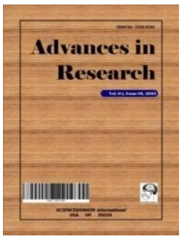

Advances in Research
9(1): 1-11, 2017; Article no.AIR.32853
ISSN: 2348-0394, NLM ID: 101666096

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Rearing Performance of Some Popular Bivoltine Silkworm (*Bombyx mori* L.) Breeds during Spring Season

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Authors' contributions

This work was carried out in collaboration between all the authors. Authors MAM, NAG and ASK conceptualized the study. Authors MAM, NAG, ASK and ZIB designed the study and wrote the protocol. Authors ZIB and MAM wrote the first draft of the manuscript and revised by authors NAG and ASK. Author SAM performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2017/32853
Editor(s):
(1) Alfredo Emilio Silveira de Borba, Department of Agrarian Sciences, University of the Azores, Portugal.
(2) Vincenzo Tufarelli, Department of DETO - Section of Veterinary Science and Animal Production, University of Bari "Aldo Moro", Italy.
Reviewers:
(1) Hamit Ayberk, Istanbul University, Turkey.
(2) H. B. Manjunatha, University of Mysore, Karnataka, India.
(3) S. Manthira Moorthy, Silkworm Breeding and Molecular Biology, CSRTI, Central Silk Board, Mysore, India.
Complete Peer review History: http://www.sciencedomain.org/abstract/18439

Original Research Article

Received 20th March 2017
Accepted 30th March 2017
Published 31st March 2017

ABSTRACT

Twelve popular bivoltine silkworm (*Bombyx mori* L.) breeds viz., CSR2, NB4D2, SK-1, CSR4, DUN6, SH6, SK-6, CSR19, SK-28, DUN22 and SK-31, were evaluated for their performance during spring 2012 and 2013. The data generated in respect of different traits during two years was recorded replication wise and pooled. The pooled data was analyzed statistically and subjected to multiple trait evaluation index using Mono's evaluation index method. Analysis of variance showed significant

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differences among the breeds for all the characters studied. The breeds were ranked as per the cumulative score and the value of a particular trait in a particular breed was compared with the ranking. Six breeds viz., NB4D2, SK-1, SH6, SK-6, SK-28 and SK-31 were short-listed. These breeds s scored higher E I values (>50) and can be used for the preparation of season specific hybrids to push up bivoltine silk productivity under specified environmental conditions in the valley.

Keywords: Bombyx mori; bivoltine; breeds; popular; rearing; spring; silkworm.

1. INTRODUCTION

Silk has been one of the cherished heritages of Jammu and Kashmir with sericulture activity in the valley. The state has a significant role in view of its salubrious climatic conditions in the country for production of bivoltine silk which has been one of the priority sectors of Indian Silk Industry, but its production is yet to meet the domestic targets. Though, the state is known for producing bivoltine silk of international quality. However, production of quality bivoltine silk is still a challenge in J & K having enormous potential to produce bivoltine silk of international grade, which can help to reduce the import of bivoltine silk in the country [1]. Of late, major thrust has been given on quality rather than quantity of silk produced. The efforts made by sericulture research institutes in this direction during the 90's have led to the evolution of highly productive CSR bivoltine breeds which have the potential to produce international grade silk [2]. These new breeds have contributed significantly under tropical conditions but did not thrive well and suffered badly in adverse conditions of low/high temperature, humidity, poor leaf quality and low management practices prevalent with the Sericultural farmers in Kashmir [3]. Unlike tropics, temperate sericulture being carried out under highly fluctuating environmental conditions and poor leaf quality urgently needs the development of broad based silkworm breeds with genetic plasticity to buffer the adverse situations. Therefore, it is of paramount importance to know the seasonal performance of silkworm breeds before formulating any breeding program for the development of season specific silkworm breeds. In this context, the seasonal performance of some popular bivoltine silkworm *B. mori* germplasm strains was assessed to identify most promising breeds which can be used in the preparation of season specific breeds/hybrids to strength the bivoltine silk production.

2. MATERIALS AND METHODS

Twelve popular bivoltine mulberry silkworm breeds namely; CSR2, NB4D2, SK-1, CSR4, DUN6, SH6, SK-6, CSR19, SK-28, DUN22 and SK-31 were reared at TSRI SKUAST-K, Mirgund under congenial laboratory conditions during the year 2012 and 2013 (May to June) following standard package of practices [4]. The silkworms were fed with mulberry leaves harvested from the popular mulberry varieties viz; Goshoerami and Ichinose maintained in Mulberry Farm of TSRI, Mirgund.

The larvae of each breed were reared in three replications and each replication comprised of 250 larvae. 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 and filament length. The data pertaining to the following 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,

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

2.3 V Instar Larval Duration (d:h)

It was calculated as the total hours taken by larvae from the first day of V instar up to mounting of the ripe larvae.

2.4 Total Larval Duration (d:h)

It was calculated as the total hours taken from the date of brushing to the mounting of ripe worms.

2.5 Weight of Ten Mature Larvae (g Larva^{-10})

Ten mature larvae were selected randomly from each replicate of each treatment and weighed separately.

2.6 Single Cocoon Weight (g)

Ten cocoons from each replicate of each treatment were selected randomly and weighed to determine the average cocoon weight.

2.7 Single Shell Weight (g)

The cocoons used for determining the average single cocoon weight were cut open and weighed to obtain shell weight.

2.8 Pupal Weight (g)

The pupae obtained from the cut open cocoons were weighed to determine the average papal weight.

2.9 Shell Ratio (%)

It was calculated as,

$$\text{Shell ratio (\%)} = \frac{\text{Single Shell wt.}}{\text{Single cocoon wt.}} \times 100$$

2.10 Cocoon Yield /10,000 Larvae

2.10.1 By number

It was calculated as,

$$\frac{\text{No. of cocoons harvested from each replicate}}{\text{No. of worms retained after 3rd moult}} \times 10{,}000$$

2.10.2 By weight (Kg)

It was calculated as,

$$\frac{\text{Weight of cocoons harvested from each replicate}}{\text{No. of worms retained after 3rd moult}} \times 10{,}000$$

2.11 Filament Length

Ten randomly selected cocoons from each treatment and replicate were reeled to determine the average filament length.

2.12 Statistical Analysis

The data recorded in respect of different parameters was pooled separately, analyzed statistically and subjected to multiple trait evaluation index method as per the procedure outlined by [5].

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

The evaluation index value for negative traits viz., V instar larval duration and total larval duration was computed separately by using the modified formula [6].

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

Where,

A = Value of a particular breed for particular trait,
B = Mean value for a particular trait of all the breeds,
C = Standard Deviation of a particular trait for all the breeds,
10 = Standard unit,
50 = Fixed value.

The average EI value fixed for selection of a breed is >50. The breeds, which scored above the limit, were considered to possess greater economic value.

3. RESULTS AND DISCUSSION

3.1 Rearing Performance

The rearing performance of the bivoltine breeds under optimal rearing conditions (25 ±1°C) and humidity (70 ± 5 %) during spring is presented in Tables 2. The data recorded on fecundity of different genotypes revealed that the maximum fecundity was manifested by SK-31 (635) while it was recorded minimum in SH_6 (613) (Table 2). The egg laying capability of *B. mori* L. has been noticed to be a heritable character expressed within the genotypic limitations of the insects like *B. mori*. The superior fecundity of these breeds in the current study indicated their genetic constitution since; the fecundity of *B. mori* varies due to variation in the genetic makeup of the silkworm breed/strain [7] which is influenced by number of physiological and ecological factors as reported by [8].

The maximum hatching % of 96.05 in the present study was exhibited by SK-6, while it was minimum in DUN_6 (94.98). Hatching percentage reflects viability of the eggs laid and maximum hatching percentage reflects the genetic background and physiological state of the female moth [9]. The survival and development of insects are at the mercy of nature and the biological and developmental activities are restricted in accordance with the prevailing ecological conditions and to a certain extent to their genetic build up [10]. The maximum hatching % obtained in the present study reflects genetic background of the breed for this trait.

In the present study, CSR_{19} recorded shorter V instar and total larval durations among all the breeds evaluated for this trait. Significantly, shorter V instar and total larval durations for this breed was recorded 6.19 and 25. 08 days, respectively (Table 2). Larval duration is considered as an important attribute of economic value in sericulture as the reduction in larval duration would not only help in minimizing the quantum of the food consumption by the insect but also in completion of larval period in desirable time period besides minimizing the labor requirement [11]. Shorter larval duration obtained in respect of the breed clearly reflects its genetic constitution for this trait. The rate of development depends on both genetic and environmental factors [12]. The larval duration varies depending on the prevailing temperature. High ambient temperature during summer tends to reduce the larval duration by several hours to one or two days, where as lower temperature during spring and autumn season extends the larval duration [13].

Present study also revealed that there was significant variation in larval weight of different breeds during spring. SK-1, SK-6, SK-31, NB_4D_2 and SK-28 recorded higher larval weight of about 50.19g, 49.47g, 49.17g, 48.87g and 48.27g, respectively (Table 2) over the other breeds evaluated. The difference in the larval weight among the breeds studied could also be attributed to the racial character, difference in degree of assimilation that differ from one breed to another and the quality and quantity of food consumed by the larvae which has a direct bearing on the performance on the growth and development of larvae. Larval weight is one of the important parameter which determines not only the health of the larvae, but also the quality of the cocoons spun [14]. The present findings are in conformity with the findings of [15] who have reported higher larval weight of 52.46g in SK-1, 49.53g in SK-6, 49.56g in SK-31 and 49.20g in SK-28 during spring under Kashmir conditions. [16] have also reported highest larval weight of 3.53g in NB14, 3.24g in SK4C and 2.43g in CSR_{19}. Higher larval weight obtained in current study reveals that silkworm breeds under study have good genetic variability and thus significant variation in larval weight was recorded. These breeds have the potential to be used in breeding programmes.

SK-1 registered the highest cocoon weight of 2.09g while SH_6 recorded minimum cocoon weight of 1.84g in present study, (Table 2). Cocoon weight, shell weight, shell ratio and filament length have been reported to be highly heritable traits which are significantly important in determining the quality, quantity and efficiency during the reeling process. Cocoon weight is an important commercial characteristic used to determine approximately the amount of raw silk that can be reeled [17]. The higher cocoon weight recorded in SK-6, SK-1, NB_4D_2, SH_6, SK-31 and SK-28 possibly indicated a clear difference in nutrient utilization by these breeds during V instar. The present findings are in agreement with the findings of [15] who have reported higher cocoon weights for these breeds. The findings of this study are also in conformity with the reports of [18] who have concluded that environmental factors influence the physiology of insects and also have deleterious effect on economic traits such as cocoon weight and shell weight. Higher cocoon weight in respect of SK-6- and SK-1 reflects their genetic potential.

The difference between Cocoon and shell weight is the weight of the pupa and are considered important with respect to commercial traits evaluated for productivity in sericulture [19]. Cocoon shell weight is an important character in determining the silk weight. During spring the mean single cocoon weight among all the breeds was found significantly higher in SK-1 (2.09g) and lower in NB_4D_2 (1.89g). However, CSR_{19} registered the significantly lowest single cocoon weight of 1.67g among all the breeds evaluated for this trait. SK-1 registered highest shell weight and shell ratio of 0.45g and 21.45% respectively whereas SK-6 registered shell weight and shell ratio of 0.43g and 21.14% respectively (Table 2). This could be attributed to racial character of these breeds. [15] have also reported higher shell weight and shell ratio in SK-1 and SK-6 indicating the better adaptability of these breeds under spring conditions. The results are in conformity with the findings of [20] who have reported that cocoon shell weight shows variability under different environmental conditions.

Higher pupal weight of 1.63g, 1.60g, 1.50g and 1.49 g were manifested by SK-1, SK-6, SK-31 and NB_4D_2, respectively. [21] have reported pupal weight of 1.38g in CSR_{18}, 1.34 g and 1.33 g in CSR_{19} and NB_4D_2 breeds, respectively. The pupal weight of *B. mori* has been noticed to be influenced by the variation in the level of secreted hormones [22] and genotype variation [23,21]. Higher pupal weight attained by the breeds indicates their better feed consumption and good larval growth during the larval periods which could also be attributed to better larval growth period and reduced meltage during pupal development [24].

Filament length is one of the important attributes of the silkworm breeds. The silk filament length is different in silkworm breeds under different set of rearing conditions and rearing seasons [25]. The highest average filament lengths of 1197.00m and 1168.00m were observed in SK-1 and SK-6, respectively. Good filament length obtained in the current study implied the superiority of these breeds over the other breeds evaluated. The results of the findings are in conformity with the findings of [15] who have identified SK-1 and SK-6 as the breeds with higher filament length during spring and summer seasons under Kashmir conditions.

A higher value for effective rate of rearing is indicative of higher silk productivity and a good cocoon crop in sericulture. ERR is an important trait in terms of studying the probability of survival of silk worm breeds. The higher cocoon yield (9367/10,000 larvae) by number in respect of SK-1 could be attributed to the nutritious mulberry leaf available during spring which lead to development of resistance towards diseases thus higher survivability and higher yield [26]. The findings of current study are well supported by [27] who have reported that bivoltine breeds have high effective rate rearing (ERR) under different sets of climatic conditions. These findings are in conformity with [28,29,26] who have reported that cocoon production is chiefly dependent on larval nutrition and nutritive value of mulberry leaves and conversion efficiency of larvae which is affected by weather conditions.

ERR by weight shows the quantum of cocoons obtained after rearing [30]. SK-1 and SK-6 recorded the highest cocoon yield of 19.24 kg and 18.76 kg respectively, among all the breeds studied for this trait (Table 2) which could be attributed to better survival rate of the larvae [31,32]. The results of present finding are well supported by [15] who have reported higher cocoon yield of 19.83 kg/10,000 larvae by weight for SK-1 during spring which confirms the better survival of these breeds thus genetic potential of the breeds. Similar types of results have been reported by [33] with maximum ERR (by number) in NB_4D_2 (252.37g/200 larvae) and [34] found maximum ERR (by weight) in CSR_2 (17.9 kg/10,000 larvae). [12] has reported cocoon yield of 14.59 kgs/10,000 larvae in CSR_{18} and 12.61 kg/ 10,000 larvae for NB_4D_2 under tropical conditions. The difference in the cocoon yield (by weight) could be attributed to climatic factors prevailing during rearing and potential of the breed to adjust to the prevailing environment [35].

The differential expression of different breeds in the present study is in conformity with the observations of several workers [36,37,38,15]. This is largely due to the variable gene frequencies at different loci in different silkworm strains which make them to respond differently to changing environmental conditions [39,40]. It is thus understood that the performance of a race or a breed is mainly dependent on the combined action of hereditary potential of its population and the extent to which such potential is permitted to express in the environment to which it is exposed.

3.2 Multiple Trait Evaluation

Evaluation index assessment is the multiple performance of a population for selection/short-listing of the breeds/hybrid combinations by taking into consideration all the economic traits. The data pertaining to the breeds recorded during spring 2012 and 2013 in respect of different traits was pooled character wise and further subjected to multiple trait evaluation as per the procedure outlined by [5,6]. Based on the performance of silkworm breeds, individual indices were calculated for each of the parameters and the data of which is presented in Table 3. The indices obtained from all the traits in each breed were combined and the average E. I. values were determined. The criteria for selection of the breed was based on the average E. I. value >50. The breeds which scored above the limit of 50 in many of the traits were considered to possess greater economic value.

Evaluation index method has been utilized for short listing some promising silkworm genotypes/hybrids for commercial exploitation [41-47] and the same has been utilized in the present study as well.

Table-1. Characteristic features of different bivoltine silkworm *B. mori* L. breeds under study

Silkworm breeds	Parental source	Larval pattern	Cocoon colour	Cocoon shape	Origin/ evolution	Source
SK-1	Shunrei × Shogetsu	Marked	White	Constricted	TSRI, SKUAST-Kashmir- Mirgund	Silkworm Germplasm
SK-6	Shogetsu × Hoshu	Plain	White	Slightly oval		Bank, TSRI, SKUAST-K, Mirgund
SK-28	Evolved Under Broad Based Germplasm Complex, Comprising 10 Breeds With Marked Larvae	Marked	White	Short dumbell		
SK-31	Evolved Under Broad Based Germplasm Complex, Comprising 10 Breeds With Plain Larvae	Marked	White	Oval		
CSR_2	Shunrei × Shogetsu	Plain bluish	Bright white	Oval	CSR&TI,	Silkworm Germplasm
CSR_4	(BN18×BCS25) × NB_4D_2	Plain bluish	Bright white	Dumbell	Mysore-India	Bank, CSGRC, Hosur-Tamilnadu, India
CSR_{18}	B201× BCS12	Plain & marked	Creamish white	Oval		
CSR_{19}	B201× BCS12	Plain & marked	Creamish white	Dumbell		
NB_4D_2	(Kokko × Seihaku) × (N124×C124)	Plain faint bluish	White	Elongated, constricted		
SH_6	Shogetsu × Hoshu	Moderately marked	White	Oval	RSRS, Majira, Dehradun- India	
DUN_6	CC1 × NN6D	Plain	White	Oval	CSR&TI,	Silkworm Germplasm
DUN_{22}	(KS × NB_4D_2) (AT × NB_4D_2)	Marked	White	Oval	Pampore-Kashmir	Bank, CSR&TI,CSB-Pampore

Table 2. Mean performance of twelve silkworm *B. mori* L. breeds during spring*

Silkworm breeds	Fecundity (no.)	Hatching (%)	V instar Larval duration (d:h)	Total larval duration (d:h)	Weight of Ten mature larvae(g)	Single cocoon Weight (g)	Single Shell weight (g)	Pupal weight (g)	Shell ratio (%)	Filament length (m)	Cocoon yield/10,000 larvae by number	Cocoon yield/10,000 larvae by weight (kg)
SK-1	577	95.24	7.06	27.09	50.19	2.09	0.45	1.63	21.45	1197.00	9367	19.23
SK-6	617	96.05	7.03	27.06	49.47	2.04	0.43	1.60	21.14	1168.00	9128	18.79
SK-28	621	94.00	7.03	27.03	48.27	1.84	0.38	1.45	20.74	1060.50	8986	16.40
SK-31	635	94.38	7.09	27.09	49.17	1.91	0.40	1.50	20.85	1148.00	9217	17.30
CSR_2	519	92.52	7.03	27.02	40.53	1.71	0.34	1.37	19.94	898.17	8994	15.42
CSR_4	514	93.73	7.06	27.08	43.48	1.74	0.35	1.38	20.07	917.48	8918	15.61
CSR_{18}	516	94.58	6.22	25.10	40.78	1.69	0.34	1.34	20.17	928.23	8713	14.54
CSR_{19}	533	95.35	6.19	25.08	39.70	1.67	0.32	1.34	19.24	920.17	8754	14.23
NB_4D_2	582	94.87	7.03	26.09	48.87	1.89	0.39	1.49	20.70	1121.00	9128	16.95
SH_6	613	95.89	7.01	26.08	42.17	1. 84	0.38	1.45	20.60	1098.00	9069	16.19
DUN_6	596	95.15	7.08	27.11	41.18	1.78	0.37	1.40	20.69	1019.50	9312	16.72
DUN_{22}	588	94.53	7.06	27.09	40.13	1.76	0.36	1.39	20.40	1013.67	9187	16.29
Mean	**575.92**	**94.69**	**6.91**	**26.58**	**44.5**	**1.83**	**0.38**	**1.45**	**20.5**	**1040.81**	**906.42**	**16.47**
S.D	**44.39**	**0.98**	**0.33**	**0.79**	**4.28**	**0.13**	**0.04**	**0.10**	**0.59**	**107.08**	**202.63**	**1.5**
CD p≤0.05	**6.51**	**0.13**	**0.87**	**1.25**	**0.32**	**0.60**	**0.61**	**0.45**	**0.15**	**23.91**	**9.72**	**0.58**

** (Data pooled over same seasons of 2012 and 2013)*

Table 3. Multiple trait evaluation index in respect of twelve silkworm *B. mori* L. breeds during spring*

Silkworm Breeds	Fecundity (no.)	Hatching (%)	V instar larval duration (d:h)	Total larval duration (d:h)	Weight of Ten mature larvae(g)	Single cocoon weight (g)	Single shell weight (g)	Pupal weight (g)	Shell ratio (%)	Filament length (m)	Cocoon yield/10,000 larvae		Average EI (%)	Rank
											by number	By weight (Kg)		
SK-1	50.24	55.62	45.37	43.50	63.31	69.43	69.51	69.37	66.21	64.59	64.93	68.41	60.87	I
SK-6	59.25	63.90	46.28	43.88	61.63	65.69	64.25	66.23	60.93	61.88	53.14	65.47	59.38	II
SK-28	60.16	42.93	46.28	44.26	58.82	50.75	51.50	50.52	54.11	51.84	46.13	49.52	50.57	VI
SK-31	63.31	46.82	44.45	43.50	60.93	55.98	56.36	55.76	55.98	60.01	57.53	55.52	54.68	III
CSR_2	37.18	27.79	46.28	44.39	40.73	41.03	40.57	42.15	40.47	36.68	46.52	42.97	40.56	XII
CSR_4	36.05	40.17	45.37	43.63	47.63	43.27	43.20	43.19	42.68	38.48	42.77	44.24	42.56	X
CSR_{18}	36.50	48.87	70.90	68.69	41.32	39.54	40.57	39.00	44.39	39.49	32.66	37.10	44.92	IX
CSR_{19}	40.33	56.74	71.81	68.94	38.79	38.04	35.31	39.00	28.53	38.73	34.68	35.03	43.83	XI
NB_4D_2	51.37	51.83	46.28	56.16	60.22	54.48	53.73	54.71	53.42	57.49	53.14	53.19	53.83	IV
SH_6	58.35	62.27	46.88	56.29	44.57	50.75	51.10	50.52	51.72	55.34	50.23	48.11	52.18	V
DUN_6	54.52	54.70	44.76	43.25	42.25	46.26	48.47	45.29	53.25	48.01	62.22	51.65	49.55	VII
DUN_{22}	52.72	48.35	45.37	43.50	39.80	44.77	45.83	44.24	48.31	47.47	56.05	48.78	47.10	VIII

** (Data pooled over same seasons of 2012 and 2013)*

The top ranking breeds manifested >95% hatching which is well supported by the earlier findings [48]. The healthiness of larvae is a very important character from the point of view of silkworm rearers and as such stabilization of cocoon crop is very important for the sericulture industry. The breeds that have shorter larval duration have less chance to get infected with diseases [49]. In the present study, out of 12, CSR_{18} and CSR_{19} recorded shorter larval durations.

The single cocoon weight in the top ranking breeds ranged from 1.84g in SK-28 to 2.09 in SK-1 (Table 3). High cocoon shell weight is an important trait for high productivity in sericulture. The cocoon shell weight shows variability in different environments. According to [5] if the breed is showing cocoon shell weight of 0.45g and above, it becomes weak and not suitable for rearing. The identified breeds in the current study recorded shell weight in the range of 0.38g (SK-28) to 0.45g (SK-1). The length of cocoon filament is one of the important attributes of the silkworm breed/hybrid. Longer the filament better it is to the filature and textile industry. Cocoon yield is yet another important character connected with the production of cocoons by Sericulturists. It is necessary to have high yielding silkworm breeds to raise the farmer's income.

The silkworm *B. mori* L. has been continuously evaluated and the promising had been selected based on the performance of economic traits [5, 50]. Evaluation index is one such method that increases the precision of selection of breed among an array of breeds by a common index giving due weightage to all the yield component traits [51]. The silk yield is contributed by more than 21 traits [52] and there exists an interrelationship between multiple traits in silkworm. Any effort to improve the yield requires consideration of cumulative effect of the major traits, which influences the silk yield impartially. A selection index makes it possible to select for a character by selecting simultaneously for two or more characters related to it.

In the present study, SK-1 and SK-6 scored E.I indices >50 for 10 characters. SK-31 and SH6 obtained E.I values >50 for 9 characters each. NB_4D_2 scored E.I values >50 for the maximum of 11 traits. However, this breed occupied fourth position in the average evaluation index score with an average E.I of 53.83. SK-1 occupied the top position with average E.I score value of 60.87 (Table 3). Obviously, the present study has yielded good information in identifying promising silkworm breeds having greater economic value in terms of maximum traits. The shortlisted breeds can be recommended for further breeding programs for breeding season specific breeds/hybrids in the interest of the industry.

4. CONCLUSION

Based on the performance and evaluation of silkworm breeds, NB_4D_2, SK-28 , SK-1, SK-6, SH_6 and SK-31 were shortlisted. These breeds scored higher E I. values (>50) and have been identified as promising breeds and are recommended for further breeding to boost bivoltine silk production in the valley.

ACKNOWLEDGEMENTS

The first author sincerely acknowledges Professor and Head, TSRI, SKUAST-K, Mirgund for proving Laboratory facilities to conduct silkworm rearing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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