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Selection of Potential Parental Lines From Multivoltine Germplasm Stocks of *Bombyx mori* L.

N. Balachandran* and C.K. Kamble
Central Sericultural Germplasm Resources Centre,
Thally Road, Hosur - 635 109, Tamil Nadu, India

Seventy three multivoltine mulberry silkworm genetic resources, that are diverse in nature with wide variability among the economic traits and morphologically unique were evaluated using multiple traits evaluation index and mano evaluation index. Potential accessions were identified from among the germplasm stocks conserved. Accession number BMI-043 was identified for nine specialized characters and accession number BMI-074 for eight characters and BMI-007 for six characters followed by BMI-061, BMI-001and BMI-066 for five specialized characters. Accession number BMI-043 was the top performer under mano's evaluation index. The silkworm genetic wealth was also compare with that of the ruling popular multivoltine parental races like Pure Mysore and Nistari with many promising accessions, that can be included in the breeding programmes.

Key words: Multivoltine, *Bombyx mori*, Germplasm.

Sericulture in India is mainly dependent on multivoltine silkworm breeds,that possess poor silk productivity and poor silk quality (Datta, 1984, Chatterjee and Datta, 1992). Despite poor in silk productivity and fibre quality, multivoltine races are highly adaptive and their genetic constitution permits acclimatization to specific regions and seasons (Venugopalapillai and Krishnaswami, 1987). Out of the 16.36 MT of mulberry raw silk produced 91.44 % (14.96 M.T) was contributed by multivoltine crossbreed silk (Anon., 2011). There is a need for evolving genetically hardy and sturdy silkworm breeds with superior fibre quality possessing international grade silk from the multivoltine cross breeds itself. In this context there is continuous need for evolving multivoltine parental breeds with superior quality fibers and international gradable silk characters.This is possible only when there is an assemblage of multivoltine germplasm with a vast diversity in genetic base and geographically isolated races.Further, some of the genetic characters are closely linked and hence even if the breeder aims at improving one/more-desired character, some other desired character gets altered (Dalton, 1987; Falconer, 1989; Anon., 1997). Varied silkworm germplasm stocks contribute immensely to the development of viable and hardy silkworm breeds for commercial exploitation (Nirmal Kumar and Sreerama Reddy, 1994). Evaluation of genetic resources is the most important aspect of germplasm management, which decides the use of genotypes in various programmes of race improvement. The stock and race differences in various biological characters are the result of adaptation during long generation (Murakami, 1994). The germplasm stocks could be utilized for improvement of local breeds or as a parent material, whereas the international needs focus towards germplasm systems that emphasize the use and employment of materials rather than more acquisition and storage (Ramesh Babu *et al.,* 2001).

Central Sericultural Germplasm Resources Centre,(CSGRC) Hosur is maintaining 73 multi voltine silkworm genetic resources, that are diverse in nature with wide variability among the economic traits and morphologically unique (Thangavelu *et al*., 1997; 2000; Kamble *et al*., 2009). These silkworm genetic resources are conserved following internationally approved conservation protocols and completed 80 generations so far. These multivoltine gene pool available with CSGRC, Hosur is an ideal resource base for evolving and developing superior hardy multivoltine parental breeds with good combining ability towards achieving the self sufficiency in the raw silk production of our country. With this intention the data recorded over generations in different seasons were evaluated using multiple traits evaluation index and potential accessions were identified from among the germplasm stocks conserved.

Materials and Methods

Seventy-three multivoltine accessions conserved at CSGRC, Hosur were utilized for the study. Multivoltine accessions are being reared five times in a year and the average data of five crops from 2010 to 2011 were analysed Disease free layings (DFLs) of these accessions were preserved in cold storage following 35 days preservation schedule and were brushed as composite

*Corresponding author email: balucsgrc@yahoo.co.in

population to avoid inbreeding depression as well as genetic erosion and to maintain the gene pool as far as possible. 40 disease free layings were chosen at random in each accession and divided into two batches of 20 dfls each. The composite layings were prepared at head pigmentation with approximately 50 eggs from each laying and wrapped in white fine tissue paper after drying. Thus each composite laying consisted of about 1000 individual eggs pooled from 20 dfls. Three replications were maintained for data collection and analysis of economically important quantitative and qualitative characters. Rearing was conducted by following standard rearing procedures (Krishna swami, 1978). These genetic resources were evaluated for 22 growth and reproductive parameters.

For analysis, the data generated on the following important traits were taken into consideration viz; fecundity (No.), weight of 10 larvae (g.), larval duration (hrs.), cocoon yield/10000 larvae by no, cocoon yield/10,000 larvae by wt. (Kg), pupation rate (%), shell ratio (%) and cocoon yield /100 dfls (Kg.).

The data on these parameters were documented for two years from 2010-2011 and analyzed based on querying from the database Silkworm Germplasm Information System (SGIS) of CSGRC, Hosur. The query on special characters was made in comparison with the two control accessions, Pure Mysore and Nistari.

In order to judge the superiority of silkworm accessions impartially, a common Evaluation Index (EI) (Mano, *et al.*, 1993) was utilized. The EI is an index of multiple traits or as a performance index, which is a single valued measure of the multiple trait performance of a population. EI was obtained as follows:

$$E.I. = \frac{A - B}{C} \times 10 + 50$$

Where A = mean of the particular trait

B = overall mean of the particular trait

C = standard deviation

10= fixed value

50 = constant

Table 1. Variability in economic traits of the multivoltine silkworm genetic resources conserved at CSGRC, Hosur

Trait	Min	Max	Mean	SD	SE	CV%
Fecundity (No.)	339	485	413	32.48	3.83	7.86
Hatching (%)	89.1	95.1	92.9	1.17	0.14	1.25
Weight of 10 larvae (g.)	19.3	29.5	23.7	2.06	0.24	8.70
Total Larval Duration (h.)	467	626	515	21.37	2.52	4.15
Fifth age larval duration (h.)	104	179	122	13.78	1.62	11.25
ERR (No.)	9491	9786	9708	60.32	7.11	0.62
ERR (g.)	9.1	12.9	10.7	0.72	0.09	6.79
Pupation Rate (%)	87.6	94.1	92.0	1.37	0.16	1.48
Single Cocoon Weight (g.)	0.95	1.50	1.11	0.09	0.01	7.98
Single Shell Weight (g.)	0.12	0.22	0.15	0.02	0.00	14.31
Shell Ratio (%)	11.8	20.7	14.2	1.54	0.18	10.87
Cocoon Yield/100dfls (Kg.)	36.4	51.6	42.6	2.91	0.34	6.84

*Err - Effective Rate of Reasoning

Results and Discussion

Variability studies on the important economic traits of the multivoltine silkworm germplasm conserved at CSGRC, Hosur showed very high degree of variability among the 73 accessions conserved (Table 1). Higher coefficient of variation was observed in single shell weight (14.31%) followed by fifth age larval duration (11.25 %) and shell ratio (10.87%) whereas the coefficient of variation was less in hatching percentage (1.25), ERR by number (0.62%) and pupation rate (1.48%).

The ten top ranking multivoltine accessions for important 12 economic traits among germplasm accessions were identified and presented in Table 2 alongwith their range of values. Accession BMI-024 was the top performing accession for both fecundity and hatching percentage. Similarly BMI-074 was the top ranking accession for 10 larval weight and single shell weight. For the effective rate of rearing (ERR) by weight and for cocoon yield/ 100 dfls accession BMI-066 was the best performing accession. Further for total larval duration accession BMI-062, for fifth age larval duration accession BMI-004, for Effective Rate of Rearing by number accession BMI-031, for pupation rate accession BMI-040, for single cocoon weight accession BMI-
7 and for shell ratio accession BMI-001 were identified.

Multiple traits analysis of the 73 multivoltine silkworm germplasm accessions indicated the better performing accessions alongwith the number of traits qualified (Table 3). Accession number BMI-043 was identified as best for nine economic characters and accession number BMI-074 for eight characters and BMI-007 for six characters followed by accession numbers BMI-061, BMI-001and BMI-066 for five economic traits each. The accession numbers BMI-065, BMI-073, BMI-062, BMI-027, BME-005 and BMI-023 were found better performing for four economic traits.

The accessions were ranked based on the cumulative evaluation index (CEI) values (Table-4) and based on the number of parameters qualified (Table 5). Accessions BMI-074, BMI-001, BMI-007, BMI-065, BMI-067, BMI-066, BMI-043, BMI-027, BMI-073 and BMI-023 were better performing. Similarly top ten accessions based on the number of qualifying parameters revealed BMI-043, BME-048, BMI-007, BMI-008, BMI-065, BMI-067, BMI-074, BMI-001, BMI-027 and BMI-073 performing better. These better performing accessions were the same in both the procedures except BMI-066 and BMI-023, which figure in CEI whereas, accessions BME-048 and BMI-008 were identified based on number of parameters qualified. The accession BMI-074 was the top performing accession based on cumulative evaluation index (66.8) with nine qualifying traits whereas BMI-043 ranked first based on the number of parameters (12) with Cumulative Evaluation Index (CEI) value of 59.6.

The evaluation data of the 73 multivoltine accessions conserved were compared with that of the ruling popular multivoltine breeds, Pure Mysore and Nistari for the individual economic traits (Table 6).

Table 2. Top ranking accessions for individual traits and range values

Traits	Range	Accession No.				
Fecundity (No.)	485 - 449	BMI-0024, BME-0012,	BMI-0074, BMI-0023,	BMI-0065, BMI-0019,	BMI-0059, BMI-0043,	BMI-0071, BMI-0055
Hatching (%)	95.15 - 94.13	BMI-0024, BMI-0025,	BMI-0001, BMI-0018,	BME-0052, BMI-0071,	BMI-0074, BME-0012,	BME-0015, BMI-0037
Weight of 10 larvae (g.)	29.51 - 25.87	BMI-0074, BMI-0007,	BMI-0066, BMI-0043,	BME-0048, BMI-0038,	BMI-0061, BMI-0025,	BMI-0065, BMI-0073
Total larval duration (h.)	467 - 506	BMI-0062, BMI-0063,	BMI-0061, BME-0047,	BMI-0064, BMI-0046,	BMI-0004, BMI-0006,	BME-0005, BME-0050
Fifth age larval duration (h.)	104 - 112	BMI-0004, BMI-0006,	BME-0005, BMI-0064,	BME-0013, BMI-0046,	BMI-0063, BMI-0019,	BME-0047, BMI-0011
ERR (No.)	9786 - 9764	BMI-0031, BME-0012,	BMI-0032, BMI-0034,	BMI-0010, BMI-0043,	BMI-0037, BME-0005,	BMI-0053, BMI-0036
ERR (g.)	12.89 - 11.29	BMI-0066, BMI-0062,	BMI-0027, BMI-0001,	BMI-0007, BME-0052,	BMI-0074, BMI-0008,	BMI-0043, BMI-0061
Pupation Rate (%)	94.05 - 93.43	BMI-0040, BMI-0071,	BME-0005, BME-0047,	BMI-0070, BMI-0036,	BMI-0031, BMI-0043,	BMI-0010, BMI-0019
Single Cocoon Weight (g.)	1.50 -1 .19	BMI-0007, BMI-0073,	BMI-0066, BMI-0023,	BMI-0074, BMI-0043,	BMI-0027, BMI-0062,	BMI-0061, BMI-0072
Single Shell Weight (g.)	0.219 - 0.18	BMI-0074, BMI-0073,	BMI-0023, BMI-0065,	BMI-0066, BMI-0027,	BMI-0007, BMI-0043,	BMI-0001, BMI-0014
Shell Ratio (%)	20.70 - 15.42	BMI-0001, BMI-0072,	BMI-0065, BMI-0007,	BMI-0023, BMI-0014,	BMI-0074, BMI-0043,	BMI-0073, BMI-0069
Cocoon Yield/100dfls (Kg.)	51.56 - 45.18	BMI-0066, BMI-0062,	BMI-0027, BMI-0001,	BMI-0007, BME-0052,	BMI-0074, BMI-0008,	BMI-0043, BMI-0061

Table 3. Ranking of germplasm accessions based on Multiple traits

Accession no.	No. of Traits qualified	Trait number* and values
BMI-0043	9	1(451), 3(26.47), 6(9765), 7(12.04), 8(93.60), 9(1.19), 10(0.18), 11(15.45), 12(48.16)
BMI-0074	8	1(485), 2(94.59), 3(29.51), 7(12.1), 9(1.31), 10(0.22), 11(16.93), 12(48.37)
BMI-0007	6	3(26.75), 7(12.31), 9(1.49), 10(0.20), 11(16.28), 12(49.24)
BMI-0061	5	3(27.22), 4(47), 7(11.29), 9(1.24), 12(45.18)
BMI-0001	5	2(94.99), 7(11.62), 10(0.2), 11(20.69), 12(46.45)
BMI-0066	5	3(27.86), 7(12.89), 9(1.35), 10(0.21), 12(51.56)
BMI-0065	4	1(462), 3(26.77), 10(0.19), 11(20.23)
BMI-0073	4	3(25.87), 9(1.20), 10(0.19), 11(16.68)
BMI-0062	4	4(467), 7(11.64), 9(1.19), 12(46.6)
BMI-0027	4	7(12.39), 9(1.24), 10(0.19), 12(49.54)
BME-0005	4	4(499), 5(104.2), 6(9764), 8(93.96)
BMI-0023	4	1(456), 9(1.19), 10(0.22), 11(17.79)

**1-Fecundity (No.), 2- Hatching (%) 3- Weight of 10 larvae (g.), 4 - Total Larval Duration (h.),5 - Fifth age larval duration (h.) 6 - ERR By No. (No.), 7 - ERR By Wt. (Kg.),8 - Pupation Rate (%),9 - Single Cocoon Weight (g.),10 - Single Shell Weight (g.), 11 -Shell Ratio(%),12- CocoonYield/100dfls(Kg.).*

Higher fecundity (> 441 eggs/dfls) was recorded in 20 potential accessions, which was 45 eggs more than the average fecundity of Pure Mysore and 95 eggs more than that of Nistari in 55 accessions. In the case of 10 larval weight, more than 21.8 g (Nistari) was recorded in 58 accessions and 62 accessions were better than Pure Mysore (21.38 g.) with a maximum of 29.51 g in accession BMI-074, which was about 8 g higher than Pure Mysore and Nistari. Shorter total larval duration of 20 - 21 days was observed in 25 accessions when compared with Nistari (21 days) and as much as 71 accessions had shorter larval duration when compared to that of Pure Mysore (26 days). In the case of fifth age larval duration, Pure Mysore had the longest time of seven days and Nistari with five days, which showed 71 accessions completing fifth age earlier than Pure Mysore and 16 accessions than that of Nistari.

Table 4. Ranking of accessions based on Mano's Cumulative Evaluation Index values.

Accession No.	Fec.	Hat.	LWt.	TL D	VLD	ERR No.	ERR (By Wt.)	PR	SC Wt	SS Wt.	SR	Cocoon Yield	CEI	No. of Parameters
BMI-0074	71.9	64.1	78.2	52.3	78	45.7	70	52.1	72.3	79.3	67.7	69.9	66.8	9
BMI-0001	58.7	67.5	38.8	101.1	86.8	49.4	63.3	50.4	51.9	70.7	92.1	63.3	66.2	8
BMI-0007	58.8	57.7	64.8	48.8	46.6	46.1	72.8	39.1	94	71.6	63.5	72.9	61.4	10
BMI-0065	64.9	55.8	64.9	51.8	55.6	54.5	58.3	51.2	57	67	89	58.4	60.7	10
BMI-0067	60.2	56.4	36.2	101.7	90.7	51.9	57.3	58.2	52.7	51.6	50.8	57.4	60.4	9
BMI-0066	48.5	50.4	70.2	51.9	52.3	37.2	81	37.4	76.9	72.9	57.2	80.8	59.7	7
BMI-0043	61.6	57.4	63.4	47	45.6	59.5	69.2	61.4	59.6	63.4	58.1	69.2	59.6	12
BMI-0027	46.6	51.1	52.4	58.6	63.3	53.4	74.1	43.6	64.9	64.8	56.5	73.9	58.6	8
BMI-0073	40.5	46.9	60.6	52.2	61.5	50.6	58.7	51.8	60.4	70.2	66.1	58.7	56.5	8
BMI-0023	63.3	41.3	44	51.6	49.3	46.9	56.9	49.5	60.2	78.8	73.2	56.9	56	7

Fec.-Fecundity (No.),Hat.- Hatching (%)LWt.- Weight of 10 larvae (g.),TLD- Total Larval Duration (h.),VLD- Fifth age larval duration (h.)ERR No. - ERR By No. (No.), ERRwt..- ERR By Wt. (Kg.),PR- Pupation Rate (%),SCwt.- Single Cocoon Weight (g.),SSWt.- Single Shell Weight (g.),SR-Shell Ratio(%), Cocoon Yield- Cocoon Yield/100dfls (Kg.),CEI- Cumulative Evaluation Index

Higher cocoon yield per 10000 larvae reared by numbers was recorded in 45 accessions (9786 - 9706) while it was 9704 in Pure Mysore and in 22 accessions when compared with Nistari (9743). Cocoon yield per 10000 larvae by weight was in the high performing accessions ranged between 12.89 - 11.63 Kg, which is higher than Pure Mysore (11.62 Kg) in six accessions and 58 accessions were ahead of Nistari (10.1 Kg). The single cocoon weight of 1.126 g observed in Pure Mysore was lesser than 27 accessions and it was 1.006 g in the case of Nistari which is lower than the values of 66 accessions. Four accessions performed better than Pure Mysore (0.2 g) and 67 accessions better than Nistari (0.13 g) for single shell weight. Higher shell ratio was observed in two accessions than Pure Mysore (17.76 %) and 61 accessions than Nistari (13.09 %). The cocoon yield/100 dfls of 46 - 51 kg was observed in six accessions than Pure Mysore (46.5 Kg) and 56 accessions were better than Nistari (40.5 Kg). In 41 accessions the pupation rate was higher than Pure Mysore (92.08 %) and seventeen accessions performed better than Nistari (93.09 %).

Table 5. Ranking of accessions based on number of parameters qualified.

Accession No.	Fec.	Hat.	LWt.	TL D	VLD	ERR No.	ERR (By Wt.)	PR	SC Wt	SS Wt.	SR	Cocoon Yield	CEI	No. of Parameters
BMI-0043	61.6	57.4	63.4	47	45.6	59.5	69.2	61.4	59.6	63.4	58.1	69.2	59.6	12
BME-0048	42.7	39.5	69	46.9	45.3	53.1	55.5	50.4	56.7	59.3	56.3	55.5	52.5	10
BMI-0007	58.8	57.7	64.8	48.8	46.6	46.1	72.8	39.1	94	71.6	63.5	72.9	61.4	10
BMI-0008	52.5	53.1	56.1	48.7	46.5	54.2	61.2	49.6	54.3	50.3	46.5	61.3	52.9	10
BMI-0065	64.9	55.8	64.9	51.8	55.6	54.5	58.3	51.2	57	67	89	58.4	60.7	10
BMI-0067	60.2	56.4	36.2	101.7	90.7	51.9	57.3	58.2	52.7	51.6	50.8	57.4	60.4	9
BMI-0074	71.9	64.1	78.2	52.3	78	45.7	70	52.1	72.3	79.3	67.7	69.9	66.8	9
BMI-0001	58.7	67.5	38.8	101.1	86.8	49.4	63.3	50.4	51.9	70.7	92.1	63.3	66.2	8
BMI-0027	46.6	51.1	52.4	58.6	63.3	53.4	74.1	43.6	64.9	64.8	56.5	73.9	58.6	8
BMI-0073	40.5	46.9	60.6	52.2	61.5	50.6	58.7	51.8	60.4	70.2	66.1	58.7	56.5	8

Fec.-Fecundity (No.),Hat.- Hatching (%)LWt.- Weight of 10 larvae (g.),TLD- Total Larval Duration (h.),VLD- Fifth age larval duration (h.)ERR No. - ERR By No. (No.), ERRwt..- ERR By Wt. (Kg.),PR- Pupation Rate (%),SCwt.- Single Cocoon Weight (g.),SSWt.- Single Shell Weight (g.),SR-Shell Ratio(%), Cocoon Yield- Cocoon Yield/100dfls (Kg.),CEI- Cumulative Evaluation Index

During last four decades, several multivoltine crossbreeds were evolved (Datta, 1984; Govindan *et al.,* 1996; Thangavelu, 1997). Heterosis breeding in silkworm has substantially contributed to the increase in cocoon production and in improving the quality of raw silk (Govindan *et al.,* 1996). The silkworm germplasm available at CSGRC, Hosur consists predominantly of evolved breeds in addition to some of the old races. This study throws light on the availability of some of the potential multivoltine silkworm accessions, which were superior to the ruling multivoltine silkworm pure breeds. Many of

Table 6. Comparative performance of multivoltine accessions with ruling popular races

Trait	Range values of high performing accessions	Pure Mysore (PM)		Nistari	
		Values	No. of accessions ≤ to PM	Values	No. of accessions ≤ to Nistari
Fecundity (No.)	485 - 441	441	20	389	55
Hatching (%)	95.15 - 95.15	94.98	1	90.69	69
Weight of 10 larvae (g.)	29.51 - 21.41	21.38	62	21.86	58
Total Larval Duration (h.)	467 - 533	624	71	509	25
Fifth age larval duration (h.)	104 - 161	173	71	114	16
ERR (By No). (No.)	9786 - 9707	9704	45	9743	22
ERR (By Wt.) (g.)	12.89 - 11.65	11.62	6	10.1	58
Pupation Rate (%)	94.05 - 92.09	92.08	41	93.09	17
Single Cocoon Weight (g.)	1.49 - 1.13	1.126	27	1.006	66
Single Shell Weight (g.)	0.219 - 0.202	0.2	4	0.13	67
Shell Ratio (%)	20.23 - 17.79	17.76	2	13.09	61
Cocoon Yield/100dfls (Kg.)	51.56 - 46.6	46.45	6	40.46	56

the characterization parameters based on morphological traits also showed very high degree of variability among the 73 multivoltine accessions studied. It is very clear that these races when used in combination with the bivoltine counter parts may contribute significantly to the heterobeltiosis in hybrid seed production programmes either by contributing to the development of parental lines, as pure breeds, or in development of the region/ season specific parental breeds.

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