.07	1.75	0.36	20.72	92.00
Average	527	93.82	9611	14.76	1.70	0.35	20.63	92.08
SD	40	2.39	104	0.69	0.07	0.02	0.74	1.55

Table.4 Evaluation index values of the oval foundation crosses during spring, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
CSR-27 × CSR-50	41.25	52.01	58.56	54.00	52.86	60.00	61.91	62.39	55.37
CSR-27 × Pam-114	40.00	53.39	66.25	55.28	51.43	55.00	55.71	62.39	54.93
CSR-27 × APS-5	37.25	25.73	50.87	39.46	40.00	45.00	53.09	43.03	41.80
CSR-50 × CSR-27	38.00	39.16	62.40	42.29	40.00	45.00	53.09	68.84	48.60
CSR-50 × Pam-114	45.75	43.72	54.71	55.10	54.29	60.00	60.23	49.48	52.91
CSR-50 × APS-5	62.75	64.35	39.33	38.01	41.43	45.00	51.37	43.03	48.16
Pam-114 × CSR-27	60.50	51.67	56.63	57.71	57.14	60.00	56.93	49.48	56.26
Pam-114 × CSR-50	49.25	47.07	48.94	66.12	67.14	65.00	53.37	55.94	56.60
Pam-114 × APS-5	52.00	53.01	37.40	32.72	35.71	25.00	24.59	36.58	37.13
APS-5 × CSR-27	46.25	60.13	33.56	46.16	51.43	45.00	39.91	36.58	44.88
APS-5 × CSR-50	49.75	47.82	48.94	45.94	47.14	45.00	44.70	49.48	47.35
APS-5 × Pam-114	58.50	51.76	52.79	62.28	62.86	55.00	43.00	43.03	53.65
FC2	67.50	60.25	40.00	54.46	57.14	55.00	51.22	49.48	54.38

Table.5 Rearing Performance of the constricted foundation crosses during summer, 2018

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)				
APS-4 × SK-6	450	91.08	9480	14.32	1.70	0.34	19.71	93.00
APS-4 × Pam-117	517	92.66	9520	13.38	1.60	0.31	19.12	92.50
APS-4 × SK-7	544	92.21	9600	14.37	1.69	0.32	18.99	92.00
SK-6 × APS-4	552	92.28	9520	14.77	1.74	0.32	18.39	93.00
SK-6 × Pam-117	517	91.56	9640	13.77	1.62	0.32	19.85	94.50
SK-6 × SK-7	561	95.14	9660	13.94	1.63	0.34	20.86	95.50
Pam-117 × APS-4	559	95.07	9600	14.57	1.71	0.35	20.53	92.50
Pam-117 × SK-6	517	92.09	9540	13.80	1.64	0.33	19.88	94.00
Pam-117 × SK-7	587	94.26	9620	14.31	1.68	0.35	20.90	93.50
SK-7 × APS-4	539	94.88	9500	13.84	1.65	0.32	19.47	92.50
SK-7 × SK-6	535	94.27	9500	14.59	1.73	0.32	18.55	92.00
SK-7 × Pam-117	509	92.28	9480	14.45	1.72	0.33	19.23	92.50
FC-1	543	93.21	9600	14.28	1.68	0.35	20.60	93.00
Average	533	93.15	9558	14.18	1.67	0.33	19.70	93.12
SD	33.26	1.41	63.49	0.40	0.05	0.01	0.84	1.02

Table.6 Evaluation index values of the constricted foundation crosses during summer, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
APS-4 × SK-6	24.95	35.32	37.71	53.38	56.00	55.00	50.06	50.00	45.30
APS-4 × Pam-117	45.13	46.52	44.01	30.04	35.00	25.00	43.15	45.10	39.24
APS-4 × SK-7	53.31	43.33	56.62	54.87	53.00	40.00	41.51	40.20	47.85
SK-6 × APS-4	55.59	43.79	44.01	64.68	64.00	40.00	34.44	50.00	49.57
SK-6 × Pam-117	45.16	38.69	62.92	39.78	39.00	40.00	51.74	64.71	47.75
SK-6 × SK-7	58.42	64.11	66.07	44.12	42.00	60.00	63.83	74.51	59.13
Pam-117 × APS-4	57.88	63.62	56.62	59.67	57.00	70.00	59.87	45.10	58.72
Pam-117 × SK-6	45.10	42.48	47.16	40.52	43.00	45.00	52.19	59.80	46.91
Pam-117 × SK-7	66.18	57.84	59.77	53.35	51.00	70.00	64.23	54.90	59.66
SK-7 × APS-4	51.83	62.27	40.86	41.38	45.00	40.00	47.21	45.10	46.71
SK-7 × SK-6	50.72	57.94	40.86	60.13	61.00	40.00	36.26	40.20	48.39
SK-7 × Pam-117	42.81	43.79	37.71	56.79	59.00	50.00	44.42	45.10	47.45
FC-1	53.08	50.39	56.62	52.45	51.00	65.00	60.68	50.00	54.90

Table.7 Rearing Performance of the oval foundation crosses during summer, 2018

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)				
CSR-27 × CSR-50	540	94.73	9600	14.71	1.72	0.36	20.94	91.50
CSR-27 × Pam-114	546	96.55	9660	14.48	1.69	0.35	20.47	92.50
CSR-27 × APS-5	499	93.00	9500	14.73	1.74	0.34	19.55	93.50
CSR-50 × CSR-27	518	92.73	9640	14.20	1.66	0.33	19.88	94.00
CSR-50 × Pam-114	561	95.24	9580	15.06	1.76	0.36	20.47	93.50
CSR-50 × APS-5	514	93.07	9700	14.74	1.71	0.34	19.65	93.00
Pam-114 × CSR-27	571	95.69	9620	15.37	1.79	0.37	20.73	92.00
Pam-114 × CSR-50	569	94.31	9620	15.57	1.81	0.38	20.78	91.50
Pam-114 × APS-5	539	92.96	9620	13.88	1.63	0.33	19.94	93.50
APS-5 × CSR-27	519	93.07	9660	13.37	1.57	0.30	19.10	94.00
APS-5 × CSR-50	537	93.21	9660	14.00	1.64	0.32	19.26	93.50
APS-5 × Pam-114	579	95.21	9580	14.82	1.74	0.36	20.75	94.00
FC2	578	94.34	9640	14.25	1.67	0.35	21.03	94.00
Average	544	94.16	9622	14.55	1.70	0.34	20.20	93.12
SD	26.33	1.25	49.97	0.61	0.07	0.02	0.66	0.94

Table.8 Evaluation index values of the oval foundation crosses during summer, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
CSR-27 × CSR-50	48.44	54.56	45.60	52.58	52.86	60.00	61.14	34.04	51.15
CSR-27 × Pam-114	50.76	69.12	57.60	48.81	47.86	52.50	54.15	44.68	53.18
CSR-27 × APS-5	32.80	40.72	25.59	52.99	55.71	50.00	40.16	55.32	44.16
CSR-50 × CSR-27	40.28	38.56	53.60	44.31	44.29	45.00	45.16	60.64	46.48
CSR-50 × Pam-114	56.53	58.60	41.59	58.41	58.57	60.00	54.02	55.32	55.38
CSR-50 × APS-5	38.64	41.24	65.61	53.10	50.71	47.50	41.62	50.00	48.55
Pam-114 × CSR-27	60.33	62.20	49.60	63.41	62.14	65.00	57.96	39.36	57.50
Pam-114 × CSR-50	59.38	51.16	49.60	66.66	65.00	67.50	58.76	34.04	56.51
Pam-114 × APS-5	48.25	40.40	49.60	39.02	40.00	42.50	46.08	55.32	45.15
APS-5 × CSR-27	40.62	41.28	57.60	30.60	31.43	30.00	33.38	60.64	40.69
APS-5 × CSR-50	47.34	42.40	57.60	40.91	40.71	37.50	35.83	55.32	44.70
APS-5 × Pam-114	63.10	58.36	41.59	54.47	55.00	60.00	58.35	60.64	56.44
FC2	63.06	51.44	53.60	45.13	45.00	55.00	62.57	60.64	54.56

Table.9 Rearing Performance of the constricted foundation crosses during autumn, 2018

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)				
APS-4 × SK-6	492	94.01	9490	13.03	1.69	0.32	18.63	92.00
APS-4 × Pam-117	518	95.61	9360	12.68	1.55	0.29	18.85	91.50
APS-4 × SK-7	492	93.21	9460	13.59	1.63	0.31	18.94	92.00
SK-6 × APS-4	480	95.03	9380	13.32	1.69	0.31	18.09	90.50
SK-6 × Pam-117	518	94.59	9480	12.12	1.47	0.25	16.85	91.50
SK-6 × SK-7	549	94.56	9640	14.15	1.54	0.32	20.44	93.00
Pam-117 × APS-4	525	93.63	9600	14.04	1.57	0.32	20.70	93.00
Pam-117 × SK-6	482	93.59	9480	12.72	1.53	0.30	19.75	92.50
Pam-117 × SK-7	544	95.88	9640	14.01	1.53	0.33	21.75	93.50
SK-7 × APS-4	505	93.69	9420	13.24	1.70	0.32	18.94	91.50
SK-7 × SK-6	482	93.87	9520	13.54	1.61	0.31	19.01	92.50
SK-7 × Pam-117	537	96.77	9460	14.03	1.45	0.29	20.36	92.50
FC-1	502	93.56	9340	12.55	1.54	0.33	21.32	88.00
Average	510	94.46	9482	13.31	1.58	0.31	19.51	91.85
SD	24	1.08	98	0.66	0.08	0.02	1.37	1.41

Table.10 Evaluation index values of the constricted foundation crosses during autumn, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
APS-4 × SK-6	42.50	45.79	50.82	45.76	63.81	52.50	43.60	51.06	49.48
APS-4 × Pam-117	53.38	60.60	37.55	40.40	45.81	40.75	45.18	47.52	46.40
APS-4 × SK-7	42.60	38.38	47.76	54.17	55.81	49.00	45.81	51.06	48.07
SK-6 × APS-4	37.29	55.28	39.59	50.12	63.25	47.50	39.64	40.43	46.64
SK-6 × Pam-117	53.46	51.20	49.80	32.04	36.13	18.75	30.57	47.52	39.93
SK-6 × SK-7	66.42	50.88	66.12	62.73	45.13	52.50	56.80	58.16	57.34
Pam-117 × APS-4	56.35	42.31	62.04	61.12	48.44	57.25	58.70	58.16	55.55
Pam-117 × SK-6	38.42	41.90	49.80	41.08	44.00	46.25	51.72	54.61	45.97
Pam-117 × SK-7	64.33	63.10	66.12	60.61	43.31	61.00	66.34	61.70	60.82
SK-7 × APS-4	48.04	42.87	43.67	48.91	65.13	56.13	45.87	47.52	49.77
SK-7 × SK-6	38.42	44.54	53.88	53.45	53.88	48.13	46.35	54.61	49.16
SK-7 × Pam-117	61.04	71.39	47.76	60.91	33.13	42.13	56.23	54.61	53.40
FC-1	46.83	41.67	35.51	38.53	44.50	58.75	63.22	22.70	43.96

Table.11 Rearing Performance of the oval foundation crosses during autumn, 2018

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)				
CSR-27 × CSR-50	516	92.41	9640	13.02	1.58	0.31	19.33	93.50
CSR-27 × Pam-114	532	94.89	9720	14.16	1.47	0.31	20.92	94.00
CSR-27 × APS-5	493	93.61	9560	13.05	1.55	0.31	19.83	93.00
CSR-50 × CSR-27	490	94.88	9480	13.00	1.56	0.31	19.91	92.00
CSR-50 × Pam-114	526	94.44	9720	14.92	1.72	0.38	22.06	93.50
CSR-50 × APS-5	510	94.69	9540	13.78	1.63	0.34	21.06	92.50
Pam-114 × CSR-27	533	96.88	9780	13.65	1.54	0.35	22.81	95.00
Pam-114 × CSR-50	513	94.32	9660	13.78	1.57	0.33	21.33	94.50
Pam-114 × APS-5	499	93.85	9340	11.91	1.47	0.28	19.26	90.50
APS-5 × CSR-27	500	94.33	9300	11.72	1.45	0.29	19.67	91.50
APS-5 × CSR-50	531	94.89	9600	13.71	1.60	0.34	21.09	92.50
APS-5 × Pam-114	499	94.57	9660	12.71	1.50	0.30	19.68	94.00
FC2	543	96.80	9620	13.81	1.53	0.32	21.13	92.50
Average	514	94.66	9586	13.32	1.55	0.32	20.62	93.00
SD	17	1.18	143	0.89	0.07	0.03	1.10	1.26

Table.12 Evaluation index values of the oval foundation crosses during autumn, 2018

Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt.(g)	Shell ratio (%)	Pupation rate (%)	Average E.I
			By No.	By Wt.(kg)					
CSR-27 × CSR-50	51.18	30.89	53.78	46.59	53.93	45.00	38.31	53.97	46.71
CSR-27 × Pam-114	60.35	51.91	59.37	59.44	38.86	46.00	52.76	57.94	53.33
CSR-27 × APS-5	37.59	41.10	48.18	47.00	50.50	46.00	42.78	50.00	45.39
CSR-50 × CSR-27	36.06	51.82	42.59	46.36	51.58	46.92	43.51	42.06	45.11
CSR-50 × Pam-114	57.00	48.14	59.37	68.01	74.36	69.83	63.07	53.97	61.72
CSR-50 × APS-5	47.82	50.25	46.78	55.11	61.79	57.92	53.97	46.03	52.46
Pam-114 × CSR-27	61.37	68.81	63.57	53.76	49.07	60.67	69.87	65.87	61.62
Pam-114 × CSR-50	49.12	47.12	55.17	55.15	52.57	54.83	56.48	61.90	54.04
Pam-114 × APS-5	41.00	43.14	32.80	34.10	38.14	37.50	37.61	30.16	36.81
APS-5 × CSR-27	41.76	47.20	30.00	31.97	36.14	38.58	41.33	38.10	38.14
APS-5 × CSR-50	60.24	51.95	50.98	54.36	57.71	56.08	54.25	46.03	53.95
APS-5 × Pam-114	41.00	49.24	55.17	43.10	43.07	41.83	41.46	57.94	46.60
FC2	67.12	68.14	52.38	55.55	46.57	50.83	54.67	46.03	55.16

In conclusion, three constricted foundation crosses SK-6 × SK-7, Pam-117 × APS-4 and Pam-117 × SK-7 and four oval foundation crosses CSR-27 × Pam-114, CSR-50 × Pam-114, Pam-114 × CSR-27 and Pam-114 × CSR-50 were found suitable for temperate region of Jammu & Kashmir which will be utilised after further evaluation for the development of bivoltine silkworm double hybrid/ hybrids suitable to temperate region of Jammu and Kashmir as an alternate for ruling CSR double hybrid (FC2×FC1).

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