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Research Paper

Evaluation and Identification of Superior Bivoltine Breeds of Silkworm, *Bombyx mori* L. during different Seasons at Jammu

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ABSTRACT

In the present study, the selected breeds were screened for the desired qualitative and quantitative traits during spring and autumn seasons (2018 and 2019). After fixation of the desired traits, eighteen breeds (BHR 2, BHR 3, B.con 1, B.con 4, ATR16, ATR29, DUN6, DUN22, CSR2, CSR6, CSR50, CSR51, RSJ1, RSJ14, SH_6 and NB_4D_2) were procured from different institutes for the study. The breed's trial was conducted and assessed for two different seasons for their performance on important economical traits. The data obtained on the traits such as fecundity, hatching, yield per 10000 larvae by number and weight, single cocoon weight, shell weight, shell ratio and filament length was analyzed with statistical tools. Based on the two popular evaluation methods such as multiple traits Evaluation Index (EI) and Sub ordinate Function (SF) methods, the eight breeds (BHR 2, BHR 3, B.con 1, B.con 4, ATR 16, CSR50, RSJ 14 and NB_4D_2) shown above 50 EI values with SF values varied from 2.07 - 6.73 identified as superior compared to other breeds. The shortlisted breeds were utilized for further breeding programme for hybrid preparation.

***Key words*:** Spring, Autumn, Evaluation index, Subordinate function

Selection of initial parent breeding materials followed by their effective utilization in different cross combinations to create genetic variability among the breeds of the silkworm [1]. Therefore, it is of paramount importance that utmost care must be taken in verifying and analyzing the genetic worth of parents to be utilized as resource material for breeding programme [2]. Selection of appropriate breeding resource materials for any breeding programme is very essential and aims at a derivation of better assemblage of gene complex which suits to express good phenotypic values on a wide range of traits by amalgamating distinct and different gene pools. Conventional breeding methods are directed not only for the evolution of new breeds but also for the identification of the promising hybrid combinations for commercial exploitation based on the heterosis. Therefore, it's imperative to evaluate diverse genotypes/breeds and to identify the distinct and different gene pools to be utilized in breeding programme for development of robust breeds/hybrids. Hybrid vigor is an important tool in increasing cocoon production, evaluation, maintenance of inbred lines and identification of promising hybrids for commercial exploitation [3]. Based on the importance of hybrids requirement in the field, they were extensively developed and evaluated by the silkworm breeders. Some of them have survived for long time and few of them have stirred out within few years of introduction in the field. The main challenge for the breeder is to prioritize the order of important characters for improvement in the resultant population. Besides, it is more important for the breeder to determine important factors responsible for the animal to survive and reproduce to its full potential [4]. The main objective of the silkworm breeding is to synthesize new genotypes with more plasticity to different climates and to select sustainable silkworm hybrids for commercial exploitation. Scientists are making constant efforts in the synthesis of superior varieties to meet the demand of sericulture farmers and silk reelers.

In the changing scenario of the globe, for the developing countries, there is a great need to develop potential silkworm hybrids of higher quality and quantity to sustain the sericulture industry. The silk yield is contributed by more than 21 traits [5] and there exists an inter - relationship between multiple traits in silkworm. Any efforts to improve the yield requires consideration of cumulative effect of the major traits which influences the silk yield. To judge the superiority of the silkworm breed impartially, a common index method was found very much essential [6], [7]. The evaluation index method developed by [7] was found to be very useful in selecting potential parents for silkworm breeding programme.

Therefore, for success of any breeding programme, the selection of breeding resource material is of prerequisite importance. The selection of superior parents determines the degree of success of the breeding programme to a large extent. Therefore, the present study was undertaken to screen the breeds which were procured from different sources and it is highly pertinent to select and evaluate the suitable silkworm breeds before initiating any breeding programme or any hybridization under subtropical condition of Jammu.

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MATERIALS AND METHODS

A study was carried out for the selected *B. mori* breeds for their qualitative and quantitative traits for selection of breeds through evaluation methods. The breeds were received for the study from different geographical region of our country listed in (Table 1).

Table 1 Showing selected breeds procured from different places with morphological features

Breeds	Source
BHR 2 BHR 3 B.con 1 B.con 4	Central Sericultural Research and Training Institute, Berhampur, West Bengal
DUN 6 DUN 22 ATR 16 ATR 29 SH_6 NB_4D_2	Regional Sericultural Research Station, Sahaspur, Dehradun, Uttarakhand
CSR2 CSR6 CSR50 CSR51	Central Sericultural Research and Training Institute, Mysore, Karnataka
JAM 2 JAM 121 RSJ1 RSJ14	Regional Sericultural Research Station, Miran Sahib, Jammu, Jammu and Kashmir

The experiment trial was carried out during spring and autumn season (2018 and 2019) at Regional Sericultural Research Station (RSRS), Miran Sahib, Jammu. All breeds were reared in three replications by following standard rearing techniques [8]. Three hundred larvae were retained after 2nd moult in each replication. The data pertaining to the economic parameters were recorded from time to time. During the entire period of research, same microclimate and feeding conditions were ensured as per the larval stage. For rearing S - 146 mulberry variety grown in loamy soil with spacing of 3 × 3 ft plantation was used for the experiment and it was maintained in the institute. The data was collected on the following parameters for pre-cocoon viz. Fecundity, Hatchability (%), Larval period, Weight of full-grown larvae (g), ERR by Weight and Number, Pupation Rate (%), Single Cocoon Weight, Single Shell Weight and Cocoon Shell Ratio (%) etc. and post cocoon parameters viz. Average filament length and Denier were recorded.

Observations on various economic traits recorded during rearing trial were analyzed statistically by one-way ANOVA using Indo-stat package. Evaluation Indices (E.I) were also determined as per [7].

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

Where,
A = Value of a particular hybrid for a character
B = Mean value of particular trait of all the hybrids combination
C = Standard deviation of particular trait of all the hybrids combinations
10 = Standard Unit
50 = Fixed value

The index value obtained for all the traits was combined separately and the average EI value was obtained. The EI value fixed for the selection of breed is > 50 for traits. The breed which scored above the limit is considered to possess greater economic value.

RESULTS AND DISCUSSION

Silkworm breeds and hybrids play a significant role in deciding the silk output and quality. However, the problems with silkworm breeds have been many and vary in different sericultural regions of the country. India is a vast country with varying climatic conditions in different agro-climate zones. The agro climatic conditions of Jammu division of Jammu and Kashmir state are totally different from the rest of the country and require special attention for development or identification of region and season specific breeds. Accordingly, the eighteen silkworm breeds selected for the present study were reared during spring and autumn season (2018 and 2019) for identification of top-ranking breeds for the seasons. The important quantitative and qualitative traits viz. fecundity, hatching percentage, larval duration, yield per 10,000 larvae by number, yield per 10,000 larvae by weight, single cocoon weight, single shell weight, shell ratio, pupation rate and filament length were recorded.

Table 2 Showing overall average data for the breeds reared during spring and autumn (2018 & 2019)

Breeds	F (No.)	H (%)	LD (D:h)	5th LD (D:h)	LW (g.)	ERR/ 10000 Larvae		SCW (g)	SSW (g)	SR (%)	PR (%)
						By No.	By Wt. (Kg)				
BHR2	476.00 (21.84)	92.52 (74.08)	23.80	5.58	45.75	9158.00 (95.70)	15.20	1.68	0.30	17.83 (24.96)	95.92 (78.45)
BHR3	480.00 (21.93)	92.01 (73.55)	23.80	5.59	45.25	9199.75 (95.92)	15.11	1.68	0.30	17.81 (24.94)	96.75 (79.61)
B.con 1	487.00 (22.09)	92.09 (73.60)	23.80	5.58	45.75	9200.00 (95.92)	15.05	1.69	0.30	17.59 (24.78)	95.00 (77.09)
B.con 4	453.75 (21.32)	93.63 (75.42)	23.80	5.58	43.50	9266.50 (96.26)	14.48	1.67	0.29	17.75 (24.90)	96.17 (78.81)
DUN6	426.58 (21.65)	91.66 (75.20)	24.08	5.33	37.50	9583.25 (96.39)	13.38	1.46	0.30	20.95 (25.13)	92.25 (77.06)
DUN22	464.58 (21.30)	89.86 (74.73)	24.03	5.58	40.75	9433.25 (97.55)	13.28	1.53	0.30	19.86 (24.94)	93.75 (75.49)
ATR16	468.00 (20.67)	93.40 (73.29)	23.84	5.57	44.25	9291.50 (97.90)	14.71	1.60	0.29	18.05 (27.22)	95.08 (73.82)
ATR29	452.67 (21.57)	92.87 (71.31)	24.05	5.56	39.75	9516.50 (97.12)	14.29	1.51	0.27	17.79 (26.45)	93.75 (75.51)
CSR2	429.50 (20.74)	90.85 (72.10)	24.31	6.02	42.75	9408.25 (97.00)	14.10	1.58	0.32	20.34 (26.79)	89.50 (70.60)
CSR6	429.50	90.76	24.05	5.55	40.50	9508.25	12.71	1.50	0.30	19.76	93.42

	(20.74)	(72.26)				(97.51)				(26.38)	(75.20)
CSR50	453.00 (21.30)	91.77 (73.37)	24.10	5.78	40.50	9441.50 (97.17)	13.81	1.51	0.31	20.70 (27.05)	94.42 (76.44)
CSR51	396.25 (19.93)	92.51 (74.09)	24.06	5.77	39.50	9516.50 (97.55)	13.34	1.50	0.30	20.01 (26.56)	93.25 (74.91)
JAM2	411.25 (20.30)	89.36 (70.83)	23.56	5.08	36.50	9591.50 (97.94)	12.80	1.45	0.24	16.59 (24.03)	94.75 (76.76)
JAM121	422.25 (20.57)	90.97 (72.51)	23.57	5.34	40.17	9466.50 (97.30)	14.36	1.52	0.28	18.83 (25.71)	92.75 (74.36)
RSJ1	446.17 (21.14)	91.55 (73.02)	23.32	5.35	35.25	9600.00 (97.98)	12.75	1.44	0.27	18.48 (25.45)	92.75 (74.35)
RSJ14	460.67 (21.48)	93.74 (75.49)	24.07	5.60	42.25	9299.75 (96.44)	13.93	1.57	0.31	20.21 (26.70)	94.50 (76.42)
SH_6	458.00 (21.42)	93.33 (75.01)	24.08	5.59	42.58	9341.50 (96.65)	13.58	1.56	0.27	17.49 (24.71)	93.00 (74.63)
NB_4D_2	460.50 (21.48)	95.28 (77.29)	24.28	5.58	43.08	9374.75 (96.82)	14.05	1.55	0.29	18.65 (25.57)	94.25 (76.12)
CD (%)	0.27	1.37	0.003	0.002	1.11	0.74	0.25	0.01	0.01	0.31	1.54
Sem±	0.09	0.47	0.001	0.001	0.38	0.26	0.08	0.005	0.004	0.10	0.53
CV (%)	0.77	1.12	0.009	0.02	1.62	0.46	1.09	0.611	2.40	0.73	1.22

F – Fecundity; H – Hatching; LD – Larval duration; D-days; H-hours; LW- Larval weight; PR- pupation rate; ERR – Effective Rate of Rearing; SCW- Single cocoon weight; SSW- Single shell weight; SR – Shell ratio; Values in parentheses are statistically transformed

Table 3 Showing overall evaluation index for the breeds reared during spring and autumn (2018 & 2019)

Breeds	F (No.)	H (%)	LW (g.)	ERR/ 10000 Larvae		SCW (g.)	SSW (g.)	SR (%)	PR (%)	AFL (mtrs)	Avg. EI
				No.	Wt. (Kg)						
BHR 2	61.10	52.69	64.16	32.87	65.72	65.04	53.21	42.40	61.70	47.37	54.62
BHR 3	62.72	49.28	62.52	35.83	64.63	65.47	54.94	42.26	66.69	40.01	54.43
B.con 1	65.56	49.78	64.16	35.84	63.85	66.30	52.00	40.60	56.23	52.86	54.72
B.con 4	52.07	60.25	56.80	40.55	56.77	63.99	51.22	41.78	63.20	45.74	53.24
ATR 16	57.85	58.66	59.25	42.33	59.64	56.17	48.41	44.14	56.72	40.77	52.39
ATR 29	51.63	55.10	44.53	58.26	54.40	44.93	39.03	42.15	48.75	47.88	48.67
DUN 6	41.05	46.91	37.17	62.99	42.95	37.90	55.59	66.35	39.79	58.79	48.95
DUN 22	56.46	34.69	47.80	52.37	41.70	47.36	56.45	57.99	48.75	51.63	49.52
CSR 2	42.23	41.43	54.35	50.60	51.99	52.65	64.06	61.69	23.35	68.86	51.12
CSR 6	42.23	40.76	46.99	57.68	34.62	43.48	52.82	57.26	46.76	53.08	47.57
CSR 50	51.77	47.64	46.99	52.95	48.35	44.25	60.51	64.47	52.74	65.39	53.51
CSR 51	28.74	52.62	43.72	58.26	42.51	43.08	54.68	59.18	45.77	64.64	49.32
JAM 2	34.83	31.30	33.90	63.58	35.81	36.54	24.07	32.94	54.73	33.39	38.11
JAM 121	39.29	42.19	45.90	54.72	55.21	45.26	45.95	50.13	42.78	33.99	45.54
RSJ 1	48.99	46.13	29.82	64.18	35.15	35.25	36.48	47.40	42.78	43.54	42.97
RSJ 14	54.88	60.97	52.71	42.91	49.90	52.09	61.81	60.67	53.24	50.37	53.95
SH_6	53.79	58.20	53.80	45.87	45.44	50.39	39.29	39.85	44.27	49.21	48.01
NB_4D_2	54.81	71.40	55.44	48.22	51.37	49.87	49.49	48.73	51.74	52.50	53.36

F – Fecundity; H – Hatching; LW- Larval weight; PR- pupation rate; ERR – Effective Rate of Rearing; SCW- Single cocoon weight; SSW- Single shell weight; SR – Shell ratio; AFL – Average filament length; EI – Evaluation index

The investigation of the data reveals that fecundity was recorded ranged from 396.25 (CSR51) to 487.00 (B.con1) which shows statistically significant among all the breeds and hatching per cent ranged from 89.86 (DUN22) to 95.28 (NB_4D_2) and showing statistically significant among all the breeds whereas larval weight was recorded to a maximum of 45.75 g (B.con 1 & BHR 2) and minimum of 35.25 g (RSJ 1) showing significant variation among all the breeds whereas pupation rate showing statistically significant among all the breeds and recorded as highest 96.75 per cent (BHR3) and less 89.50 per cent (CSR2). With regard to yield per 10,000 larvae by number, RSJ1 was recorded highest (9600.00) and lowest in BHR2 (9158.00). Yield per 10,000 larvae by weight (Kg), ranged to the maximum of 15.20 Kg in BHR2 and minimum of 12.71 Kg in CSR6 showing significant variations among all the breeds with regard both by number and weight basis. The cocoon weight ranged from the maximum of 1.69 g (B.con1) and minimum of 1.44 g (RSJ1). The shell weight was maximum (0.32 g) in CSR2 and minimum in JAM 2 (0.24 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 DUN6 (20.95) and lowest in JAM2 (16.59) respectively (Table 2). The performance of breed mainly depends on the combined action of its hereditary potential and extent to which such potential is permitted to express in the environment [1]. One of the objectives of the breeder is to recommend stable breeds to the farmers for rearing under different environmental conditions [9].

The multiple evaluation index values obtained for each of the trait on fecundity, larval weight, yield/10000 larvae by number and weight, pupation rate, cocoon weight, shell weight, shell ratio, filament length an average value presented in (Table 3, Fig 1). The average evaluation index values ranged to the maximum of 54.72 (B.con1) followed by 54.62 (BHR2), 54.43 (BHR3), RSJ14 (53.95), CSR50 (53.51), NB_4D_2 (53.36), B.con 4 (53.24), ATR16 (52.39) and CSR 2 (51.12). Based on the evaluation index values, the breeds were ranked accordingly and B.con 1 (54.72) assigned first rank followed by BHR2 (54.62), BHR3 (54.43) and RSJ14 (53.95) whereas the breed JAM2 (38.22) was placed in the last position. Further, the cumulative values obtained for the individual trait by applying subordinate function method were ranged to the maximum of 6.73 (B.con 1) and minimum of 2.07 (Jam 2). Based on the cumulative values, the breeds were ranked accordingly (Table 4, Fig 2) and B.con 1 (6.73) followed by BHR2 (6.66), BHR 3 (6.59), RSJ 14 (6.41), CSR50 (6.34), NB_4D_2 (6.26), B.con 4 (6.24), ATR16 (6.03) and JAM 2 (2.07) occupied last rank as the method followed by [10], [11]. In silkworm large number of breeds was tested and promising ones are selected based on the economic traits [7], [6]. 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 [6].

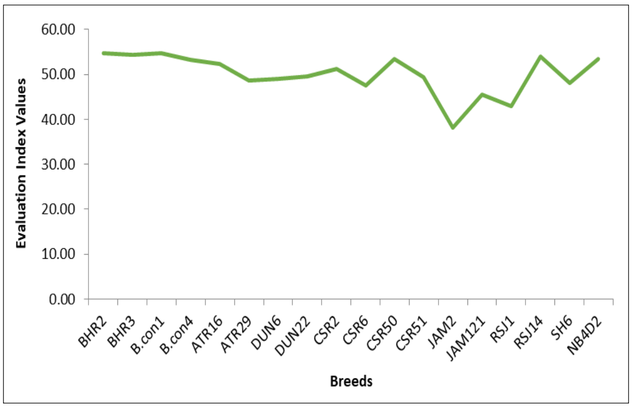

Fig 1 Showing overall evaluation index for the breeds reared during spring and autumn (2018 & 2019)

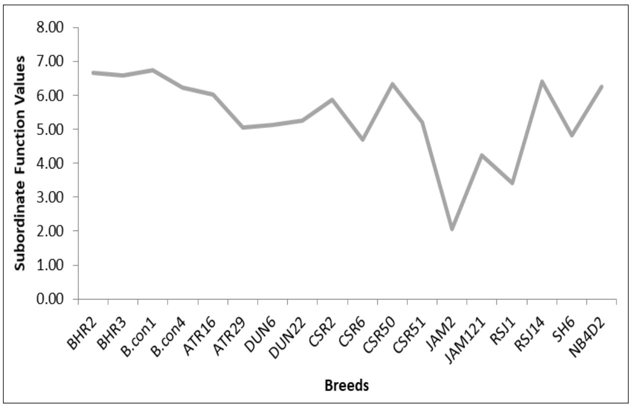

Fig 2 Showing overall subordinate function values for the breeds reared during spring and autumn (2018 & 2019)

Table 4 Subordinate function values on economically important traits for the selected breeds for the study

Breeds	F (No.)	H (%)	LW (g.)	ERR/ 10000 Larvae		SCW (g.)	SSW (g.)	SR (%)	PR (%)	AFL (mtrs)	Cum. SF Values
				By No.	By Wt. (Kg)						
BHR 2	0.88	0.53	1.00	0.00	1.00	0.96	0.73	0.28	0.89	0.39	6.66
BHR 3	0.92	0.45	0.95	0.09	0.96	0.97	0.77	0.28	1.00	0.19	6.59
B.con 1	1.00	0.46	1.00	0.10	0.94	1.00	0.70	0.23	0.76	0.55	6.73
B.con 4	0.63	0.72	0.79	0.25	0.71	0.93	0.68	0.26	0.92	0.35	6.24
ATR 16	0.79	0.68	0.86	0.30	0.80	0.67	0.61	0.34	0.77	0.21	6.03
ATR 29	0.62	0.59	0.43	0.81	0.64	0.31	0.37	0.28	0.59	0.41	5.05
DUN 6	0.33	0.39	0.21	0.96	0.27	0.09	0.79	1.00	0.38	0.72	5.14
DUN 22	0.75	0.08	0.52	0.62	0.23	0.39	0.81	0.75	0.59	0.51	5.26
CSR 2	0.37	0.25	0.71	0.57	0.56	0.56	1.00	0.86	0.00	1.00	5.88
CSR 6	0.37	0.24	0.50	0.79	0.00	0.27	0.72	0.73	0.54	0.56	4.70
CSR 50	0.63	0.41	0.50	0.64	0.44	0.29	0.91	0.94	0.68	0.90	6.34
CSR 51	0.00	0.53	0.40	0.81	0.25	0.25	0.77	0.79	0.52	0.88	5.20
JAM 2	0.17	0.00	0.12	0.98	0.04	0.04	0.00	0.00	0.72	0.00	2.07
JAM 121	0.29	0.27	0.47	0.70	0.66	0.32	0.55	0.51	0.45	0.02	4.23
RSJ 1	0.55	0.37	0.00	1.00	0.02	0.00	0.31	0.43	0.45	0.29	3.41
RSJ 14	0.71	0.74	0.67	0.32	0.49	0.54	0.94	0.83	0.69	0.48	6.41
SH_6	0.68	0.67	0.70	0.42	0.35	0.49	0.38	0.21	0.48	0.45	4.82
NB_4D_2	0.71	1.00	0.75	0.49	0.54	0.47	0.64	0.47	0.66	0.54	6.26

F - Fecundity; H - Hatching; LW- Larval weight; PR- pupation rate; ERR - Effective Rate of Rearing; SCW- Single cocoon weight; SSW- Single shell weight; SR - Shell ratio; AFL- Average filament length; Cum. SF Values- Cumulative Subordinate Function values

With both the statistical methods of average evaluation index and cumulative subordinate function values were arranged in descending order and accordingly given ranks to each breed (Table 5). Top ranked eight breeds viz. B.con1, BHR2, BHR3, RSJ14, CSR50, NB_4D_2, B.con 4, and ATR16 which stood high in both evaluation index and subordinate function methods were identified as potential breeds. The shortlisted breeds were also ranked higher than the other breeds which were used for the study viz. CSR2, DUN22, CSR51, DUN6, ATR29, SH6, CSR6, JAM121, RSJ1 and

JAM2. Evaluation of genetic resources promotes effective and higher utilization of the germplasm, particularly in breeding and crop improvement programme. Improvement of silk productivity depends on the magnitude of genetic variability and the extent to which the associated traits are heritable in silkworm. The challenges in silkworm breeding are the selection of suitable parent lines to build heterotic combinations. Genetic divergence, one of the criteria for selection of parents is considered in most of the breeding experiments as means to generate crosses which segregate in later generations into genotypes transgressing the performance of better parents [12], [13].

Table 5 Ranking of breeds in ascending order based on evaluation index (EI) and cumulative subordinate function values (Cum. SF)

Breeds	Average EI Values	Ranking	Breeds	Cum. SF Values	Ranking
B.con1	54.72	1	B.con1	6.73	1
BHR2	54.62	2	BHR2	6.66	2
BHR3	54.43	3	BHR3	6.59	3
RSJ14	53.95	4	RSJ14	6.41	4
CSR50	53.51	5	CSR50	6.34	5
NB_4D_2	53.36	6	NB_4D_2	6.26	6
B.con4	53.24	7	B.con4	6.24	7
ATR16	52.39	8	ATR16	6.03	8
CSR2	51.12	9	CSR2	5.88	9
DUN22	49.52	10	DUN22	5.26	10
CSR51	49.32	11	CSR51	5.20	11
DUN6	48.95	12	DUN6	5.14	12
ATR29	48.67	13	ATR29	5.05	13
SH_6	48.01	14	SH_6	4.82	14
CSR6	47.57	15	CSR6	4.70	15
JAM121	45.54	16	JAM121	4.23	16
RSJ1	42.97	17	RSJ1	3.41	17
JAM2	38.11	18	JAM2	2.07	18

Therefore, the objective of silkworm breeding is not only to synthesize new genotypes or hybrid combinations but also to identify sustainable silkworm hybrids for commercial exploitation by farmers. Selection of suitable parents and information on nature and magnitude of gene action of traits of economic importance determine the success of any crop [14]. Critical assessment of variability present in the breeding materials is one of the prerequisites for paving the way of combining most of the desirable traits present in different genotypes into single hybrid combination. However, the performance of parental breeds is not always be the good reflection of the combining ability and its analysis therefore helps the breeders to understand the nature of gene action to identify prospective parents/hybrids [15].

In the present study an attempt was being made to identify the superior breed through assessment on multiple traits of the studied silkworm breeds as an important task in predicting the potential breeding material. The present data was analyzed with equal weight to all the important economic traits using both multiple evaluation index [7] and subordinate function methods [16]. These methods were successfully employed by many silkworm breeders for evaluation of the silkworm hybrids and breeds [17], [18], [19], [20].

CONCLUSIONS

Among all the breeds reared in the laboratory, eight breeds viz. B.con1, BHR2, BHR3, RSJ14, CSR50, NB_4D_2, B.con 4, and ATR16 was well performed and can be utilized for further breeding programme. The findings of this study prove the superiority of the breeds with improved productivity traits than the selected other breeds. The breeds having scored above the limit are considered to possess greater economic value and shortlisted breeds can be utilized in future breeding programmes for development of season specific hybrids for subtropical climatic conditions of Jammu.

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