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EVALUATION OF NEW BIVOLTINE SILKWORM HYBRIDS OF *Bombyx mori* L. FOR SUB-TROPICAL CONDITIONS

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ABSTRACT
While Central Sericultural Research and Training Institute, Pampore had evolved specific silkworm hybrids suitable to sub-tropical conditions of northern India, Satellite Silkworm Breeding Station, Coonoor had undertaken a silkworm improvement study to address the development of new silkworm breeds possessing relatively shorter larval duration vis-à-vis good productivity traits. Involving ten new breeds evolved, a systematic hybrid study was taken up with forty-eight new hybrids of all possible combinations along with a ruling hybrid, CSR 2 x CSR 4. Evaluation of these forty-eight new hybrids with multiple trait index (Evaluation index) suggested by Mano *et al* (1992, 1993) reveals that twenty new hybrid combinations scored >50 as index value. After considering fitness, cocoon and fibre traits along with larval duration and cocoon uniformity, five superior hybrid combinations, viz, SLD 4 x SLD 8, SLD 1 x SLD 8, SLD 2 x SLD 8, SLD 4 x SLD 6 and SLD 4 x SLD 9 were selected as superior hybrid combinations.

KEYWORDS: Evaluation, Multiple trait index, Sub-tropical conditions, Superior silkworm hybrids.

INTRODUCTION

Various silkworm improvement studies have been undertaken at different Sericultural Research Institutions, across the globe. Satellite Silkworm Breeding Station, Coonoor is one amongst such designated Institution in India, undertaking silkworm improvement studies orienting the objectives to meet out the regional requirements. Sub-tropical climate prevailing in the Nilgiris hill area brings boon, together with bane. Though the semi-temperate / sub-tropical conditions prevailing in the western ghats of Nilgiris been an ideal, to realize the full potential of bivoltine silkworm breeds and hybrids, the prolonged larval duration observed with sericulturists of the area acts as a deter to this avocation. The prolonged larval duration exposes more duration to the vagaries of hill climate and often leads to poor yield from crops succumbing to pathogens. It became imperative to take up silkworm improvement studies with an objective of developing breeds with relatively shorter larval duration with out compromising on productivity traits. One such study has been completed at Satellite Silkworm Breeding Station, Coonoor and ten new bivoltine breeds with relatively shorter larval duration possessing good productivity traits were evolved.

It is well documented that F1 hybrids are superior to their parents in many qualitative and quantitative traits (Toyama, 1906). Chinese and Japanese breeders have made notable progress through the improvement of ecomically important quantitative traits in silkworm (Harada, 1961; Gamo, 1976; Mano, et al, 1991; Chen et al, 1994). Evaluation studies on various objectives of screening silkworm breeds / hybrids for tropical climate (Sudhakar Rao, *et al.,* 2001, 2002, Lakshmi, H and Chandrashekharaiah, 2008), identification of silkworm breeds for thermo-tolerance (Lakshmi, H and Chandrashekariah, 2007, Harjeet Singh and Suresh kumar, N , 2008) were taken up by many authors. Identification of different agro-climatic zones in India on the merits of climatic conditions, soil conditions and production constraints were also, attempted (Iyengar et al, 1993, Iyengar, 1995). Development of silkworm breeds / hybrids suitable to sub-tropical conditions of Northern India is primarily undertaken by Central Sericultural Research and Training Institute, Pampore and this institute had reported the development of new bivoltine hybrids, viz., YS3 x SF19, SH6 x KA, Pam 101 x SF19, SH6 x NB4D2 during 1980's and CP1B x JP1B, CP1B x J-Plain, CS6 x PAM 101, Dun 6 x Dun 21, RSJ3 x RSJ1, RSJ14 x RSJ11 during 1990'sand also, Dun 6 x Dun 22 and Dun 16 x Dun 17 in recent times and further, CS6 x PAM 101, Dun 6 x Dun21 and RSJ3 x RSJ1 were authorized by provincial race authorization committee (Annual reports of CSRTI, Pampore). Similarly, Satellite Silkworm Breeding Station, Coonoor had undertaken silkworm improvement studies to address the specific needs of sub-tropical hill conditions and the hybrid vigour in these newly evolved silkworm breeds was exploited through a systematic diallel study, having all possible combinations. The evaluation studies on the new bivoltine hybrids developed is presented in this paper.

MATERIALS AND METHODS

Ten newly evolved bivoltine breeds from a breeding programme conducted at Satellite Silkworm Breeding Station, Coonoor, viz., SLD 1, SLD 2, SLD 3, SLD 4 (Spin oval shaped cocoons), SLD 5, SLD 6, SLD 7, SLD 8, SLD 9, SLD

10 (Spin dumbbell shaped cocoons) were utilized for the study. Four oval and six dumbbell parents were crossed in all possible combinations and obtained fourty eight F1 combinations including reciprocals. These forty eight new F1 combinations along with the control hybrid, CSR 2 x CSR 4, the ruling bivoltine hybrid, were reared in three replicates twice during March/April, 2007 and May/June, 2007. Standard method of rearing practices were followed (Datta, 1992). The data pertaining to fourteen traits viz., fecundity, fifth age larval duration, total larval duration, pupation percentage, cocoon yield by weight for 10,000 larvae, cocoon weight, cocoon shell weight, cocoon shell percentage, average filament length, denier, raw silk percentage, renditta, reelability and neatness were recorded.

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

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

Where, A = Value obtained for a trait in a hybrid combination,

B = Mean value of a trait of all the hybrid combinations,

C = Standard deviation of a trait of all the breeds

10 = Standard Unit

50 = Fixed value

The values for negative and positive traits are calculated separately.

Further, the index values for each fourteen traits taken under the study were pooled together and mean (evaluation index) was calculated for each new hybrid combinations. The hybrids with index value > 50 are considered to be better performers which were otherwise, the resultant of index measurement made on fourteen important traits covering various economic parameters.

RESULTS

The data on fourteen economically important traits of fourty eight new bivoltine hybrid combinations measured in two rearings conducted were compiled and mean of two trials were calculated. Further from the mean values of two trials on fourteen traits for all forty eight hybrid combinations, the grand mean and standard deviation for each fourteen traits were calculated. (Table-1).

TABLE-1 Performance of forty-eight new hybrid combinations.

Sl No.	Hybrid	Fec.	Lar. Dur. Vth (D;Hrs)	Lar. Dur. Total (D;Hrs)	Pup. Rate	ERR Wt (Kgs)	SCW (g)	SSW (g)	Shell (%)
1	SLD 1 x SLD 5	544	6.19	22.17	95.87	21.325	2.122	0.469	22.12
2	SLD 1 x SLD 6	524	6.00	21.02	94.65	20.607	2.110	0.461	21.84
3	SLD 1 x SLD 7	548	6.21	22.21	93.07	19.607	2.014	0.448	22.24
4	SLD 1 x SLD 8	548	6.07	21.17	96.98	20.667	2.006	0.468	23.32
5	SLD 1 x SLD 9	546	6.17	22.17	95.52	20.653	2.023	0.467	23.07
6	SLD 1 x SLD 10	548	6.07	22.07	95.08	20.510	2.039	0.439	21.52
7	SLD 2 x SLD 5	534	6.17	22.17	94.95	20.274	2.055	0.454	22.13
8	SLD 2 x SLD 6	537	6.05	21.05	95.92	19.780	1.991	0.429	21.57
9	SLD 2 x SLD 7	560	6.12	22.12	95.28	20.100	2.015	0.440	21.83
10	SLD 2 x SLD 8	565	6.06	22.06	95.45	19.423	1.962	0.454	23.11
11	SLD 2 x SLD 9	541	6.17	22.17	95.82	19.550	1.962	0.436	22.25
12	SLD 2 x SLD 10	579	6.05	22.05	96.59	20.034	2.035	0.437	21.48
13	SLD 3 x SLD 5	532	6.05	22.00	94.89	19.200	1.976	0.420	21.24
14	SLD 3 x SLD 6	543	6.02	21.12	93.74	19.114	1.966	0.421	21.40
15	SLD 3 x SLD 7	559	6.09	22.02	94.42	19.200	1.963	0.421	21.42
16	SLD 3 x SLD 8	551	6.08	21.18	95.92	19.859	2.013	0.444	22.05
17	SLD 3 x SLD 9	549	6.17	21.19	94.92	19.200	1.906	0.413	21.68
18	SLD 3 x SLD 10	554	6.02	21.02	95.09	19.780	1.986	0.422	21.23
19	SLD 4 x SLD 5	551	6.20	22.20	96.25	20.557	2.067	0.457	22.10
20	SLD 4 x SLD 6	575	6.02	21.02	95.05	19.834	2.001	0.442	22.08
21	SLD 4 x SLD 7	528	6.17	21.17	95.65	19.890	1.981	0.435	21.97
22	SLD 4 x SLD 8	564	6.06	22.06	96.68	20.357	2.031	0.472	23.22
23	SLD 4 x SLD 9	524	6.16	22.16	96.00	19.537	1.959	0.447	22.84
24	SLD 4 x SLD 10	569	6.07	22.00	95.67	19.782	1.961	0.430	21.92
25	SLD 5 x SLD 1	558	6.19	22.19	93.93	19.817	2.029	0.441	21.74

26	SLD 5 x SLD 2	547	6.20	22.20	93.90	19.583	1.971	0.428	21.72
27	SLD 5 x SLD 3	549	6.16	22.04	94.04	18.480	1.983	0.423	21.30
28	SLD 5 x SLD 4	551	6.19	22.19	94.59	20.115	1.976	0.439	22.22
29	SLD 6 x SLD 1	529	6.07	21.07	93.34	19.387	1.984	0.435	21.95
30	SLD 6 x SLD 2	541	6.07	21.07	94.38	19.249	1.977	0.427	21.58
31	SLD 6 x SLD 3	540	6.07	21.17	94.27	19.029	1.945	0.420	21.59
32	SLD 6 x SLD 4	570	6.07	21.07	96.07	19.640	1.980	0.439	22.16
33	SLD 7 x SLD 1	564	7.00	23.00	93.58	19.409	2.012	0.442	21.99
34	SLD 7 x SLD 2	552	6.16	22.16	93.74	18.889	1.952	0.426	21.79
35	SLD 7 x SLD 3	536	6.14	22.02	94.18	19.495	1.981	0.425	21.45
36	SLD 7 x SLD 4	552	6.19	21.21	94.94	18.942	1.944	0.425	21.85
37	SLD 8 x SLD 1	561	6.12	21.22	95.67	19.810	2.001	0.460	22.96
38	SLD 8 x SLD 2	556	6.09	22.09	96.00	19.760	1.963	0.452	23.03
39	SLD 8 x SLD 3	551	6.15	22.15	94.39	19.610	1.948	0.427	21.89
40	SLD 8 x SLD 4	572	6.10	22.10	96.07	20.507	2.059	0.470	22.82
41	SLD 9 x SLD 1	548	6.19	22.19	93.75	19.255	2.055	0.457	22.23
42	SLD 9 x SLD 2	557	6.19	22.19	94.64	19.792	1.977	0.434	21.96
43	SLD 9 x SLD 3	537	6.20	22.00	93.44	18.430	1.916	0.412	21.49
44	SLD 9 x SLD 4	533	6.16	22.16	93.87	19.240	1.970	0.437	22.18
45	SLD 10 x SLD 1	554	6.07	22.07	94.10	19.302	1.975	0.427	21.63
46	SLD 10 x SLD 2	547	6.07	22.07	95.30	18.967	1.958	0.423	21.58
47	SLD 10 x SLD 3	570	6.12	21.12	94.00	18.397	1.957	0.419	21.38
48	SLD 10 x SLD 4	530	6.09	21.19	93.72	18.884	1.952	0.421	21.54
49	CSR 2 x CSR 4 (Control)	544	7.02	23.07	95.47	19.277	1.995	0.448	22.48
	Mean	549	6.12	22.03	94.92	19.635	1.992	0.438	22.00
	SD	13.5	0.06	0.13	0.98	0.622	0.044	0.016	0.55
	CD 5%	3.7	0.01	0.03	0.27	0.171	0.012	0.004	0.15
	CV%	2.45	4.06	2.58	1.04	3.17	2.21	3.71	2.52

TABLE-1 Performance of forty-eight new hybrid combinations (Continued)

Sl No	Hybrid	AVFL (m)	Denier (d)	Raw Silk (%)	Rend	Reel(%)	Nt. (Pts)
1	SLD 1 x SLD 5	1039	2.91	17.06	5.86	84.33	93
2	SLD 1 x SLD 6	1030	2.99	16.71	5.99	85.50	93
3	SLD 1 x SLD 7	1027	2.93	17.24	5.81	87.17	92
4	SLD 1 x SLD 8	1256	2.63	18.55	5.39	85.67	94
5	SLD 1 x SLD 9	1030	3.30	17.55	5.70	84.00	92
6	SLD 1 x SLD 10	991	2.70	15.88	6.31	85.00	92
7	SLD 2 x SLD 5	1003	3.36	17.16	5.85	86.34	92
8	SLD 2 x SLD 6	1031	2.90	17.27	5.80	85.00	93
9	SLD 2 x SLD 7	974	3.00	17.33	5.77	87.67	92
10	SLD 2 x SLD 8	1163	2.74	18.51	5.41	86.33	94
11	SLD 2 x SLD 9	1074	2.93	17.87	5.60	86.50	94
12	SLD 2 x SLD 10	1016	3.13	15.89	6.30	85.67	93
13	SLD 3 x SLD 5	1157	2.80	17.10	5.85	86.67	93
14	SLD 3 x SLD 6	1034	3.03	15.93	6.29	87.84	92
15	SLD 3 x SLD 7	976	3.16	16.78	5.97	89.00	93
16	SLD 3 x SLD 8	1102	2.85	17.07	5.87	84.00	93
17	SLD 3 x SLD 9	1118	2.69	16.09	6.22	87.17	93
18	SLD 3 x SLD 10	970	2.74	16.65	6.01	86.34	93

19	SLD 4 x SLD 5	999	3.00	16.75	5.98	84.83	92
20	SLD 4 x SLD 6	1091	3.06	17.90	5.59	85.00	94
21	SLD 4 x SLD 7	1105	3.01	17.03	5.88	88.00	93
22	SLD 4 x SLD 8	1161	2.86	19.46	5.14	88.00	94
23	SLD 4 x SLD 9	1162	2.87	18.63	5.37	86.00	94
24	SLD 4 x SLD 10	1055	2.94	17.21	5.82	86.33	93
25	SLD 5 x SLD 1	1024	3.03	16.45	6.09	85.00	93
26	SLD 5 x SLD 2	1026	3.22	17.16	5.83	84.00	93
27	SLD 5 x SLD 3	1032	2.98	16.71	5.99	85.00	93
28	SLD 5 x SLD 4	971	3.13	16.98	5.90	84.33	93
29	SLD 6 x SLD 1	1008	3.15	16.56	6.04	86.00	93
30	SLD 6 x SLD 2	1018	2.96	16.81	5.95	86.33	93
31	SLD 6 x SLD 3	1033	3.03	15.76	6.35	85.67	92
32	SLD 6 x SLD 4	1070	2.95	17.86	5.61	84.33	94
33	SLD 7 x SLD 1	1002	3.15	17.24	5.81	86.00	92
34	SLD 7 x SLD 2	984	2.80	16.66	6.01	85.34	92
35	SLD 7 x SLD 3	989	3.04	16.13	6.20	84.00	92
36	SLD 7 x SLD 4	1041	3.23	16.75	5.98	84.00	93
37	SLD 8 x SLD 1	1226	2.58	18.06	5.54	85.00	94
38	SLD 8 x SLD 2	1139	2.66	18.42	5.43	87.00	94
39	SLD 8 x SLD 3	1066	2.88	16.68	6.00	83.00	93
40	SLD 8 x SLD 4	1229	2.62	18.58	5.39	84.67	94
41	SLD 9 x SLD 1	1055	3.30	17.20	5.82	85.67	93
42	SLD 9 x SLD 2	1021	3.12	17.22	5.81	83.34	94
43	SLD 9 x SLD 3	1020	2.91	16.15	6.20	84.34	93
44	SLD 9 x SLD 4	1104	2.86	17.45	5.74	85.00	94
45	SLD 10 x SLD 1	956	2.80	15.52	6.45	85.00	92
46	SLD 10 x SLD 2	941	3.10	15.77	6.34	83.00	93
47	SLD 10 x SLD 3	981	2.92	16.39	6.11	84.67	92
48	SLD 10 x SLD 4	1013	3.09	16.54	6.05	83.67	92
49	CSR 2 x CSR 4 (Control)	1124	2.83	17.97	5.57	82.67	94
	Mean	1054	2.96	17.07	5.88	85.42	92.98
	SD	73.96	0.19	0.87	0.29	1.43	0.75
	CD 5%	20.31	0.05	0.24	0.08	0.39	0.21
	CV%	7.02	6.27	5.07	4.98	1.67	0.81

TABLE-2. Evaluation (Multiple trait) Index for forty-eight new combinations.

Sl No.	Hybrid	Fec.	Lar. Vth	Dur. Total	Pup. rate	ERR Wt (Kgs)	SCW (g)	SSW (g)	Shell (%)
1	SLD 1 x SLD 5	45.97	39.60	40.63	59.70	77.16	79.53	68.80	52.11
2	SLD 1 x SLD 6	31.14	68.85	68.21	47.31	65.62	76.80	63.88	47.07
3	SLD 1 x SLD 7	48.94	36.52	37.81	31.25	49.55	55.01	55.89	54.27
4	SLD 1 x SLD 8	48.94	58.07	57.61	70.98	66.58	53.20	68.18	73.74
5	SLD 1 x SLD 9	47.46	42.68	40.63	56.15	66.36	57.06	67.57	69.23
6	SLD 1 x SLD 10	48.94	58.07	47.71	51.68	64.06	60.69	50.35	41.30
7	SLD 2 x SLD 5	38.55	42.68	40.63	50.35	60.27	64.32	59.58	52.29
8	SLD 2 x SLD 6	40.78	61.15	70.33	60.21	52.33	49.79	44.20	42.20

9	SLD 2 x SLD 7	57.84	50.38	44.17	53.71	57.47	55.24	50.97	46.88
10	SLD 2 x SLD 8	61.55	59.61	48.41	55.43	46.60	43.21	59.58	69.95
11	SLD 2 x SLD 9	43.75	42.68	40.63	59.19	48.64	43.21	48.51	54.45
12	SLD 2 x SLD 10	71.94	61.15	49.12	67.02	56.41	59.78	49.12	40.58
13	SLD 3 x SLD 5	37.07	61.15	52.66	49.74	43.01	46.39	38.67	36.25
14	SLD 3 x SLD 6	45.23	65.77	61.14	38.06	41.63	44.12	39.28	39.14
15	SLD 3 x SLD 7	57.10	55.00	51.24	44.97	43.01	43.44	39.28	39.50
16	SLD 3 x SLD 8	51.17	56.54	56.90	60.21	53.60	54.79	53.43	50.85
17	SLD 3 x SLD 9	49.68	42.68	56.19	50.05	43.01	30.50	34.36	44.18
18	SLD 3 x SLD 10	53.39	65.77	68.21	51.78	52.33	48.66	39.90	36.07
19	SLD 4 x SLD 5	51.17	34.98	38.51	63.56	64.82	67.04	61.42	51.75
20	SLD 4 x SLD 6	68.97	65.77	68.21	51.37	53.20	52.06	52.20	51.39
21	SLD 4 x SLD 7	34.10	42.68	57.61	57.47	54.10	47.52	47.89	49.41
22	SLD 4 x SLD 8	60.81	59.61	48.41	67.93	61.60	58.87	70.64	71.93
23	SLD 4 x SLD 9	31.14	44.22	41.34	61.02	48.43	42.53	55.27	65.09
24	SLD 4 x SLD 10	64.52	58.07	52.66	57.67	52.36	42.98	44.82	48.51
25	SLD 5 x SLD 1	56.36	39.60	39.22	39.99	52.93	58.42	51.58	45.26
26	SLD 5 x SLD 2	48.20	38.06	38.51	39.69	49.17	45.25	43.59	44.90
27	SLD 5 x SLD 3	49.68	44.22	52.66	41.11	31.45	47.98	40.51	37.33
28	SLD 5 x SLD 4	51.17	39.60	42.05	46.70	57.71	46.39	50.35	53.91
29	SLD 6 x SLD 1	34.85	58.07	64.68	34.00	46.02	48.20	47.89	49.05
30	SLD 6 x SLD 2	43.75	58.07	64.68	44.56	43.80	46.61	42.97	42.38
31	SLD 6 x SLD 3	43.01	58.07	57.61	43.45	40.27	39.35	38.67	42.56
32	SLD 6 x SLD 4	65.26	58.07	64.68	61.73	50.08	47.29	50.35	52.83
33	SLD 7 x SLD 1	60.81	31.90	35.68	36.44	46.37	54.56	52.20	49.77
34	SLD 7 x SLD 2	51.91	44.22	41.34	38.06	38.02	40.94	42.36	46.16
35	SLD 7 x SLD 3	40.04	47.30	51.24	42.53	47.75	47.52	41.74	40.04
36	SLD 7 x SLD 4	51.91	39.60	54.78	50.25	38.87	39.12	41.74	47.25
37	SLD 8 x SLD 1	58.58	50.38	54.07	57.67	52.81	52.06	63.26	67.25
38	SLD 8 x SLD 2	54.87	55.00	46.29	61.02	52.01	43.44	58.35	68.51
39	SLD 8 x SLD 3	51.17	45.76	42.05	44.67	49.60	40.03	42.97	47.97
40	SLD 8 x SLD 4	66.74	53.46	45.58	61.73	64.01	65.23	69.41	64.73
41	SLD 9 x SLD 1	48.94	39.60	39.22	38.16	43.90	64.32	61.42	54.09
42	SLD 9 x SLD 2	55.62	39.60	39.22	47.21	52.53	46.61	47.28	49.23
43	SLD 9 x SLD 3	40.78	38.06	52.66	35.01	30.64	32.77	33.75	40.76
44	SLD 9 x SLD 4	37.81	44.22	41.34	39.38	43.66	45.02	49.12	53.19
45	SLD 10 x SLD 1	53.39	58.07	47.71	41.72	44.65	46.16	42.97	43.28
46	SLD 10 x SLD 2	48.20	58.07	47.71	53.91	39.27	42.30	40.51	42.38
47	SLD 10 x SLD 3	65.26	50.38	61.14	40.70	30.11	42.07	38.05	38.78
48	SLD 10 x SLD 4	35.59	55.00	56.19	37.86	37.94	40.94	39.28	41.66
49	CSR 2 x CSR 4 (Control)	45.97	31.90	30.73	55.64	44.25	50.70	55.89	58.60

TABLE-2. Evaluation (Multiple trait) Index for forty-eight new combinations (Continued).

Sl No.	Hybrid	AVFL (m)	Denier (d)	Raw Silk (%)	Rend	Reel (%)	Nt. (Pts)	AVG EI
1	SLD 1 x SLD 5	48.00	52.51	49.84	50.59	42.41	50.27	54.08
2	SLD 1 x SLD 6	46.78	66.72	45.79	44.2	50.59	50.27	54.05

3	SLD 1 x SLD 7	46.37	51.43	51.91	52.3	62.26	36.93	47.89
4	SLD 1 x SLD 8	77.34	67.61	67.04	66.64	51.77	63.61	63.67
5	SLD 1 x SLD 9	46.78	31.48	55.49	56.05	40.1	36.93	51.00
6	SLD 1 x SLD 10	41.51	63.83	36.21	35.23	47.09	36.93	48.83
7	SLD 2 x SLD 5	43.13	28.24	50.99	50.93	56.46	36.93	48.24
8	SLD 2 x SLD 6	46.92	53.05	52.26	52.64	47.09	50.27	51.66
9	SLD 2 x SLD 7	39.21	47.66	52.95	53.66	65.76	36.93	50.92
10	SLD 2 x SLD 8	64.76	61.68	66.58	65.95	56.39	63.61	58.81
11	SLD 2 x SLD 9	52.73	51.43	59.19	59.47	57.58	63.61	51.79
12	SLD 2 x SLD 10	44.89	40.64	36.32	35.57	51.77	50.27	51.04
13	SLD 3 x SLD 5	63.95	58.44	50.3	50.93	58.77	50.27	49.83
14	SLD 3 x SLD 6	47.32	46.04	36.78	35.91	66.95	36.93	46.02
15	SLD 3 x SLD 7	39.48	39.03	46.6	46.84	75.06	50.27	47.91
16	SLD 3 x SLD 8	56.51	55.75	49.95	50.25	40.1	50.27	52.88
17	SLD 3 x SLD 9	58.68	64.37	38.63	38.3	62.26	50.27	47.37
18	SLD 3 x SLD 10	38.67	61.68	45.1	45.47	56.46	50.27	50.98
19	SLD 4 x SLD 5	42.59	47.66	46.25	46.5	45.9	36.93	49.93
20	SLD 4 x SLD 6	55.03	44.42	59.54	59.81	47.09	63.61	56.62
21	SLD 4 x SLD 7	56.92	47.12	49.49	49.91	68.06	50.27	50.90
22	SLD 4 x SLD 8	64.49	55.21	77.55	75.17	68.06	63.61	64.57
23	SLD 4 x SLD 9	64.63	54.67	67.97	67.32	54.08	63.61	54.38
24	SLD 4 x SLD 10	50.16	50.89	51.57	51.96	56.39	50.27	52.34
25	SLD 5 x SLD 1	45.97	46.04	42.79	42.74	47.09	50.27	47.02
26	SLD 5 x SLD 2	46.24	35.79	50.99	51.62	40.1	50.27	44.46
27	SLD 5 x SLD 3	47.05	48.73	45.79	46.15	47.09	50.27	45.00
28	SLD 5 x SLD 4	38.80	40.64	48.91	49.23	42.41	50.27	47.01
29	SLD 6 x SLD 1	43.81	39.57	44.06	44.45	54.08	50.27	47.07
30	SLD 6 x SLD 2	45.16	49.81	46.95	47.52	56.39	50.27	48.78
31	SLD 6 x SLD 3	47.19	46.04	34.82	33.87	51.77	36.93	43.83
32	SLD 6 x SLD 4	52.19	50.35	59.07	59.13	42.41	63.61	55.50
33	SLD 7 x SLD 1	42.99	39.57	51.91	52.3	54.08	36.93	46.11
34	SLD 7 x SLD 2	40.56	58.44	45.22	45.47	49.47	36.93	44.22
35	SLD 7 x SLD 3	41.24	45.5	39.09	38.99	40.1	36.93	42.86
36	SLD 7 x SLD 4	48.27	35.25	46.25	46.5	40.1	50.27	45.01
37	SLD 8 x SLD 1	73.28	70.31	61.38	61.51	47.09	63.61	59.52
38	SLD 8 x SLD 2	61.52	65.99	65.54	65.27	61.07	63.61	58.75
39	SLD 8 x SLD 3	51.65	54.13	45.45	45.81	33.11	50.27	46.04
40	SLD 8 x SLD 4	73.69	68.15	67.39	66.64	44.78	63.61	62.51
41	SLD 9 x SLD 1	50.16	31.48	51.45	51.96	51.77	50.27	48.34
42	SLD 9 x SLD 2	45.56	41.18	51.68	52.3	35.49	63.61	47.65
43	SLD 9 x SLD 3	45.43	52.51	39.33	38.99	42.48	50.27	40.96
44	SLD 9 x SLD 4	56.79	55.21	54.34	54.69	47.09	63.61	48.96
45	SLD 10 x SLD 1	36.77	58.44	32.05	30.45	47.09	36.93	44.26
46	SLD 10 x SLD 2	34.75	42.26	34.94	34.21	33.11	50.27	42.99
47	SLD 10 x SLD 3	40.15	51.97	42.1	42.06	44.78	36.93	44.61
48	SLD 10 x SLD 4	44.48	42.8	43.83	44.11	37.79	36.93	42.46
49	CSR 2 x CSR 4 (Control)	59.49	56.82	60.34	60.49	30.8	63.61	50.37

The evaluation index as described above in the materials and methods were obtained for fourteen traits for all fourty eight new hybrid combinations (Table-2). Values for fifth age larval duration and total larval duration were first converted from Day: Hours in to Hours and then, index values were obtained, to keep the arithmetic right.

A quick glance on the Table-2 reveals that out of fourty eight new hybrid combinations, twenty combinations had scored > 50 as evaluation index value. They are, SLD 1 x SLD 5, SLD 1 x SLD 6, SLD 1 x SLD 8, SLD 1 x SLD 9, SLD 2 x SLD 6, SLD 2 x SLD 7, SLD 2 x SLD 8, SLD 2 x SLD 9, SLD 2 x SLD 10, SLD 3 x SLD 10, SLD 3 x SLD 10, SLD 4 x SLD 6, SLD 4 x SLD 7, SLD 4 x SLD 8, SLD 4 x SLD 9, SLD 4 x SLD 10, SLD 6 x SLD 4, SLD 8 x SLD 1, SLD 8 x SLD 2 and SLD 8 x SLD 4. The highest index score of 64.57 was observed with SLD 4 x SLD 8, followed by 63.67 with SLD 1 x SLD 8. The least index score of 40.96 was observed with SLD 9 x SLD 3. As a female component, it was clearly seen that SLD 4, SLD 2 and also, SLD 1 had performed well with 5, 5 and 4 combinations respectively, out of total 6 combinations made and whereas SLD 3 had performed well only with 2 out of total 6 combinations. As a male component, SLD 8, had performed very well of having combined fairly with all 4 out of 4 combinations. Further, there was a clear indication of reciprocal effect as the straight combinations as much as 16 out of total 24 combinations had performed well by scoring > 50 index value, whereas only 4 out of total 24 combinations as reciprocals could score > 50 as index value.

While considering the individual traits, 22 combinations had scored >50 index value for fecundity, 26 combinations had scored >50 index value for fifth age larval duration, 23 combinations had scored > 50 index value for total larval duration, 25 combinations had scored > 50 index value for pupation rate, 23 combinations had scored >50 for cocoon yield by weight for 10,000 larvae, 19 combinations had scored >50 for cocoon weight, 23 combinations had scored >50 for cocoon shell weight, 20 combinations had scored >50 for cocoon shell percentage, 19 combinations had scored >50 for average filament length, 26 combinations had scored > 50 for cocoon filament size, 22 combinations had scored >50 for raw silk content, 25 combinations had scored >50 for renditta, 23 combinations had scored for reelability and 35 combinations had scored >50 for neatness, out of 49 combinations (including control hybrid).

On the consideration of top performers, SLD 4 x SLD 8 had scored an index value of 64.57 and its reciprocal, SLD 8 x SLD 4, had scored an index value of 62.51. The second best combination, SLD 1 x SLD 8 had scored 63.67 as index value, while the reciprocal, SLD 8 x SLD 1, had scored 59.52. Other significant performers includes, SLD 2 x SLD8 and SLD 4 x SLD 6, with the score of 58.81 and 56.62 as index value respectively, while their reciprocals, SLD 8 x SLD 2 and SLD 6 x SLD 4, has also, scored 58.75 and 55.50, as index values. Though the combinations SLD 1 x SLD 5 and SLD 1 x SLD 6, had scored 54.08 and 56.74 as index values, their reciprocals, SLD 5 x SLD 1 and SLD 6 x SLD 1, had scored only 47.02 and 47.07 as index values. Same is the case in SLD 4 x SLD 9, as though it had scored 54.38 as index value, the reciprocal, SLD 9 x SLD 4, had scored only 48.96. There are also, other mediocre performers viz., SLD 1 x SLD 9, SLD 2 x SLD 6, SLD 2 x SLD 7, SLD 2 x SLD 9, SLD 2 x SLD 10, SLD 3 x SLD 10, SLD 4 x SLD 7 and SLD 4 x SLD 10, wherein the index values hovers around 50 to 52, while their reciprocals could only get <50.

DISCUSSION

Forty-eight new hybrid combinations after multiple trait index scoring were short-listed to twenty combinations which had scored >50, which is about 41% of total combinations made for the study. This on the one hand, shows that a good number of combinations had in possession of various economic traits at a desirable level and on the other hand the extent of phonotypic expression had more or less in nearby spheres, though their parental resources are from distinct groups. Alternately, one can say that the objective of obtaining hybrid combinations possessing genetic constellation as desired by way of target perceived in the breeding programme and the degree of success obtained through adopting various breeding manipulation strategies, has been largely satisfactory as denoted by the performance scored by above 41% combinations.

Clearly the best performers are SLD 4 x SLD 8 and SLD 1 x SLD 8, wherein the compatibility expressed in most of the economically important traits in both straight as well as reciprocals are significantly higher. Further, it can well be derived that SLD 2 x SLD 8 and SLD 4 x SLD 6, were also, in the run for the potentially good combiners as evidenced by their fairly good expression of various economic traits. On the other hand, the odd performers, SLD 1 x SLD 5, SLD 1 x SLD 6, SLD 4 x SLD 9, reveals that their compatibility and the combining ability were less in the expression of many economically important traits.

According to Kovolov (1970), the improvement of indigenous races could be achieved through hybridization utilizing exotic races. Further, Harada (1956) opined that new silkworm breeds could only be evolved through hybridization followed by selection. Hybridisation studies involving distinct group of parents in the present study, had resulted in the development of new breeds with relatively shorter larval duration and possessing productivity traits In silkworms, studies carried out for various characters have shown that the characters could be changed to suit the breeders choice, since selection for one trait has correlation with genetic change of other characters. The correlation for few traits is negative and for some it is positive (Tsuchiya and Kurashima, 1959 and 1960; Ohi *et al.,* 1970; Gamo and Ichiba, 1971; Gamo, 1976). Most of the economic traits in silkworm are of polygenic nature and are under the influence of environment (Yokoyama, 1979). By adopting appropriate selection pressure on early spinners and monitoring the possession of productivity traits in such segregated population, polygenes of desired genetic constellation are obtained in the new breeds developed.

The final aim of the breeder is primarily to evolve a breed which can give rise to stabilized crops and secondly to improve both quantity and quality of silk (Tazima, 1984). Evaluation studies carried out covering fourteen economically important traits on pre-cocoon, cocoon and post-cocoon areas in the present study is certainly, aimed in this direction. The new superior hybrid combinations developed from this study viz., SLD 4 x SLD 8, SLD 1 x SLD 8, SLD 2 x SLD 8, SLD 4 x SLD 6 and SLD 4 x SLD 9, are clearly directed towards this goal and are expected to fare under not only sub-tropical conditions as they are derived with relatively shorter larval duration but also, under plain conditions as they are in better position to overcome poor yield levels.

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