Int. J. Indust. Entomol. Vol. 3, No. 1, 2001, pp. 31~35

International Journal of
Industrial Entomology

Evaluation and Identification of Promising Bivoltine Hybrids of Silkworm, *Bombyx mori* L., for Tropics

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(Received 7 May 2001; Accepted 19 July 2001)

Ten newly evolved bivoltine hybrids of silkworm (*Bombyx mori* L) were evaluated with control hybrid KA × NB4D2 during three seasons of a year for their seasonal performance. Analysis of variance and other statistical methods were employed and the performance was observed in respect of 10 quantitative traits. The results showed significant genotype × environment interaction with respect to four quantitative characters viz. fecundity, yield/10,000 larvae, filament length and raw silk (%). Environmental effects were significant for nine characters out of ten characters evaluated. A 105 × J2 and B × NB4D2 were considered as highly adaptable hybrids to local conditions with high mean for maximum characters studied and found suitable to rear in all seasons.

Key words : Cocoon yield, Genotype × environment interaction, Adaptability, Hybrids

Introduction

The stability of a variety or a breed is greatly influenced by the genotype environment interactions. The choice of a breed/ hybrid, therefore depends not only the genotype itself but also on its performance under diverse environmental conditions. (Rahman and Ahmed, 1988). Silkworm, *Bombyx mori L.*, is very sensitive to climatic fluctuations and as a consequence silk content in the cocoon is greatly affected. The climatic conditions specially temperature, humidity and leaf quality during the rearing seasons highly variable. Moreover the adaptability of bivoltine silkworm races in tropics found to be inconsistent in the expression of quantitative traits in the different seasons of the year resulting frequent crop losses. In the present investigation some newly evolved bivoltine hybrids of *Bombyx mori L.* were evaluated during different seasons along with control hybrid (KA × NB4D2) in an attempt to identify the most suitable variety or varieties with respect to silk yield under diverse climatic conditions of India.

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Materials and Methods

Nine newly evolved bivoltine breeds i.e. A 101, A 102, A 103, A 104, A 105 (Chinese type) B102(P), B102(M), B103 and B104 (Japanese type) and popular breeds KA, NB4D2 and Productive breeds i.e. CSR2, CSR18, CSR19, CSR4, CSR5, B, and J2 evolved by Central Sericulture Research and Training Institute, Mysore were formed experimental material. Eighty-one hybrids were prepared and reared in 3 replicates of each having 300 larvae once during favourable season and short listed to 10 hybrids based on Evaluation Index method (Mano *et al.*, 1993). All the ten hybrids along with control hybrid KA x NB4D2 were reared twice in three different seasons each i.e., Pre-Mon soon (March - May) characterised by high-temperature, low humidity and no rainfall, in the Monsoon season (June- October) characterised by moderate temperature, high humidity and moderate to heavy rainfall and in the Post-monsoon season (November-February) characterized by low temperature and low humidity. The rearing performance of the new and control hybrids were studied in 3 different seasons of the year with respect to the 10 quantitative traits i.e.: fecundity, larval duration, yield/10,000 larvae by number, by weight, cocoon weight, shell weight, shell ratio (%), filament length, raw silk (%)

and reelability (%). Fifty to sixty good cocoons were randomly selected and reeled by using semi-automatic/multi ends reeling machine. The results obtained were subjected to two-way classification (Kempthorne, 1952) to know the genotype- environment interaction and evaluated by applying two Evaluation methods to identify the most promising hybrids.

1. Two-way classification model (Kempthorne, 1952)

Yij = U + Ri + Sj + (RS) ij + eij where

Table 1. Seasonal mean values of short- listed hybrids

Hybrid	Season	Fecundity	Larval duration	Yield/10,000 larvae By No	Yield/10,000 larvae By Wt. (Kg)	Cocoon wt. (g)	Shell wt (g)	Shell. Ratio %	Filament length (m)	Raw silk %	Reelability%
A102 x B102	Pre monsoon	525	20.68	8211	16.26	1.764	0.409	23.18	1169	17.09	84.88
A102 x 102	Monsoon	543	22.40	9322	16.88	1.988	0.453	22.78	1174	18.47	84.89
A102 x B102	Post monsoon	554	21.38	9555	18.25	1.807	0.403	22.30	1090	17.74	76.02
A102 x J2	Pre monsoon	518	20.08	7833	15.62	1.679	0.369	21.97	1061	16.93	79.03
A102 x J2	Monsoon	553	21.75	9277	15.84	1.834	0.422	23.01	1031	17.97	85.42
A102 x J2	Post monsoon	593	21.08	9483	17.60	1.786	0.400	22.39	1048	17.48	73.71
A103 x	Pre monsoon	510	20.37	8856	16.22	1.646	0.370	22.47	1008	17.60	87.26
NB4D2	Monsoon	562	22.04	9155	18.52	1.989	0.442	23.48	1244	17.82	90.34
"	Post monsoon	535	20.44	9377	16.37	1.767	0.400	22.63	1097	18.93	83.66
A103 x J2	Pre monsoon	527	20.37	9122	14.77	1.646	0.372	22.60	1060	16.96	89.51
A103 x J2	Monsoon	547	22.04	9177	17.45	1.814	0.427	23.54	1035	17.62	88.55
A103 x J2	Post monsoon	543	21.34	9288	17.06	1.727	0.375	21.71	1132	19.18	84.36
A104 x B102	Pre monsoon	507	20.12	8578	15.31	1.808	0.429	23.72	1055	14.64	89.33
A104 x B102	Monsoon	560	22.04	9144	16.81	1.908	0.444	23.27	1046	18.64	89.18
A104 x B102	Post monsoon	526	21.37	9588	17.41	1.835	0.428	23.32	1109	17.58	87.65
A104 x J2	Pre monsoon	497	20.41	8918	15.62	1.762	0.390	22.13	1099	17.32	90.54
A104 x J2	Monsoon	594	22.10	9367	17.83	1.893	0.432	22.82	1007	18.02	91.22
A104 x J2	Post monsoon	572	21.34	9189	16.82	1.908	0.412	21.60	1060	18.71	87.55
A104 x	Pre monsoon	512	20.37	8589	16.21	1.782	0.395	22.17	1004	15.43	87.74
NB4D2	Monsoon	561	22.39	9322	16.76	1.935	0.437	22.59	965	18.83	83.94
"	Post monsoon	554	21.70	9435	18.32	1.932	0.422	21.84	1044	18.11	89.43
A105 x J2	Pre monsoon	508	20.14	9011	15.47	1.795	0.412	22.97	1109	14.91	90.45
A105 x J2	Monsoon	581	22.04	9216	15.72	1.889	0.447	23.66	1042	16.72	90.65
A105 x J2	Post monsoon	561	21.40	9572	19.69	1.968	0.452	22.96	1014	19.32	82.12
B x NB4D2	Pre monsoon	515	20.08	9067	16.77	1.788	0.398	22.25	1090	16.49	88.98
B x NB4D2	Monsoon	521	22.19	9222	19.03	1.950	0.460	23.58	1017	17.48	90.24
B x NB4D2	Post monsoon	527	21.39	9394	19.81	1.819	0.421	23.14	1048	17.41	83.22
B xJ2	Pre monsoon	427	20.14	9039	14.61	1.780	0.394	22.13	1023	16.44	88.84
B xJ2	Monsoon	585	22.06	9189	18.45	1.788	0.406	22.70	1061	17.18	91.52
B xJ2	Post monsoon	581	21.41	9380	17.47	1.957	0.449	22.94	1105	17.59	86.86
KA x	Pre monsoon	519	20.19	8544	15.21	1.774	0.370	20.85	990	13.20	82.06
NB4D2	Monsoon	545	23.45	9144	16.12	1.882	0.394	20.94	998	13.67	87.10
control	Post monsoon	532	21.39	9267	16.58	1.875	0.385	20.53	1009	13.42	81.19

Yij = Effect of i th race in the j th season
U = Constant effect
Ri = Effect of i th race
Sj = Effect of j th season
(RS) ij = Interaction effect of i th race and j th season
eij = Random component effect

2. Subordinate function method (Gower, 1971). The values of subordinate function is calculated using the following formula:

Xu = (Xi – X min) / (X max – X min)

where,

Xu = Subordinate function.
Xi = Measurement of character of a tested genotype.
X max = The maximum value of the character from all the tested genotypes.
Xmin = Minimum value of the character among all the tested genotypes.

3. Evaluation Index (Mano *et al.*, 1993) The values of evaluation index were calculated by using the following formula.

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

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

Results

The data obtained were pooled in Table 1, 2, 3 and 4. The analysis of variance (ANOVA) results depicted in Table 1 showed significant differences among the hybrids for larval duration, shell weight, shell ratio (%), filament length, raw silk (%) and reelability (%). Genotype × environmental effects were highly significant ($P < 0.01$) for four quantitative traits i.e. fecundity, yield/10,000 larvae, filament length and raw silk (%). Among the hybrids, significant seasonal variations were found for all the ten quantitative traits evaluated.

The highest mean values (Table 2) for the majority of the traits i.e., yield/10,000 larvae by number, by weight, cocoon weight, shell weight, shell ratio (%), filament length, raw silk (%) and reelability (%) were recorded for two newly evolved hybrids A 105 × J2 and B × NB4D2 in both the methods. The values of sub-ordinate function and Evaluation Index were presented in Table 3 and 4. Based on the highest values obtained for majority of the traits in both the methods, hybrids A 105 × J2 and B × NB4D2 were excelled over control hybrid KA × NB4D2 and adjudged as most promising hybrids suitable to rear in all seasons.

Discussion

The primary goal of silkworm breeding includes simultaneous genetic improvement in the economic value of the population and to exploit it commercially. To assess the

Table 2. Mean sum of squares (M.S) values for important economic traits

	Fecundity	Larval duration	ERR No	ERR .wt	Cocoon wt.	Shell wt	S.R %
Race	1263.17 N.S	0.429*	144358.35 N.S	4.134 N.S	0.020 NS	0.002*	3.867**
Season	21988.16**	31.696**	3411497.54**	35.148**	0.1663**	0.111**	5.560**
Race x Season	2625.86**	0.285 N.S	307057.47**	3.065 N.S	0.0143 N.S	0.0010 N.S	0.587 N.S
Error	902.52	0.181	134810.28	2.554	0.02000	0.001	0.767
CD (R)	28.295	0.401	345.820	1.505	0.133	0.0331	0.825
CD (S)	14.776	0.209	180.598	0.786	0.069	0.0172	0.430
CD (R x S)	49.009	0.694	598.978	2.607	0.231	0.0573	1.429

	Filament length	Raw Silk %	Reel ability %
Race	19327.36**	16.410**	126.422**
Season	13901.85*	17.042**	178.815**
Race x Season	7738.13**	3.172**	25.551 N.S
Error	3231.27	0.894	26.198
CD (R)	53.539	0.890	4.820
CD (S)	27.960	0.465	2.517
CD (R x S)	92.733	1.543	8.349

Table 3. Evaluation index values of short listed hybrids

Hybrid	Fecundity	ERR No	ERR. wt	Cocoon wt	Shell wt	SR %	Filament Length	Raw Silk %	Reel ability %	Avg. E.I value
A 102 x B102	51.61	42.30	54.11	54.40	55.67	52.65	70.46	55.27	36.04	52.50
A102 x J2	65.22	27.61	41.76	35.54	40.44	46.72	46.30	52.76	27.88	42.69
A 103 x NB4D2	46.45	51.19	52.61	42.98	44.76	54.31	63.52	58.07	52.54	51.82
A103 J2	49.52	57.11	42.70	27.45	37.07	49.49	53.40	56.52	53.77	47.44
A104 x B102	42.06	48.87	44.21	53.91	60.96	62.52	52.06	48.66	57.76	52.33
A104 x J2	65.00	53.71	48.14	54.71	49.36	44.74	48.38	57.28	61.45	53.64
A104 x NB4D2	53.14	49.91	53.58	61.04	53.27	44.49	35.90	52.73	52.38	50.71
A!05 x J2	60.50	63.37	51.38	61.23	65.42	61.36	48.33	48.89	54.63	57.23
B x NB4D2	31.96	59.91	76.37	54.30	58.62	57.42	47.42	50.10	53.79	54.43
B x J2	41.84	57.69	49.54	52.02	52.65	52.00	50.30	49.61	58.89	51.61
KA x NB4D2 (Control)	42.71	38.32	35.58	52.41	31.79	24.30	33.93	20.11	40.88	35.55

Table 4. Sub-ordinate function values

Hybrid	Fecundity	ERR No	ERR. wt	Cocoon wt	Shell wt	SR %	Filament length	Raw Silk %	Reel-ability %	Total value
A 102 x B102	0.590	0.410	0.455	0.800	0.666	0.744	1.000	0.925	0.243	5.833
A102 x J2	1.000	0.000	0.151	0.266	0.333	0.589	0.337	0.859	0.000	3.535
A 103 x NB4D2	0.435	0.659	0.416	0.466	0.333	0.786	0.806	1.000	0.734	5.635
A103 J2	0.538	0.824	0.175	0.000	0.166	0.661	0.530	0.959	0.771	4.614
A104 x B102	0.303	0.594	0.210	0.800	0.833	1.000	0.493	0.752	0.889	5.874
A104 x J2	0.993	0.729	0.307	0.800	0.500	0.535	0.393	0.978	1.000	6.235
A104 x NB4D2	0.636	0.623	0.439	1.000	0.666	0.531	0.053	0.859	0.729	5.536
A!05 x J2	0.858	1.000	0.385	1.000	1.000	0.970	0.392	0.756	0.796	7.157
B x NB4D2	0.000	0.902	1.000	0.800	0.833	0.866	0.367	0.788	0.771	6.237
B x J2	0.297	0.839	0.342	0.733	0.666	0.728	0.446	0.776	0.923	5.750
KA x NB4D2 (Control)	0.323	0.299	0.000	0.733	0.000	0.000	0.000	0.000	0.387	1.742

productivity of silkworm hybrids and to judge their suitability to different seasons, hybrids evolved are subjected to different seasons to evaluate them. The concept of genotype and environment interaction has been well documented in both plants and animal species (Griffing and Zsiorios, 1971). The newly evolved bivoltine hybrids exhibit high degree of phenotypic variability and responded well to the variable climatic conditions prevailing in the tropics. Although it is not necessary to breed a genotype that is adapted to all ecological conditions, breeding methods can be designed towards producing a high yielding one with a considerable degree of general adaptability. The data analyzed regarding the rearing and reeling performance revealed maximum expression for majority of the quantitative traits during the Monsoon and Post-monsoon season. This is in conformity with the earlier findings of Krishnaswami and Narasimhanna, (1974), Das *et al.* (1995), Kalpana and Reddy (1998). The results of present study clearly indicate that the hybrids A105 × J2 and B × NB4D2 has excelled for important economic traits like yield/10,000 larvae, shell ratio (%), filament length and raw silk (%). Eberhart and Russell (1966) defined a stable genotype as one with high mean, regression co-efficient of unity and a minimum deviation from the regression line. Based on mean and stability parameters, it is found that the hybrids A105 × J2 and B × NB4D2 performed well for most of the characters of economic importance and proved to be most suitable hybrids to rear in all seasons. Among the new hybrids, seven hybrids A 102 × B102(P), A102 × J2, A103 × NB4D2, A103 × J2, A104 × J2, A104 × NB4D2 and A105 × J2 possessed more fecundity. Nine hybrids except, A102 × J2 shown more yield/10,000 larvae by number. All the ten new hybrids expressed significant values for yield by weight, shell weight, shell ratio (%), filament length, raw silk (%) and eight hybrids given more reelability (%) when compared to control hybrid KA × NB4D2. This may be attributed to the more efficient synthesis of required proteins and their conversion to raw silk. The longer larval duration in both the newly evolved hybrids and control hybrid may be due to slow growth with reduced rate of metabolism in Monsoon and post monsoon due to low temperature and other associated environmental conditions (Morohoshi, 1969). Thus the above results clearly indicates the superiority of new hybrids over control hybrid KA × NB4D2. Hence the most promising hybrids adjudged to rear are A105 × J2 and B × NB4D2 through out the year under diverse environmental conditions prevails in the tropics.

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