A NEW COMPREHENSIVE EVALUATORY STUDY OF SILK YIELD TRAITS OF GENETIC RESOURCES IN THE MULBERRY SILKWORM, *Bombyx mori*. L

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ABSTRACT

Existing silkworm genetic resources are derived from not only the resultants of the genetic drift occurred in nature due to genotype and environment reactions but man made alterations through breeding studies also, brought up a good number of improved stocks. Evaluating these genetic stocks continuously from time to time, is essential to utilize them for further improvement studies as well as to ascertain their status of maintenance. It will be fair and precise to take the decision based on the multiple traits spanning the various stages, pre-cocoon, cocoon and post-cocoon, so that adequate weightage is given to various characters that are representing different entities of sericulture as a whole. Thirty one silkworm stocks available at Satellite Silkworm Breeding Station, Coonoor were subjected for such evaluation by multiple trait index method along with a modified multiple trait evaluation index on negative traits. Distinct groups on fitness, productivity, fiber and crop duration merits were identified. Based on these studies, twelve breeds viz., A120, A121, B120, European, G146, CJ3P, SPJ2, SPC1, M2, J2P, JA1 and 36PC were selected for amalgamation of fitness, productivity, fibre and shorter larval duration. Such comprehensive evaluation is of immense value for improvement studies of varying objectives.

Key words: Silkworm genetic stocks, negative traits, comprehensive evaluation, distinct merit groups.

I. INTRODUCTION

Today, Silkworm races are available to the mankind in quite good number possessing considerable variation in different characters. Cause of such variations are mainly, because of the geographical differences wherein the natural selection and the genotype × environment interactions have played a significant role, by drifting them from their original stocks. Mankind is more interested in looking into these drifts/changes happened which are advantageous to his well being. However, the introduction of different stocks in different geographical/agroclimates and simply leaving to the nature to select, is time consuming and hence, he took up the Silkworm breeding techniques as a tool to bring in these “drifts” or changes in the original population/stocks. Large number of such improvement studies had resulted in quite a good number of silkworm genetic resources.

Silkworm breeders in tropical countries like India have the task of exploiting the potential of different stocks having superior qualities (of bivoltines) which are mainly not acquired in our conditions. Hence, it makes that more difficult to derive few appropriate population or lines or breeds from these stocks which possess meaningful characters for our agro-climates.

Selection of appropriate breeding resource materials for any improvement programme is very essential but not a simple one. All animal improvement programmes aims at a derivation of better constellation of gene complex which suits to express good phonotypic values on a wide range of traits by amalgamating distinct and different gene pools. It is a well known fact that no breeder can expect a readymade supply of information on distinctness or the magnitude of difference existing amongst one another in a group of breeding resource materials available to him. Therefore, it is imperative to a breeder to identify distinct and different gene pools existing in a group of resource materials.

Assessment of all quantitative traits through their phenotypic expression were continuously attempted, for both to make decision on the selection of breeding resource material as well as to measure the extent of improvement achieved in a breeding study of various objectives. However, these quantitative traits which need to be measured are both negative as well as positive. Earlier attempts were made to design evaluation methods and indexing based on two to three traits (Saito, 1977; Iyengar, *et al*, 1983). The most commonly used method to evaluate quantitative traits is suggested by Mano *et al* (1992 and 1993) considers multiple traits at a time and is being used widely since then by many silkworm breeders (Nirmal Kumar and Sreerama Reddy, 1998; Mano, *et. al.*, 1998; Nassema Begum, *et al,* 2001 and 2008; Ramesh Babu, *et. al.*, 2002; Ramesha, *et. al.*, 2009; Sudhakar Rao, *et. al.* 2001 and 2002). However, measurement of negative traits by using this method has been an obstacle so far. The author group has come up with a modification on the method suggested by Mano, *et al* (1992 and 1993) to suit it to measure negative traits such as larval duration, denier, renditta, etc and thereby attempting a comprehensive evaluation of various economic traits.

II. MATERIALS AND METHODS

Thirty one different genetic stocks of mulberry silkworm (Bivoltines), *Bombyx mori.* L., available at Satellite Silkworm Breeding Station, Coonoor, were taken up for the above study.

Table 1 (a) Salient features of silkworm genetic stocks available at Satellite Silkworm Breeding Station, Coonoor.

Sl No	Race	Geographical origin	Larval Marking	Cocoon colour / Cocoon shape / shell grains / floss
1	C108	China	Plain	white / oval / ordinary / less
2	C120	China	Plain	white / oval / medium / Less
3	Dong 306	China	Plain	white / short oval / medium / more
4	NN6D	China	Plain	white / oval / ordinary / less
5	J1(M)	Japan	Marked	white / elongate
6	J2 (P)	Japan	Plain	white / elongate
7	J2(M)	Japan	Marked	white / deeply constricted / medium / less
8	JC2 (P)	Japan	Plain	white / oval / medium / less
9	CJ3(P)	Japan	Plain	white / oval / medium / less
10	M2	Japan	Plain	white / slight constriction / medium / less
11	SPC1	Japan	Plain	white / short oval / medium / less
12	SPJ1	Japan	Marked	white / slender constriction / medium / less
13	SPJ2	Japan	Marked	white / slender constriction / medium / less
14	N4	Japan	Marked	white / constricted / medium / less
15	J122	Japan	Plain	white / mild constriction / medium / less
16	14M	Japan	Marked	white / dumbbell / medium / less
17	36 (PC)	Japan	Plain	white / dumbbell / medium / less
18	SN1	Japan	Plain/Marked	white / dumbbell / medium / less
19	NJ1	Japan	Plain/Marked	white / dumbbell / medium / less
20	JA1	India	Marked	white / dumbbell / medium / less
21	JB2	India	Marked	white / dumbbell / medium / less
22	SH2	India	Plain	white / oval / fine / less
23	NB1	India	Plain	white / oval / medium / less
24	EUROPEAN	France	Plain	white / dumbbell / medium / less
25	JZH(PO)	Brazil	Plain	white oval medium / less
26	JZH(MC)	Brazil	Marked	white / constricted / medium / less
27	G177	Vietnam	Plain	white / oval / medium / less
28	G146	Vietnam	Plain	white / constricted / medium / less
29	A120	India	Plain	white / oval / fine / less
30	A121	India	Plain	white / oval / medium / less
31	B120	India	Marked	white / dumbbell / medium / less

Of which, fourteen breeds, viz., C108, C120, Dong 306, NN6D, CJ3P, SPC1, SH2, J2P, JC2P, JZH PO, NB1, G177, A120 and A121, spin Chinese type or oval shaped cocoons and seventeen breeds, viz., N4, NJ1, SN1, SPJ1, SPJ2, 36PC, J1M, J2M, JA1, JB2, J122, JZH MC, M2, G146, 14M, European and B120, spin Japanese type or peanut shaped cocoons (Table-1 (a)).

Standard method of rearing practices were followed (Datta, 1992). The data pertaining to nine economically important traits viz., total larval duration, pupation rate, cocoon yield by weight for 10,000 larvae, cocoon weight, cocoon shell weight, cocoon shell percentage, average filament length, denier, and raw silk were recorded (Table-1b).

Table 1 (b) Performance of silkworm genetic stocks available at Satellite Silkworm Breeding Station, Coonoor

Sl No	Race	Larval Duration (Hrs)	Pupation Rate (%)	Cocoon yield/ 10000 Larvae (Kgs)	Single Cocoon Weight (g)	Single Shell Weight (g)	Shell (%)	Avg Filament Length (m)	Denier (d)	RAW SILK (%)
1	C108	706	85.62	15.632	1.814	0.343	18.90	917	2.56	14.59
2	C120	696	83.07	12.590	1.514	0.345	22.78	1070	2.27	18.67
3	CJ3P	700	89.17	14.992	1.680	0.363	21.60	1016	2.31	17.38
4	Dong 306	705	88.96	14.476	1.625	0.311	19.13	980	2.35	14.58
5	NN6D	689	80.31	12.258	1.526	0.285	18.67	968	2.23	14.34
6	N4	729	81.01	13.690	1.688	0.370	21.91	1002	2.33	17.45
7	NJ1	715	69.68	12.128	1.740	0.377	21.66	1061	2.48	17.00
8	SN1	734	74.71	13.170	1.762	0.365	20.71	1011	2.56	16.35
9	SPC1	750	75.61	11.980	1.582	0.359	22.69	1093	2.27	17.97
10	SPJ1	740	75.56	12.710	1.682	0.356	21.16	981	2.60	17.05
11	SPJ2	732	84.75	12.980	1.724	0.362	20.99	976	2.63	16.33
12	SH2	743	71.43	12.235	1.699	0.378	22.24	1031	2.50	17.69
13	36PC	705	87.01	15.602	1.792	0.389	21.70	928	2.69	17.28
14	J1M	729	85.84	15.278	1.768	0.370	20.92	996	2.26	16.40
15	J2M	722	84.50	15.240	1.792	0.370	20.64	986	2.57	15.92
16	JA1	724	80.65	13.650	1.692	0.356	21.04	998	2.75	16.38
17	JA2	742	76.70	13.560	1.762	0.374	21.22	1016	2.44	17.00
18	J122	709	88.96	15.965	1.790	0.352	19.66	960	2.47	15.42
19	J2P	741	88.82	15.490	1.742	0.364	20.89	992	2.23	16.37
20	JC2P	712	88.33	14.900	1.681	0.354	21.05	1069	2.13	16.63
21	JZHPO	704	86.99	14.515	1.662	0.335	20.15	965	2.36	15.83
22	JZHMC	712	74.70	12.680	1.694	0.368	21.72	988	2.57	17.06
23	M2	714	87.86	13.980	1.590	0.328	20.62	981	2.62	15.90
24	G146	704	91.00	14.936	1.638	0.385	20.45	984	2.51	16.13
25	G177	674	84.74	10.982	1.289	0.234	18.15	782	2.07	13.90
26	14M	749	78.85	13.450	1.694	0.385	22.72	1044	2.70	18.07
27	European	725	80.20	13.480	1.678	0.363	21.63	978	2.00	17.27
28	NB1	694	91.12	16.218	1.776	0.368	20.72	992	2.40	16.40
29	A120	654	88.66	16.200	1.824	0.426	23.36	1198	2.52	18.81
30	A121	652	89.10	15.612	1.745	0.404	23.15	1068	2.53	18.43
31	B120	652	89.00	14.622	1.635	0.360	22.01	1106	2.36	17.44
	Mean	711.52	83.32	14.039	1.686	0.356	21.10	1004	2.43	16.65
	SD	26.46	6.02	1.406	0.106	0.034	1.26	68.72	0.18	1.21
	CD 5%	9.85	2.24	0.524	0.039	0.013	0.47	25.58	0.07	0.45
	CV%	3.72	7.22	10.02	6.29	9.49	5.97	6.84	7.62	7.27

I. Multiple trait (Evaluation) Index:

Multiple trait (Evaluation) Index was calculated as per the procedure suggested by Mano, *et al* (1992 and 1993).

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

Where,

$A =$ Value obtained for a trait in a breed

$B =$ Mean value of a trait of all the breeds

$C =$ Standard deviation of a trait of all the breeds

$10 =$ Standard Unit

$50 =$ Fixed value

In the above method, the objective as a whole is to select out those varieties/breeds which are scoring values above mean for any given trait. However, as mentioned earlier, evaluation of negative traits in the silkworm has been not attempted, so far.

II. Measurement of Negative traits:

Measurement of negative traits such as larval duration and denier of thirty one silkworm genetic stocks were taken for the analysis.

Adopting the same principle followed in the above method outlined by Mano, *et al,* (1992 and 1993) and rather keeping it intact, the author group has modified the evaluation index for negative traits, as below:

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

Where,

$A =$ Value obtained for a trait in a breed

$B =$ Mean value of a trait of all the breeds

$C =$ Standard deviation of a trait of all the breeds

$10 =$ Standard Unit

$50 =$ Fixed value

By above modification, one can make out the measurement of negative traits which is desired to be lesser than the mean value for a given trait and the traits such as total larval duration, denier, etc., can be measured successfully.

As prescribed for positive traits, the varieties / breeds with average index value 50, on negative traits are considered to be better performers which were the resultant of index measurement made on number of important traits covering various economic parameters.

A cumulative evaluation of thirty one silkworm genetic stocks was derived from considering all nine economically important traits taken up for the study. However, it is pertinent to evaluate distinct groups on fitness merits, productivity merits, fibre traits and on crop duration.

Therefore, to evaluate silkworm genetic stocks on fitness merits, the traits of pupation rate and cocoon yield per 10000 larvae were considered; to evaluate on productivity merits, the traits of cocoon weight, cocoon shell weight, shell percentage and raw silk content were considered; to evaluate on fibre merits, the traits of average filament length, filament size denier and raw silk content were considered and to evaluate on crop duration merits, the trait of total larval duration was considered.

III. RESULTS

Salient features of thirty one silkworm genetic stocks and the values on nine economically important traits observed were given in Table-1a & Ib. The larval duration ranged from 652 to 749 hours with the shortest larval duration of 652 hours recorded for B120 and the longest larval duration of 749 hours recorded for 14M. The pupation rate ranged from 69.68 to 91.12 with the lowest of 69.68 recorded for NJ1 and the highest of 91.12 recorded for NB1. The yield/10,000 larvae by weight ranged from 10.982 to 16.218 kg with the lowest of 10.982 kg recorded for G177 and the highest of 16.33 kg recorded for NB1. The cocoon weight ranged from 1.289 to 1.824 g with the lowest of 1.289 g recorded for G177 and the highest of 1.824 g recorded for A120. The cocoon shell weight ranged from 0.234 to 0.426 g with the lowest of 0.234 g recorded for G177 and the highest of 0.447 g recorded for A120. The cocoon shell percentage ranged from 18.15 to 23.36% with the lowest of 18.15% recorded for G177 and the highest of 23.36% recorded for A120. The average cocoon filament length ranged from 782 to 1198 m with the shortest of 782 m recorded for G177 and the longest of 1198 m recorded for A120. The cocoon

Table 2. Evaluation index assessed on nine important traits.

Race	LarvalDuration (Hrs)	Pupation Rate (%)	Coc. yield/ 10000 Larvae (Kgs)	Sing Coc. Wt (g)	Sing. Shell Wt (g)	Shell (%)	Avg Fil. Length (m)	Denier (d)	Raw Silk (%)	Evaluation Index
C108	52.08	53.82	61.33	62.03	46.03	32.51	37.28	42.87	33.00	46.77
C120	55.86	49.59	39.70	33.74	46.63	63.30	59.54	58.55	66.73	52.62
CJ3P	54.35	59.72	56.78	49.39	51.95	53.93	51.69	56.38	56.07	54.47
Dong 306	52.46	59.37	53.11	44.21	36.58	34.33	46.45	54.22	32.92	45.96
NN6D	58.51	45.00	37.34	34.87	28.89	30.68	44.70	60.71	30.93	41.29
N4	43.39	46.16	47.51	50.15	54.01	56.39	49.65	55.30	56.64	51.02
NJ1	48.68	27.34	36.41	55.05	56.08	54.41	58.23	47.19	52.91	48.48
SN1	41.50	35.69	43.82	57.13	52.54	46.87	50.96	42.87	47.55	46.55
SPC1	35.46	37.19	35.36	40.15	50.76	62.58	62.89	58.55	60.94	49.32
SPJ1	39.24	37.11	40.55	49.58	49.88	50.44	46.59	40.70	53.34	45.27
SPJ2	42.26	52.38	42.47	53.54	51.65	49.09	45.86	39.08	47.38	47.08
SH2	38.10	30.24	37.17	51.18	56.38	59.01	53.87	46.11	58.63	47.86
36PC	52.46	56.13	61.12	59.95	59.63	54.73	38.88	35.84	55.24	52.66
J1M	49.75	54.19	58.81	57.69	54.01	48.54	48.78	50.73	47.96	52.27
J2M	46.04	51.96	58.54	59.95	54.01	46.31	47.32	42.33	43.99	50.05
JA1	45.28	45.56	47.24	50.52	49.88	49.45	49.07	32.59	47.80	46.38
JB2	38.48	39.00	46.60	57.13	55.20	50.92	51.69	49.36	52.92	49.03
J122	50.95	59.37	63.70	59.77	48.69	38.54	43.54	47.73	39.86	50.24
J2P	38.86	59.14	60.32	55.24	52.24	48.30	48.19	60.71	47.71	52.30
JC2P	49.82	58.33	56.13	49.86	49.29	49.57	59.40	66.12	49.86	54.22
JZHPO	52.84	56.10	53.39	47.69	43.67	42.43	44.26	53.68	43.25	48.59
JZHMC	49.82	35.68	40.34	50.71	53.42	54.88	47.61	42.33	53.42	47.58
M2	49.06	57.55	49.58	40.90	41.60	46.16	46.59	39.62	43.83	46.10
G146	52.84	62.76	56.38	45.43	43.67	44.81	47.03	45.57	45.73	49.36
G177	64.18	52.36	28.26	12.52	13.82	26.56	17.63	69.36	27.29	34.66
14M	35.84	42.57	45.81	50.71	58.45	62.82	55.76	35.30	61.77	49.89
European	44.91	44.82	46.03	49.20	51.95	54.17	46.16	73.14	55.16	51.72
NB1	56.62	62.96	65.50	58.45	53.42	46.95	48.19	51.52	47.96	54.62
A120	71.73	58.87	65.37	62.97	70.56	67.90	78.17	45.03	67.89	65.39
A121	72.49	59.61	61.19	55.52	64.06	66.23	59.25	44.49	64.75	60.84
B120	72.49	59.44	54.19	45.15	51.06	57.19	64.78	53.68	56.56	57.17

filament size ranged from 2.07 to 2.75 d with the thinnest of 2.07 recorded for G177 and the thickest of 2.75 recorded for JA1. The raw silk percentage ranged from 13.90 to 18.81% with the lowest of 13.90 recorded for G177 and the highest of 18.81% recorded for A120.

The multiple trait evaluation index measured on nine various traits taken up for the study were given in Table-2. It was shown in the table that fourteen silkworm stocks had scored >50 as evaluation index on cumulative merits. They are, viz., A120, A121, B120, NB1, CJ3P, JC2P, 36 PC, C120, J1M, J2P, European, N4, J122 and J2M with index values of 65.39, 60.84, 57.17, 54.62, 54.47, 54.22, 52.66, 52.62, 52.27, 52.30, 51.72, 51.02, 50.24 and 50.05, respectively in the order of merit.

Table 3. Evaluation Index on Fitness merit and Productivity merit

Breed	Fitness Merit		Evaluation Index for Fitness merits	Productivity merit				Evaluation Index for Producti-vity merit.
	Pupation Rate (%)	Cocoon Yield/ 10000 larvae (kgs)		Single Cocoon weight (g)	Single Shell Weight (g)	Shell (%)	Raw silk (%)	
C108	53.82	61.33	57.58	62.03	46.03	32.51	33.00	43.39
C120	49.59	39.70	44.64	33.74	46.63	63.30	66.73	52.60
CJ3P	59.72	56.78	58.25	49.39	51.95	53.93	56.07	52.83
Dong 306	59.37	53.11	56.24	44.21	36.58	34.33	32.92	37.01
NN6D	45.00	37.34	41.17	34.87	28.89	30.68	30.93	31.34
N4	46.16	47.52	46.84	50.15	54.01	56.39	56.64	54.30
NJ1	27.34	36.41	31.87	55.05	56.08	54.41	52.92	54.62
SN1	35.69	43.82	39.76	57.13	52.54	46.87	47.55	51.02
SPC1	37.19	35.36	36.27	40.15	50.76	62.58	60.94	53.61
SPJ1	37.11	40.55	38.83	49.58	49.88	50.44	53.34	50.81
SPJ2	52.38	42.47	47.42	53.54	51.65	49.09	47.38	50.42
SH2	30.24	37.17	33.71	51.18	56.38	59.01	58.63	56.30
36PC	56.13	61.12	58.62	59.95	59.63	54.73	55.24	57.39
J1M	54.19	58.81	56.50	57.69	54.01	48.54	47.96	52.05
J2M	51.96	58.54	55.25	59.95	54.01	46.31	43.99	51.07
JA1	45.56	47.24	46.40	50.52	49.88	49.45	47.80	49.41
JB2	39.00	46.60	42.80	57.13	55.20	50.92	52.92	54.04
J122	59.37	63.70	61.54	59.77	48.69	38.54	39.86	46.71
J2P	59.14	60.32	59.73	55.24	52.24	48.30	47.71	50.87
JC2P	58.33	56.13	57.23	49.86	49.29	49.57	49.86	49.64
JZHPO	56.10	53.39	54.74	47.69	43.67	42.43	43.25	44.26
JZHMC	35.68	40.34	38.01	50.71	53.42	54.88	53.42	53.11
M2	57.55	49.58	53.56	40.90	41.60	46.16	43.83	43.12
G146	62.76	56.38	59.57	45.43	43.67	44.81	45.73	44.91
G177	52.36	28.26	40.31	12.52	13.82	26.56	27.29	20.05
14M	42.57	45.81	44.19	50.71	58.45	62.82	61.77	58.44
European	44.82	46.03	45.42	49.20	51.95	54.17	55.16	52.62
NB1	62.96	65.50	64.23	58.45	53.42	46.95	47.96	51.69
A120	58.87	65.37	62.12	62.97	70.56	67.90	67.89	67.33
A121	59.61	61.19	50.40	55.52	64.06	66.23	64.75	62.64
B120	59.44	54.19	56.81	45.15	51.06	57.19	56.56	52.49

The evaluation index measured on fitness merits and productivity merits were given in the Table-3. It was shown in the table that sixteen silkworm stocks had scored 50 as evaluation index on fitness merits. They are, viz., NB1, A120, J122, A121, J2P, G146, 36 PC, CJ3P, C108, JC2P, B120, J1M, Dong 306, J2M and JZH PO with index values of 64.23, 62.12, 61.54, 60.40, 59.73, 59.57, 58.62, 58.25, 57.58, 57.23, 56.81, 56.50, 56.24, 55.25 and 54.74, respectively in the order of merit. It was shown in the table that as much as twenty one silkworm stocks had obtained >50 as index value on productivity merits. They are, viz., A120, A121, 14M, 36 PC, SH2, NJ1, N4, JB2, SPC1, JZH MC, CJ3P, European, C120, B120, J1M, NB1, J2M,

Table 4. Evaluation Index on the merit of Fibre quality and Crop Duration

Breed	Fibre Merit			Evaluation Index for fibre merit	Crop Duration Merit
	Average Filament Length (m)	Denier (d)	Raw Silk (%)		Total Larval Duration (D:Hrs)
C108	37.28	42.87	33.00	37.71	52.08
C120	59.54	58.55	66.73	61.61	55.86
CJ3P	51.69	56.38	56.07	54.71	54.35
Dong 306	46.45	54.22	32.92	44.53	52.46
NN6D	44.70	60.71	30.93	45.45	58.51
N4	49.65	55.30	56.64	53.86	43.39
NJ1	58.23	47.19	52.92	52.78	48.68
SN1	50.96	42.87	47.55	50.46	41.50
SPC1	62.89	58.55	60.94	60.79	35.46
SPJ1	46.59	40.70	53.34	46.88	39.34
SPJ2	45.86	39.08	47.38	44.11	42.26
SH2	53.87	46.11	58.63	52.87	38.10
36PC	38.88	35.84	55.24	43.32	52.46
J1M	48.78	50.73	47.96	49.16	49.75
J2M	47.32	42.33	43.99	44.55	46.04
JA1	49.07	32.59	47.80	43.15	45.28
JB2	51.69	49.36	52.92	51.32	38.48
J122	43.54	47.73	39.86	43.71	50.95
J2P	48.19	60.71	47.71	52.21	38.86
JC2P	59.40	66.12	49.86	58.46	49.82
JZHPO	44.26	53.68	43.25	47.06	52.84
JZHMC	47.61	42.33	53.42	47.79	49.82
M2	46.59	39.62	43.83	43.35	49.06
G146	47.03	45.57	45.73	46.11	52.84
G177	17.63	69.36	27.29	38.10	64.18
14M	55.76	35.30	61.77	50.94	35.84
European	46.16	73.14	55.16	58.15	44.91
NB1	48.19	51.52	47.96	49.22	56.62
A120	78.17	45.03	67.89	63.70	71.73
A121	59.25	44.49	64.75	56.16	72.49
B120	64.78	53.68	56.56	58.34	72.49

SN1, J2P, SPJ1 and SPJ2 with index value of 67.33, 62.64, 58.44, 57.39, 56.30, 54.62, 54.30, 54.04, 53.61, 53.11, 52.83, 52.62, 52.60, 52.49, 52.05, 51.69, 51.07, 51.02, 50.87, 50.81 and 50.42, respectively in the order of merit.

The evaluation index measured on the fibre merits and crop duration were given in the Table-4. It was shown in the table that fifteen silkworm stocks had scored >50 as evaluation index on fibre merits. They are, viz., A120, C120, SPC1, JC2P, B120, European, A121, CJ3P, N4, SH2, NJ1, J2P, JB2, 14M and SN1 with index value of 63.70, 61.61, 60.79, 58.46, 58.34, 58.15, 56.16, 54.71, 53.86, 52.87, 52.78, 52.21, 51.32, 50.94 and 50.46 respectively in the order of merit.

It was shown in the table that fourteen silkworm stocks had scored 50 as evaluation index on larval duration. They are, viz., A121, B120, A120, G177, NN6D, NB1, C120, CJ3P, G146, JZH PO, 36 PC, Dong 306, C108 and J122 with index values of 72.49, 72.49, 71.73, 64.18, 58.51, 56.62, 55.86, 54.35, 52.84, 52.84, 52.46, 52.46, 52.08, 50.95, respectively in the order of merit.

IV. DISCUSSION

Characterisation and evaluation of silkworm genetic stocks are essential not only to weigh their further utility in improvement studies, but also, to ascertain their present status on the phenotypic expression of various traits and thereby to make necessary amendments in the race maintenance strategies. The joint scoring method suggested by Arunachalam, and Bandyopadhyay, (1984) was used by many authors (Lakshmi, and Chandrashekharaiah, 2008; Harjeet Singh and Suresh kumar, 2008,). Some attempts were also made recently to assess genetic distance and heterosis through evaluation index method (Talebi and Subramanya, 2009). However, the need for a simple and reliable measurement is always felt. Therefore, the multiple trait evaluation method suggested by Mano, *et al* (1992 and 1993) was modified to suit the measurement of negative traits by the author group, thereby enabling them to have a comprehensive evaluation of all traits necessary for a race maintenance study or to the improvement study of different objectives.

The measurement of negative trait of larval duration is very crucial, as it bears a strong correlation on fitness as well productivity traits. As also, the role of moderate or thin filament denier is always in the desirable list of traits for many silkworm breeding studies.

Modifications attempted in this direction of such measurement methods in the present study, clearly convinces any user on the adoptability, as there is no difference seen on the resultant values from the measurement of positive values exercised so far widely by many authors. Index values shown in Table-2 depicting the measurement of negative traits, viz., total larval duration and filament denier along with other positive traits, had confirmed the same. There is corresponding degree of increments in the measured index values which is inversely proportional to the trait values as seen from the table (Table-1b) that higher the trait value, least the index value (Table-2) and lower the trait value, the most the index value (Table-1b & Table-2).

Generally, the superiority of silkworm breeds is judged according to the manifestation of multiple traits. Considering, the magnitude of the exercise, it is painstaking effort and should result in fairly reliable and repeatable result. One strategy which can increase the precision of the selection of breeds among array of breeds is to set a common index giving adequate weightage to all the yield component traits. As such, it will be fair and precise to take the decision based on the multiple traits spanning various stages, pre-cocoon, cocoon and post-cocoon so that adequate weightage is given to various traits representing entities in the entirety of the sericulture on the whole.

Therefore, it becomes imperative to devise the evaluation index so that it can be used to maximize the genetic importance of multiple traits simultaneously. Table-2 depicting such index values for both negative and positive values of nine economically important traits shows that fourteen silkworm stocks are scoring >50 as index values. The nine traits considered for the study covers all essential parameters on pre-cocoon, cocoon and post-cocoon aspects and thereby enables one to have assessment of silkworm stocks on the whole.

No single race or a breed possess all quantitative traits on pre-cocoon, cocoon and post-cocoon aspects that are desired to use by various stake holders of the sericulture industry. However, all improvement studies aims at a derivation of better constellation of gene constellation which suits to express good phonotypic values on a wide range of traits. But attempts are always made to achieve this, by amalgamating distinct and different gene pools. Therefore, the efforts are made to identify distinct and different gene pools existing in a group of silkworm genetic resource materials.

Fitness merits are truly represented by pupation rate and also, the quantity of cocoon yield to be obtained by utilizing a particular silkworm stock. The productivity merits are represented by cocoon weight, cocoon shell weight, the shell percentage and the raw silk content which is the ultimate productive trait desired. Fibre merits are well represented by considering average filament length, filament size denier and raw silk content and the crop duration is represented by considering total larval duration of the silkworm stock.Table-5 depicts a picture on representation of silkworm stocks under various groups of fitness, productivity, fibre and crop duration. Index measurement shown that sixteen, twenty one, fifteen and fourteen silkworm stocks qualify under these distinct merits. Representation on the productivity being the most, twenty one, indicates that most of the silkworm stocks considered are good in this category. Further, it is clearly shown that there are distinct groups on the merit of fitness, productivity, fiber and crop duration as represented by marked variation amongst these groups. Figure-1 brings out the pictorial presentation, wherein the clear existence of above distinct groups on different merits can be seen.

Selection of breeds for any genetic improvement studies depends on the magnitude of phonotypic

Table 5. Representation of silkworm stocks on various merits.

Sl No	Race	Larval Duration	Fitness	Productivity	Fibre	Cumulative
1	C108	Y	Y	–	–	–
2	C120	Y	–	Y	Y	Y
3	CJ3P	Y	Y	Y	Y	Y
4	Dong306	Y	Y	–	–	–
5	NN6D	Y	–	–	–	–
6	N4	–	–	Y	Y	Y
7	NJ1	–	–	Y	Y	–
8	SN1	–	–	Y	Y	–
9	SPC1	–	–	Y	Y	–
10	SPJ1	–	–	Y	–	–
11	SPJ2	–	–	Y	–	–
12	SH2	–	–	Y	Y	–
13	36PC	Y	Y	Y	–	Y
14	J1M	–	Y	Y	–	Y
15	J2M	–	Y	Y	–	Y
16	JA1	–	–	–	–	–
17	JB2	–	–	Y	Y	–
18	J122	Y	Y	–	–	Y
19	J2P	–	Y	Y	Y	Y
20	JC2P	–	Y	–	Y	Y
21	JZHPO	Y	Y	–	–	–
22	JZHMC	–	–	Y	–	–
23	–	Y	–	–	–	
24	G146	Y	Y	–	–	–
25	G177	Y	–	–	–	–
26	14M	–	–	Y	Y	–
27	European	–	–	Y	Y	Y
28	NB1	Y	Y	Y	–	Y
29	A120	Y	Y	Y	Y	Y
30	A121	Y	Y	Y	Y	Y
31	B120	Y	Y	Y	Y	Y

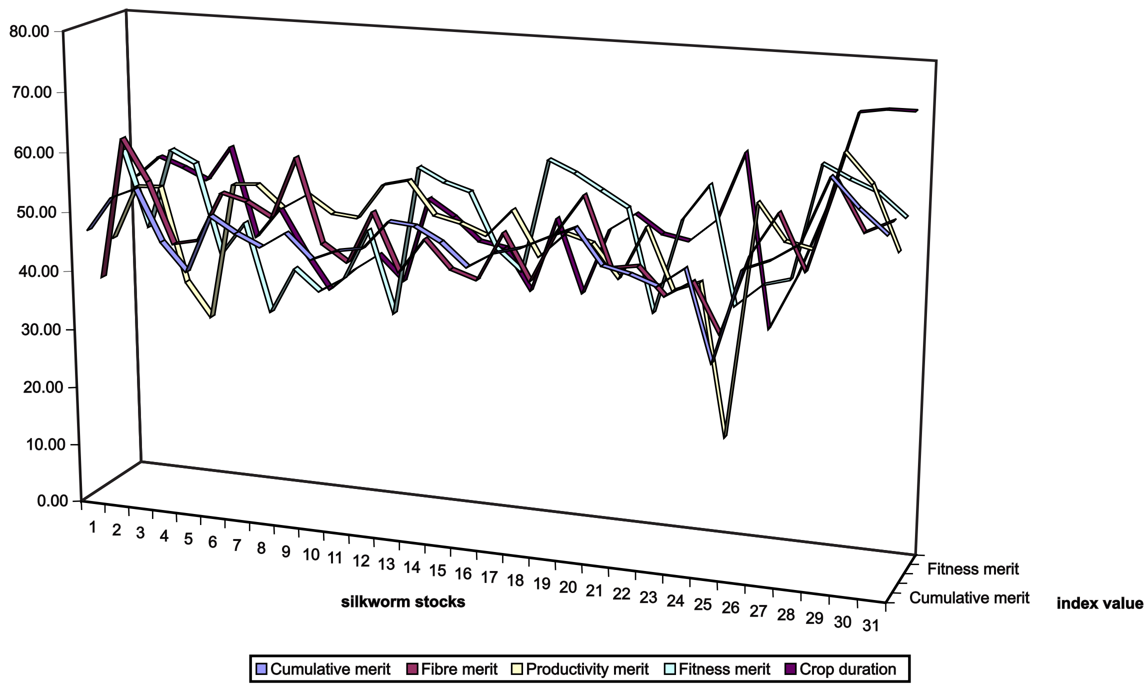

Fig. 1. Comprehensive evaluation of silkworm stocks

expression derived in a conditioned environment on which the breeds were screened. Further, breeds with higher phonotypic values for the traits on which the improvement objectives are set, deserves selection over other resources. Apart from such considerations, mating system proposed in the study facilitating the possible achievement of objective, also, plays a major role. Further, to execute an improvement study, larval marking, cocoon type and their linkage with many other attributes and co-relation of various other traits are also, needs to be considered. In this context, the present study took stock of assessment of various silk yield traits in thirty one genetic resources conserved and brought out their merits on fitness, productivity, fibre quality and crop duration.

Therefore, it can well be concluded that the silkworm genetic stocks considered in this study possess various distinct traits in different groups categorized and the knowledge elicited, therefore, can be utilized well for silkworm improvement studies of varying objectives.

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