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Research Article

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Seasonal Variations in the Performance of Bivoltine Mulberry Silkworm (*Bombyx mori* L.) Breeds under Kashmir Climatic Conditions

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ABSTRACT

Background: The present research was carried out to evaluate the performance of bivoltine silkworm, *Bombyx mori* L., breeds (CSR2, CSR6, CSR27, CSR26, CSR50, PAM114, PAM117, APS4, APS5, SK6 and SK7) of different origin under Kashmir climatic conditions during spring (May-June), summer (July-August) and autumn (August-September), 2019 at Central Sericultural Research and Training Institute, Pampore, Jammu and Kashmir, India.

Methods: These eleven silkworm parental breeds were evaluated for their performance in nine 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 (%), pupation rate (%) and Filament length (m). The data generated were analyzed statistically and subjected to multiple trait Evaluation Index (E.I). The rearing was carried out under the uniformed laboratory condition by adopting the standard method.

Results: Based on the evaluation index values ranking CSR2, CSR26, CSR27, PAM114 and PAM117 performed well in all the three seasons with E.I value above 50. APS4 has performed well in spring and summer season whereas CSR50 recorded E.I value above 50 in summer and autumn only. Three breeds viz., CSR6, APS5 and SK7 recorded E.I value below 50 in all the three seasons. SK6 recorded E.I value above 50 only in the spring season.

Conclusion: The occurrence of seasonal variation in the performance is due to the silkworm breeds, which originated from different progenitors coupled with the change in climatic conditions during three seasons (spring, summer and autumn) in Kashmir valley.

Key-words: Evaluation index, Mulberry Silkworm, Seasonal variation, Silkworm breeds, Sericulture

INTRODUCTION

The mulberry silkworm *B. mori* L. (Lepidoptera: *Bombycidae*) domesticated for silk production is the most well-studied lepidopteran model system because of its rich repertoire of well-characterized mutations affecting virtually every aspect of the organism's morphology, development, behaviour and its considerable importance [1]. The commercial silkworm rearing in Kashmir region can be conducted during spring season (May-June) summer season (July- August) and autumn season (August- September). But the majority of sericulture activities are being carried out during spring season which is congenial for silkworm rearing. So far only few silkworm breeds and hybrids were developed specifically for the spring season in Jammu and Kashmir [2-4]. In the case of summer season only 10–15% of farmers take up sericulture activities [5] and attempts were made for the development and identification of hybrids for autumn and summer season [6-10].

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Despite all the efforts, CSR double hybrid developed in the southern part of the country is commercially popular in this region among sericulture rearers.

Selection of parental material is the crucial step to develop hybrids suitable for Kashmir climatic conditions for which systematic breeding approach by silkworm breeders will play an important role [11-13]. To select the parental stocks, one should have thorough knowledge regarding the diversity in the genetic constitution along with the traits that need to be improved in the hybrid material. Genetic diversity in the parental material is directly proportional to the chances of obtaining a higher amount of heterotic potential and also more variability is expected to appear in segregating generations of such crosses [14]. The impact of the exploitation of heterosis is seen in the sericulture industry in terms of growth, vigour and economic traits of silkworm hybrids compared to pure breeds.

The crossing of genetically diverse parents helps in the recombination of genes from diverse resources [15] producing high heterotic effects and more variability in segregating generations.

Hence selection of genetically pure and divergent parental strains is critical to the success of a hybridization programme in silkworm [1]. It is also needed for the hour to develop silkworm hybrids/ double hybrids withstanding climate change [16].

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

MATERIALS AND METHODS

The present investigation was carried out at Central Sericultural Research and Training Institute, Pampore, Jammu & Kashmir (J&K) during spring (May-June), summer (July-August) and autumn (August- September), 2019 to study and assess the seasonal variation in the performance of eleven silkworm breeds (CSR2, CSR6, CSR27, CSR26, CSR50, PAM114, PAM117, APS4, APS5, SK6 and SK7) of different origin under Kashmir climatic conditions. The characteristics of the parental breeds are presented in Table 1.

Table 1: Characteristic features of the eleven silkworm parental breeds

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

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, pupation rate and Filament length were recorded in all the eleven silkworm breeds during spring, summer and autumn, 2019. 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 standard rearing techniques were followed. The evaluation index value was calculated for all the nine traits studied. The evaluation index (EI) was calculated as per the below-mentioned procedure [17].

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

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 breed was 50 or >50. The line, which scored above the limit, is considered to possess greater economic value.

RESULTS

The perusal of spring 2019 parental data presented in Table 2 revealed that highest fecundity (568), hatching percentage (96.08), yield/10,000 larvae by weight (15.76), single cocoon weight (1.78), shell ratio (21.14) and filament length (921) observed in SK6, SK6, CSR2, PAM117, CSR27 and CSR2 respectively. Average multi-traits evaluation Index of spring 2019 parental data presented in Table 3 and same was depicted as a graph in Fig. 1 revealed that Seven breeds *viz*., CSR2 (54.29), CSR26 (52.90), CSR27 (56.74), PAM114 (51.85), PAM117 (57.51), APS4 (51.17) and SK6 (50.00) were performed well in the spring season except for CSR50 (42.90), SK7 (46.39), CSR6 (42.77) and APS5 (43.57).

Table 2: Rearing performance of the eleven silkworm parental breeds during spring, 2019

S.No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)
				By No.	By Wt. (kg)					
1	CSR-2	484	92.52	9700	15.76	1.74	0.37	21.08	93.00	921
2	CSR-6	437	94.52	9387	12.97	1.54	0.32	20.87	90.00	754
3	CSR-26	552	95.30	9640	15.61	1.70	0.35	20.69	93.00	700
4	CSR-27	567	95.32	9667	15.42	1.72	0.36	21.14	93.00	816
5	CSR-50	515	94.50	9040	13.34	1.58	0.32	20.31	87.00	800
6	Pam-114	467	94.80	9667	15.03	1.70	0.34	20.14	94.00	823
7	Pam-117	563	95.40	9707	15.61	1.78	0.37	20.53	94.00	814
8	APS-4	532	94.50	9760	15.64	1.60	0.32	19.65	94.00	816
9	APS-5	553	95.50	9060	14.02	1.55	0.30	19.33	87.00	796
10	SK-6	568	96.08	9760	14.76	1.60	0.29	18.11	93.00	814
11	SK-7	566	95.33	9640	12.76	1.47	0.28	19.00	93.00	845
	Avg.	528	94.89	9548	14.63	1.64	0.33	20.08	91.91	809
	SD	46	0.93	266	1.15	0.10	0.03	0.96	2.66	54

Table 3: Evaluation of index values of eleven silkworm parental breeds during spring, 2019

S.No.	Parental breeds	Fecundity (No)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)	Mean E.I
				By No.	By Wt. (kg)						
1	CSR-2	40.46	24.55	55.73	59.81	60.73	62.16	60.43	54.10	70.68	54.29
2	CSR-6	30.35	46.02	43.93	35.60	40.35	47.71	58.28	42.83	39.85	42.77
3	CSR-26	55.35	54.42	53.47	58.53	56.62	57.34	56.41	54.10	29.88	52.90
4	CSR-27	58.55	54.65	54.47	56.86	58.55	61.09	61.13	54.10	51.29	56.74

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5	CSR-50	47.17	45.84	30.88	38.83	43.89	47.18	52.41	31.56	48.34	42.90
6	Pam-114	36.76	49.07	54.47	53.45	57.13	54.67	50.67	57.85	52.58	51.85
7	Pam-117	57.81	55.51	55.98	58.48	64.67	61.62	54.71	57.85	50.92	57.51
8	APS-4	50.96	45.84	57.99	58.77	46.69	45.57	45.55	57.85	51.29	51.17
9	APS-5	55.58	56.58	31.63	44.73	41.44	40.76	42.22	31.56	47.60	43.57
10	SK-6	58.71	62.81	57.99	51.14	46.53	37.55	29.45	54.10	50.92	50.00
11	SK-7	58.30	54.70	53.47	33.81	33.42	34.34	38.74	54.10	56.65	46.39

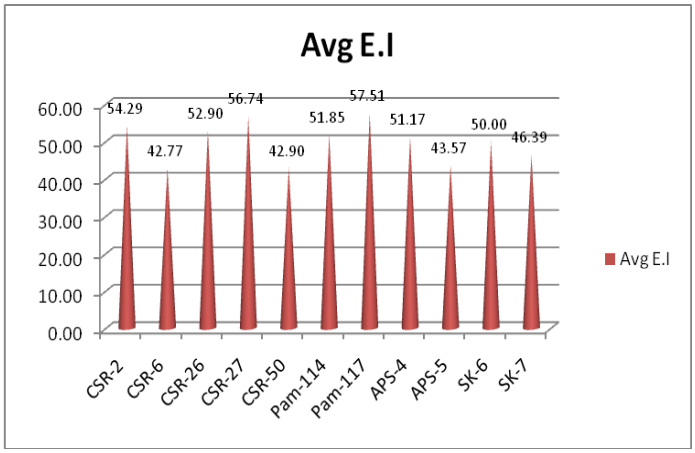

Fig. 1: Average multi-traits evaluation Index values of parental breeds during spring 2019

Further, summer 2019 data presented in Table 4 revealed that highest fecundity (546), hatching percentage (95.77), yield/10,000 larvae by number (9240), yield/10,000 larvae by weight (14.72), single cocoon weight (1.67), shell ratio (20.30), pupation rate (88.00) and filament length (927) observed in CSR27, CSR2, PAM117, APS4, PAM117, CSR2, PAM117 and CSR26 respectively. Average multi-traits evaluation Index of summer 2019 parental data was presented in Table 5 & same was depicted as a graph in Fig. 2 revealed that, except CSR6 (41.44), APS5 (47.12), SK6 (42.02) and SK7 (43.88) remaining breeds viz., CSR2 (54.24), CSR26 (52.96), CSR27 (53.93), CSR50 (50.00), PAM114 (51.86), PAM117 (60.65) and APS4 (51.89) shown E.I above 50.

Table 4: Rearing performance of the eleven silkworm parental breeds during summer, 2019

S.No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)
				By No.	By Wt. (kg)					
1	CSR-2	542	95.77	8840	13.70	1.65	0.34	20.30	84.00	821
2	CSR-6	483	94.61	8507	12.52	1.63	0.32	19.81	83.00	830
3	CSR-26	510	94.97	8933	13.84	1.63	0.33	19.99	85.00	927
4	CSR-27	546	94.92	9000	13.17	1.63	0.33	20.21	86.00	871
5	CSR-50	543	94.77	8733	13.43	1.64	0.32	19.53	84.00	885
6	Pam-114	539	94.84	9160	13.23	1.59	0.31	19.24	87.00	906
7	Pam-117	541	95.03	9240	13.87	1.67	0.34	20.14	88.00	926
8	APS-4	529	94.05	9120	14.72	1.62	0.31	19.19	87.00	857
9	APS-5	537	94.83	9060	13.90	1.54	0.30	19.22	84.00	871
10	SK-6	528	94.23	9080	13.48	1.58	0.29	18.07	85.00	774
11	SK-7	534	94.19	9000	13.50	1.61	0.29	18.01	85.00	809
	Avg.	530	94.75	8970	13.58	1.62	0.31	19.43	85.27	861
	SD	19	0.48	210	0.55	0.04	0.02	0.80	1.56	49

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Table 5: Evaluation index values of eleven silkworm parental breeds during summer, 2019

S.No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)	Mean E.I
				By No.	By Wt. (kg)						
1	CSR-2	56.35	71.30	43.81	52.23	58.68	61.27	60.97	41.82	41.75	54.24
2	CSR-6	24.59	47.11	27.96	30.75	53.97	54.89	54.77	35.38	43.57	41.44
3	CSR-26	39.14	54.73	48.24	54.78	54.42	56.71	57.07	48.25	63.30	52.96
4	CSR-27	58.51	53.69	51.41	42.64	54.10	58.54	59.82	54.68	51.96	53.93
5	CSR-50	56.96	50.50	38.73	47.25	55.59	53.07	51.29	41.82	54.76	50.00
6	Pam-114	54.73	52.03	59.02	43.61	43.77	45.77	47.63	61.11	59.05	51.86
7	Pam-117	55.81	55.84	62.82	55.26	64.44	62.19	58.92	67.54	63.06	60.65
8	APS-4	49.40	35.43	57.12	70.79	49.42	47.60	47.05	61.11	49.07	51.89
9	APS-5	53.66	51.65	54.26	55.87	28.17	39.39	47.33	41.82	51.96	47.12
10	SK-6	48.81	39.28	55.22	48.22	39.34	33.92	32.94	48.25	32.23	42.02
11	SK-7	52.04	38.44	51.41	48.59	48.09	36.65	32.20	48.25	39.29	43.88

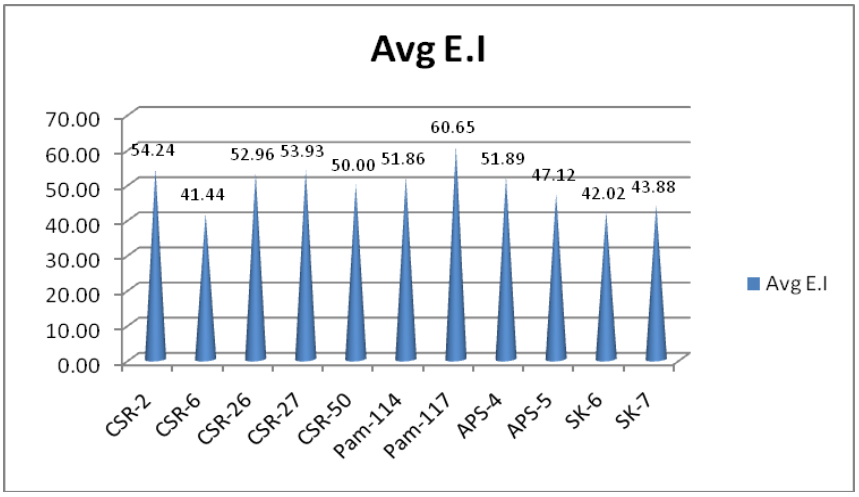

Fig. 2: Average multi-traits evaluation Index values of parental breeds during summer 2019

In case of autumn 2019, data presented in Table 6 revealed that highest fecundity (526), hatching percentage (95.24), yield/10,000 larvae by number (9700), yield/10,000 larvae by weight (14.94), single cocoon weight (1.69), single shell weight (0.35), shell ratio (20.73), pupation rate (94.50) and filament length (860) observed in SK6, CSR50, CSR2, CSR2, PAM114, PAM114, CSR2, CSR50 and PAM114 respectively. Average multi-traits evaluation Index of autumn 2019 parental data was presented in Table 7 & same was depicted as a graph in Fig. 3 revealed that, except CSR6 (36.82), APS4 (47.90), APS5 (45.53), SK6 (44.58) and SK7 (48.76) remaining breeds *viz*., CSR2 (54.69), CSR26 (52.68), CSR27 (52.73), CSR50 (52.95), PAM114 (60.00) and PAM117 (53.37) shown E.I above 50.

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Table 6: Rearing performance of the eleven silkworm parental breeds during autumn, 2019

S.No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)
				By No.	By Wt. (kg)					
1	CSR-2	520	94.05	9700	14.94	1.64	0.34	20.73	93.50	752
2	CSR-6	459	94.79	9373	13.09	1.56	0.31	19.91	91.00	853
3	CSR-26	518	94.77	9640	14.71	1.61	0.32	20.14	93.33	852
4	CSR-27	523	94.81	9613	14.65	1.63	0.33	20.08	93.00	859
5	CSR-50	524	95.24	9680	13.94	1.54	0.32	20.46	94.50	762
6	Pam-114	521	95.12	9640	14.83	1.69	0.35	20.54	93.67	860
7	Pam-117	520	95.03	9680	14.48	1.67	0.33	20.01	93.33	763
8	APS-4	519	94.68	9580	13.98	1.56	0.32	20.20	93.50	778
9	APS-5	516	95.00	9620	13.62	1.52	0.31	20.12	93.50	723
10	SK-6	526	94.28	9680	13.78	1.51	0.31	20.15	93.50	699
11	SK-7	522	94.94	9640	13.84	1.59	0.32	20.18	93.00	738
	Avg.	515	94.79	9622	14.17	1.59	0.32	20.23	93.26	785
	SD	19	0.36	90	0.59	0.06	0.01	0.24	0.85	60

Table 7: Evaluation index values of eleven silkworm parental breeds during autumn, 2019

S.No.	Parental breeds	Fecundity (No.)	Hatching (%)	Yield / 10, 000 larvae brushed		Single cocoon wt. (g)	Single shell wt. (g)	Shell ratio (%)	Pupation rate (%)	Filament length (m)	Mean E.I
				By No.	By Wt. (k)						
1	CSR-2	52.24	29.01	58.63	63.12	58.32	63.16	70.45	52.86	44.44	54.69
2	CSR-6	20.17	49.96	22.29	31.69	44.37	41.44	36.87	23.37	61.24	36.82
3	CSR-26	51.58	49.49	51.95	59.15	52.50	51.10	46.32	50.89	61.11	52.68
4	CSR-27	53.89	50.62	48.99	58.24	56.06	53.51	43.97	46.96	62.33	52.73
5	CSR-50	54.79	62.61	56.40	46.10	41.45	45.06	59.31	64.66	46.13	52.95
6	Pam-114	53.21	59.33	51.95	61.19	66.36	67.99	62.60	54.83	62.52	60.00
7	Pam-117	52.68	56.71	56.40	55.29	62.64	58.34	41.06	50.89	46.29	53.37
8	APS-4	52.02	46.73	45.28	46.78	44.72	45.06	48.89	52.86	48.73	47.90
9	APS-5	50.43	55.73	49.73	40.66	37.41	37.82	45.60	52.86	39.55	45.53
10	SK-6	55.64	35.62	56.40	43.38	37.02	37.82	46.85	52.86	35.57	44.58
11	SK-7	53.35	54.18	51.95	44.40	49.15	48.68	48.07	46.96	42.09	48.76

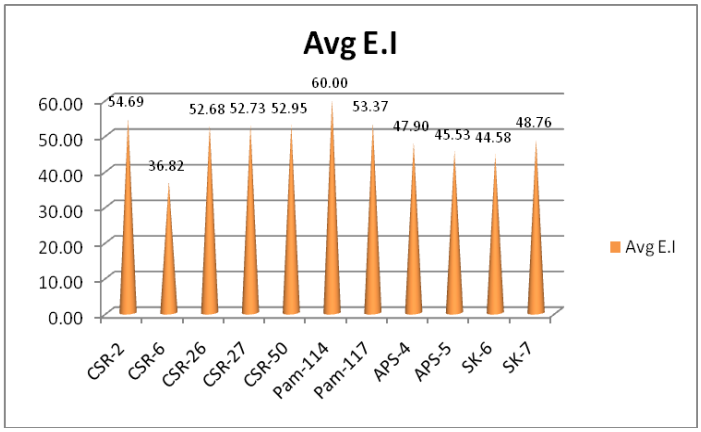

Fig. 3: Average multi-traits evaluation Index values of parental breeds during autumn 2019

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DISCUSSION

The agro-climatic conditions of the union territory of Jammu and Kashmir enjoy the temperate climate in Kashmir division and sub-tropical in Jammu division. This peculiar climatic conditions specific to the union territory of J&K is interesting and will not found anywhere else in the country. In Kashmir region, the climatic conditions vary rapidly among three seasons viz., spring, summer and autumn of which spring found to be most favourable for silkworm rearing [18]. To find outbreeds suitable for a particular season is the most challenging task for the scientists/researchers in this region. Development of hybrids/ double hybrids suitable for a particular season will only succeed based on the silkworm breed performance in that particular season [19]. Silkworm hybrids and double hybrids play an important role in deciding the cocoon production along with silk quality of which silkworm double hybrids are superior over single hybrids [20,21].

In spring 2019, among CSR breeds CSR2, CSR26 and CSR27 performed well compared to CSR6 and CSR50. Rearing results revealed that PAM114, PAM117, APS4 and SK6 recorded EI above 50. Interestingly even though spring season found to be favourable for silkworm rearing CSR6, CSR50, APS5 and SK7 recorded EI below 50. In summer 2019, CSR2, CSR26, CSR27, CSR50, PAM114, PAM117 and APS4 recorded EI above 50. A similar trend is observed in autumn season 2019, where CSR2, CSR26, CSR27, CSR50, PAM114 and PAM117 recorded EI above 50 excluding CSR6, APS4, APS5, SK6 and SK7. Only CSR6, APS5 and SK7 didn't perform in all the three seasons with EI less than 50. The present research findings conform to Bharath *et al*. [22].

Among CSR breeds originated from CSR&TI, Mysore CSR2, CSR26, CSR27 performed well in all the three seasons except CSR6. CSR50 breed didn't record EI above 50 only in the spring season. Only APS4 breed originated from APSSRDI, Hindupur performed well in spring and summer whereas, SK6 breed originated from CSR&TI, Berhampore recorded E.I value above 50 during spring only. SK-7 and APS-5 breeds didn't perform well in all the three seasons. PAM114 and PAM117 originated from CSR&TI, Pampore performed well in all the three seasons. Even though CSR breeds originated from single progenitor the performance of these breeds varies under Kashmir climatic condition. The variation in the performance of the above breeds will be useful to find out the breed to be used for that particular season for the development of season-specific hybrids/ double hybrids [23]. Based on the results CSR6, APS5 and SK7 will not be considered for hybrid/ double hybrid production in any of the three season's and APS-4, APS-5 SK-6 and SK-7 specifically not for autumn specific hybrids. The abiotic factors prevailing in summer and autumn season majorly hinders the performance of breeds along with other biotic factors. Hence, the selection of breeds withstanding the unfavourable abiotic and biotic factors will be a key factor for the successful development of hybrids/ double hybrids for Kashmir climatic conditions. Similar studies based on evaluation index values had also been conducted by Nooruldin *et al*. [24], Rayar [25], Kumaresan *et al.* [26] and Moorthy *et al*. [27]. The present research findings confirmed by Mir *et al*. [28] and Bharath *et al*. [29].

CONCLUSIONS

The eleven mulberry silkworm parental breeds performed well during spring (CSR2, CSR26, CSR27, PAM114, PAM117, APS4 and SK6), summer (CSR2, CSR26, CSR27, CSR50, PAM114, PAM117 and APS4) and autumn (CSR2, CSR26, CSR27, CSR50, PAM114 and PAM117), 2019. The seasonal variation in the performance of these silkworm breeds during three different seasons (spring, summer and autumn) under Kashmir climatic conditions indicates the degree of genetic variability.

The identified silkworm parental breeds will be utilized for the development of sustainable bivoltine silkworm double hybrids suitable for Kashmir climatic conditions.

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