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Evaluation and Identification of Promising Bivoltine Breeds in the Silkworm *Bombyx mori* L.

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Under the all India programme of evaluation of mulberry and silkworm genotypes, twelve bivoltine silkworm breeds obtained from Central Silkworm Germplasm Resource Centre, Hosur (CSGRC) were evaluated at the bivoltine silkworm breeding laboratory, Central Sericultural Research & Training Institute, Mysore (CSR&TI). These breeds were tested during September-October 2003, August-September 2004 and February-March 2005. The average temperature and humidity during September-October 2003 was 26.5°C and 72.6% RH, while during August-September 2004, it was 26.5°C and 75.2% RH and during February-March 2005 it was 24°C and 48% RH respectively. The performance of the breeds in respect of 21 traits was studied and statistically analyzed using analysis of variance (Singh and Choudhary, 1985). Silkworm breeds were short-listed using multiple trait evaluation index method as suggested by Mano *et al.*, (1993). Evaluation Index values were calculated for all the 11 traits of economic importance and six breeds were short-listed based on average index value 50 and above 50. Two breed viz., BV 183 (SMGS-1) have recorded average E.I. > 50 in 10 traits (except in neatness) and ranked first and the breed BV 262 (SMGS-9) with E.I. value > 50 in nine traits except in cocoon weight and neatness ranked second, in the order of merit. These two breeds may be selected as resource material for evolving region specific silkworm breeds.

Key words: Bivoltine, Evaluation, Identification, Promising, Silkworm breeds, *Bombyx mori*

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Introduction

The climatic variation, feed quality and input status necessitated the rearing of silkworm breeds specific to the region where they are adapted. The spring season with favorable climate and good quality mulberry is conducive for rearing bivoltine silkworm breeds with high productivity merits and hence breeds with cocoon shell percentage of 24-26 and 20 to 21% raw silk recovery are recommended for rearing during spring season. High temperature, humidity and poor quality mulberry leaf are the characteristic features of summer and autumn seasons and hence breeds with high survival and shell percentage of 20-22 with low silk recovery are recommended for rearing during the unfavorable season. In sericulturally advanced countries like Japan, silkworm rearing was conducted only during spring season till 1887 and thereafter extended even to summer and autumn seasons (Yokoyama, 1973).

China has been successful in developing region and season specific silkworm breeds suitable for their prevalent climatic conditions. But in India, based on the physical parameters like the temperature, humidity and rainfall, the silkworm rearing is carried out during spring, summer, autumn and winter seasons. However, silkworm rearing is restricted only to certain seasons in some places. In the southern part of Karnataka, Tamil Nadu, Andhra Pradesh and Kerala, silkworm rearing is conducted through out the year except during April and May, where there are negligible differentiations between seasons. On the other hand, in U.P and Jammu regions, bivoltine silkworm rearing during spring and autumn seasons and polyvoltine hybrids during summer is carried out. In the hilly and

selected plain areas of West Bengal, the pure breed Nistari during summer and rainy seasons and Nistari x bivoltine and KPG x P5 during autumn and summer seasons are reared. On the contrary, in the irrigated areas of Karnataka, till 1990 the cross breeds PM × NB4D2/NB18 and from 2000 onwards PM × CSR2 is reared. In the rainfed areas of Karnataka, PM × bivoltine from August to October and in all other seasons the polyvoltine hybrid PM x C.nichi are reared. The bivoltine hybrids with high productivity merits are recommended for rearing only during favorable period from September to February.

In view of the climatic variations in India, the Central Silk Board with the co-ordination of Central Sericultural Research and Training Institute and Karnataka State Sericulture Research Development Institute took steps for the classification of each state in to different agro-climatic zones on the basis of climatic factor, soil condition, technology adoption and production constraints (Iyengar *et al.*, 1993, Iyengar, 1995). There after, the silkworm breeds are periodically evaluated at the silkworm breeding centers during different seasons. Further, the All India coordinated experiments for testing of the mulberry and silkworm breeds were started by the Central Silk Board in twenty locations with the participation of five agencies.

Keeping in view of the need for evolving season and region specific silkworm breeds, the evaluation of the bivoltine silkworm breeds obtained from Central Silkworm Germplasm Resource Centre, Hosur was taken up at different silkworm breeding centers of India in different seasons. Based on the performance the silkworm breeds are selected and recommended as resource material for evolving new silkworm breeds for that region.

Materials and Methods

Twelve bivoltine silkworm breeds namely BV6, BV13, BV24, BV44, BV50, BV84, BV95,BV183, BV187, BV197, BV222 and BV262 from Central Silkworm Germplasm Resource Centre, Hosur were selected for evaluation at the silkworm breeding laboratory, Central Sericulture Research and Training Institute, Mysore. The characteristics of the breeds are following.

All the twelve bivoltine silkworm breeds were reared in three replications of one disease free laying in each during September-October 2003, August-September 2004 and February-March 2005. The average temperature and humidity during September-October 2003 was 26.5°C and 72.6% RH, while during August-September 2004, it was 26.5°C and 75.2% RH and during February-March 2005 it was 24°C and 48% RH respectively. The standard rearing techniques as recommended by Krishnaswami (1978) were followed. The performance of the silkworm breeds in respect of all the morpho-metric traits (from the time of incubation of eggs till reeling of cocoons) was recorded. Observations with reference to rearing parameters, post – cocoon aspects and reeling aspects were recorded. Information in respect of fecundity (No.), egg hatching (%), matured larval weight (g), total larval duration (hr) and 5^{th} instar period (hr) during the larval growth were recorded. At the time of harvest of the cocoons the dead larvae were counted and recorded. After the harvest of the cocoons, the details in respect of the good cocoon number, double cocoons, flimsy, melted cocoons, uzi infested, open end cocoons were recorded. The weight of the live cocoons and double cocoons were recorded for the determination of total cocoon yield. Twenty five female and male

Table 1. Characteristics of the bivoltine silkworm breeds

SL.No	Accession Number	Breed	Larval marking	Cocoon shape	Cocoon colour
1	BBE-0006	B-36	Plain	Elongated oval with faint constriction	White
2	BBE-0013	Chung Naung	Plain	Oval	White
3	BBE-0024	Hauchi	Plain	Elongated oval with faint constriction	Golden yellow
4	BBE-0044	NB4D2	Plain	Dumbbell with constriction	White
5	BBE-0050	UKR-2	Marked	Elongated with faint constriction	White
6	BBE-0084	CA2	Plain	Oval	White
7	BBE-0183	SMGS-1	Marked	Elongated oval	White
8	BBE-0095	KA	Plain	Oval	White
9	BBE-0187	SMGS-5	Marked + plain	Elongated with faint constriction	White
10	BBE-0197	A	Marked	Elongated with faint constriction	White
11	BBE-0222	JC2M	Marked	Elongated with medium constriction	White
12	BBE-0262	SMGS-9-Anzali	Marked	Elongated oval with faint constriction	White

Table 2. Rearing performance of the silkworm breeds (average of 3 trials)

Accession No.	Hatching (%)	Fecundity (No)	Good Cocoon (No)	Double cocoon (%)	Flimsy (%)	Melt (%)	Cocoon Weight (g)	Shell wt weight (g)	Shell percentage (%)	5th instar larval period (h)	Total larval period (h)	Pupation rate (%)	Cocoon yield by wt. (kg)
BV6	94.9	719	76	2.0	3.2	2.4	1.653	0.284	17.2	143	545	77.0 (61.3)	13.4
BV13	96.5	611	84	1.4	2.0	6.8	1.520	0.255	16.8	133	535	81.6 (64.6)	13.5
BV24	93.6	622	84	1.8	3.3	2.8	1.587	0.263	16.6	133	537	89.4 (71.0)	14.8
BV44	93.6	618	78	2.9	3.5	5.7	1.594	0.269	16.9	140	548	83.0 (65.6)	13.3
BV50	94.6	580	83	4.1	1.0	3.7	1.730	0.324	18.7	136	532	89.8 (71.3)	16.7
BV84	92.1	600	76	2.7	3.5	5.1	1.769	0.321	18.1	142	538	77.5 (61.6)	14.8
BV95	87.7	691	81	2.2	3.2	5.1	1.686	0.285	16.9	132	531	84.5 (66.8)	15.7
BV183	97.2	669	91	1.0	1.4	2.7	1.840	0.354	19.2	137	539	93.1 (74.7)	17.9
BV187	95.8	621	82	2.0	2.1	3.6	1.845	0.370	20.1	143	545	86.3 (68.2)	16.4
BV197	97.1	684	79	0.6	2.8	2.4	1.755	0.360	20.5	132	531	75.5 (60.3)	13.5
BV222	92.8	572	85	1.6	3.7	4.3	1.642	0.324	19.7	132	531	86.5 (68.4)	14.8
BV262	95.1	633	88	2.7	1.4	4.3	1.568	0.327	20.9	144	540	89.0 (70.6)	14.4
CD at 5%	3.9	--	--	--	1.6	--	0.143	0.036	1.1	--	--	--	--
CV %	2.46	12.02	10.07	3.34	3.78	9.29	5.01	6.74	3.65	10.61	3.61	8.57	11.73

(Values in parentheses indicate angular transformed)

cocoons were randomly selected from each replication for the determination of single cocoon weight, shell weight and cocoon shell percentage. Sixty cocoons were selected from each replication and reeling was carried out in multi-end reeling machine and the details in respect of reelability percentage, total filament length, non-breakable filament length, renditta, raw silk percentage, raw silk recovery, denier and neatness were studied.

Results

Rearing results

The data of three trials for 21 traits were statistically evaluated using analysis of variance (ANOVA).and presented in (Table 2 and 3). Higher values for various traits in different breeds were observed. Significant results were observed for the trait hatching percentage but no significant results for the traits viz., fecundity, total larval period & 5th instar duration, pupation rate and cocoon yield were observed. The results are as following:

Fecundity (No.): The number of eggs ranged from 572 in BV 222 (JC2 M) to 719 in BV 6 (B36).

Hatching %: It ranged from 87.7 in BV 95 (KA) to 97.2 in BV 183 (SMGS-I).

Total larval duration and 5th instar period (h): The total larval period and 5th instar duration ranged from 531 hr and 132 hr in BV 95(KA), BV 197(A) & BV 222(JC2M) to 548 hr in BV 44(NB4D2) and 144 hr in BV 262(SMGS-9).

Cocoon assessment results

Good cocoon %: No significant differences for the trait good cocoon percentage among the breeds were observed.

Table 3. Reeling performance of the silkworm breeds (average of 3 trials)

Accession No.	Reel-ability	Filament length	Non-breakable Filament length	Renditta	Rawsilk	Raw silk recovery	Denier	Neatness
	(%)	(m)	(m)		(%)	(%)	(d)	(p)
BV6	85.0 (67.2)	922	784	6.5	15.4	81.8	2.6	93.0
BV13	85.0 (67.2)	822	698	6.9	14.5	84.9	2.2	90.0
BV24	86.0 (68.0)	710	611	7.2	14.0	84.7	2.8	90.0
BV44	86.0 (68.0)	648	557	7.4	13.5	82.5	2.8	92.0
BV50	82.0 (64.9)	960	787	7.3	13.7	75.3	2.1	91.0
BV84	85.0 (67.2)	811	689	6.9	14.5	84.2	2.6	92.0
BV95	85.5 (67.6)	934	798	7.3	13.8	82.2	2.3	91.0
BV183	86.0 (68.0)	1094	941	6.7	15.0	80.6	2.5	88.0
BV187	87.0 (68.8)	1000	870	7.4	13.6	69.9	2.4	92.0
BV197	85.0 (67.2)	793	674	6.4	15.6	76.3	3.0	90.0
BV222	86.0 (68.0)	930	804	6.4	15.6	79.0	2.5	92.0
BV262	86.0 (68.0)	1157	995	6.0	16.6	80.7	2.4	90.0
CD at 5%	(0.3)	32	26	0.2	0.4	2.3	0.1	--
CV %	0.29	2.07	2.00	1.66	1.64	1.68	1.62	1.10

(Values in parentheses indicate angular transformed)

However, the good cocoon number ranged from 75.5 in BV 84 (CA2) to 91.4 in BV 183 (SMGS-1).

Double cocoon %: No significant differences among the breeds were observed. Lower values of 0.6 in BV 197 (A) and higher values of 4.1 in BV50 (UKRA-2) were observed.

Flimsy cocoon %: Significant differences ($p<0.05$) among the breeds for this trait were observed. The flimsy cocoon percentage was low in BV 50 (UKR-2) 1.0 and high in BV 222 (JC2M) 3.7.

Melting cocoon %: Melting cocoon percentage was low in the breeds BV 197 (A) and BV6 (B-36) 2.4 and high in BV 13 (Chung Naung) 6.8.

Pupation %: It ranged from 75.5 in the breed BV 197 (A) to 93.1% in BV 183 (SMGS-1).

Cocoon yield by weight (Kg): Cocoon yield was high in BV183 (SMGS-1) 17.9 kg and low in BV44 (NB4D2) 13.3 kg.

Significant results for the traits namely cocoon weight, shell weight and shell percentage was observed.

Cocoon weight (g): It ranged from 1.520 g in BV 13 (Chung Naung) to 1.845 g in BV 187 (SMGS-5).

Cocoon shell weight (g): It ranged from 0.255 g in BV 13 (Chung Naung) to 0.370 g in BV 187 (SMGS-5).

Cocoon shell percentage (%): It ranged from 16.6% in BV 24 (Hauchi) to 20.9% in BV 262 (SMGS-9).

Post cocoon results: Significant results for the traits namely reelability %, filament length, non-breakable filament length, renditta, raw silk % and denier were observed. No significant results for the trait filament neatness were also observed.

Reelability %: It ranged from 82.0 in BV 50 (UKR-2) to 87.0% in BV 187 (SMGS-5).

Filament length (m): Cocoon filament length was longer in the breed BV 262 (SMGS-9) 1157 m and filament length was shorter in BV44 (NB4D2) 648 m.

NBFL (m): It ranged from 557 m in BV44 (NB4D2) to 995 m in BV 262 (SMGS-9).

Renditta: It ranged from 6.0 in BV 262 (SMGS-9) to 7.4 in BV187 (SMGS-5) and BV44 (NB4D2) respectively.

Raw silk %: Significant differences ($p<0.05$) among the breeds were observed. It ranged from 13.5% in BV44 (NB4D2) to 16.6% in BV262 (SMGS-9).

Raw silk recovery %: Significant differences ($p<0.05$) for this trait among the breeds were observed. Higher values in the breed BV 13 (Chung Naung) (84.9%) and Lower value in the breed BV50 (UKR-2) 75.3% were observed.

Denier: Significant differences ($p<0.05$) for the trait among the breeds were observed. It ranged from 2.1 in BV50 (UKR-2) to 3.0 in the breed BV 197 (A).

Filament neatness points: No significant differences ($p<0.05$) for this trait among the breeds were observed. Higher values in the breed BV 6 (B 36) 93.0p and lower values in BV 183 (SMGS-1)90.0p were observed.

Further multiple trait evaluation index method as suggested by Mano *et al.*, (1993) was employed for short-listing and selection of breeds with higher Evaluation Index

(E.I.) values in most of the economic traits.
An Evaluation Index (E.I.) was calculated for each character using the formula:

$$E.I = A - B/C \times 10 + 50$$

where A = Value of a particular breed
B = Mean value of all the breeds
C = Standard deviation of all the breeds
10 = Standard unit
50 = Fixed value.

Multiple trait or Evaluation Index (E.I.) is the multiple performance of a population for short-listing of breeds by taking in to consideration of all the economic traits. Based on the performance of the 12 breeds, individual indices were calculated for each of the eleven traits. Evaluation index values were calculated for each breed in all the eleven characters following the above method (Table 4). The indices obtained from all the characters in each breed were combined and the average E. I value was calculated. The criteria for the selection of the breed were based on the average E. I value 50 or > 50. The breeds which scored above the limit were considered to possess greater economic value. In six breeds the average E.I. values ranged from 50 to 58 (Figure 1). However, the individual index value was more than 50 for all the 10 traits except in neatness in the breed BV183 (SMGS-1). In this breed the average index value was 58. Similarly the individual index value was >50 in nine traits except in cocoon weight and neatness in the breed BV 202-SMGS-9 and the average index value was 56.

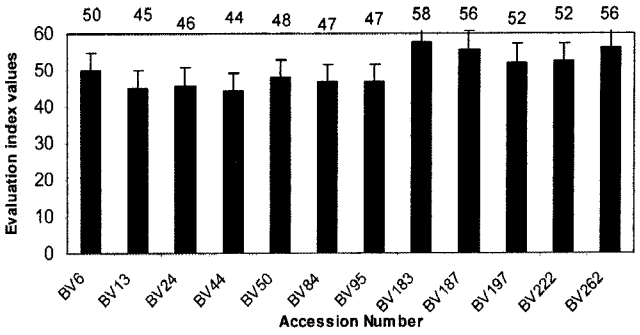

Fig. 1. Average evaluation index values in breeds.

Discussion

In the present study the mulberry bivoltine silkworm breeds obtained from CSGRC, Hosur were evaluated under the programme of all India co-ordinated experiments for evaluation of mulberry genotypes and silkworm breeds.In the current study all the silkworm breeds were tested three times at the bivoltine breeding laboratory, CSR&TI, Mysore under different environmental conditions. But variations in different quantitative traits among the breeds were observed. The variation in different characters may be due to the racial differences among the breeds. The racial differences in various biological characters are due to the adaptation in those places over long generation (Murakami, 1994). The genetic variation observed in different breeds for various traits forms a genetic resource for evolving new breeds. This observation is in conformity with the works of Frankel and Brown, (1983).In the present study the silkworm breeds

Table 4. Evaluation index values of the silkworm breeds

Accession No.	Hatching	Fecundity	Good cocoon	Cocoon weight	Shell Weight	Shell percentage	Pupation rate	Reel-ability	Filament length	Raw silk	Neatness	Average evaluation index
BV6	52	68	38	47	43	42	37	47	52	58	65	50
BV13	59	45	54	35	36	39	45	47	45	48	43	45
BV24	48	47	54	41	38	38	59	55	37	43	43	46
BV44	48	46	41	42	39	40	47	55	33	38	58	44
BV50	51	38	51	54	53	52	60	23	54	40	51	48
BV84	42	42	36	58	52	48	38	47	44	48	58	47
BV95	25	62	47	50	43	40	50	51	52	41	51	47
BV183	61	57	70	65	61	55	65	55	63	54	29	58
BV187	56	47	49	65	65	60	53	63	57	39	58	56
BV197	61	61	43	57	62	63	34	47	43	60	43	52
BV222	44	36	55	46	53	58	54	59	52	60	58	52
BV262	53	50	63	39	54	65	58	55	67	70	43	56

evaluated in different seasons with different temperature and humidity conditions showed variation in the different economic traits may be due to the temperature and genetic potentiality of the breeds. This observation corroborates the earlier work of Kobayashi *et al.*, (1986) where they have reported that environment is dynamic which brings about profound changes in the physical and biotic factors governing the expression of commercial characters in the organism. It is also in concurrence to the reports of Falconer (1990) where it was stated that the performance of the insect improved by selection in the environment where they are subsequently exploited. In this study all the breeds were studied in respect of 21 characters, but while short-listing, eleven traits of economic importance were considered. It has been established that during the breeding of silkworm, the selection pressure applied for one character results in correlated changes in other quantitative traits of economic importance (Kobari and fujimoto, 1966). Keeping in view of this, due importance was given to all the characters of economic importance while short-listing of the breeds. Multiple trait evaluation index method as suggested by Mano *et al.*, (1993) was employed for short-listing of the breeds by taking in to consideration of all the traits of economic importance. These results are in concurrence with the works of Singh and Subbha Rao, 1993, Vidyunmala *et al.*, (1998), Kumarasan *et al.*, 2000 Ramesh Babu *et al.*, 2002, Mal Reddy *et al.*, (2002), Kamal Jaiswal and Rachna Goel 2003, Chandrashekharaiah, (2003) and Rao *et al.*, (2004).

However, in the present study, there was not even one breed with average index value more than 50 in all the 11 traits. The breed, BV 183 (SMGS-1) have recorded average E.I. >50 in 10 traits (except in neatness) and ranked first and the breed BV 262 (SMGS-9) with E.I. value >50 in nine traits except in cocoon weight and neatness ranked second, in the order of merit. These two breeds may be selected as resource material for the development of season specific breeds.

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