韓蠶學誌 39(2), 205~209(1997)
Korean J. Seric. Sci.
<Short report>

Line X Tester Analysis for Economic Characters in the Bivoltine Silkworm, *Bombyx mori* L.

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ABSTRACT

In a line X tester crossing programme (24 lines and 2 testers) the general combining ability (GCA) and specific combining ability (SCA) effects were analyzed for five economic characters in the bivoltine silkworm, *Bombyx mori* L. The results showed desired GCA effects in 934D1 (9500), 934B (9789) and 934A1 (9855) for cocoon yield per 10,000 larvae brushed by number. Likewise, the lines found to be superior based on GCA effects for other characters were as follows; 931D (14.040 Kgs), 935E (17.023 Kga.), 934D1 (15.643 Kgs.) and 934B (15.687 Kgs.) for cocoon yield by weight: 931D (1.717 g) and 930E (1.796 g) for single cocoon weight; 932B (0.330 g) for single shell weight; 932B (18.7%), 933A (18.86%) and 935A (19.89%) for shell ratio. SCA effects showed the superiority of 932D×KA (9822 cocoon yield per 10,000 larvae brushed by number); 932A×NB4D2 (16.933 Kgs. cocoon yield per 10 000 larvae brushed by weight); 931C×KA (1.911 g single cocoon weight); 934×NB4D2 (0.371 g single shell weight and 21.0% shell ratio). The analysis indicated non-additive gene action for all the five characters.

Key words : Cocoon yield, Non-additive gene action, Combining ability, *Bombyx mori*

INTRODUCTION

There is an urgent need to evolve farmer-friendly bivoltine silkworm races, which do not requrie stringent laboratory conditions for their rearing. Selection of parents on the basis of their combining ability is one of the methods for improvement of the economic characters (Tharvorn-Anukulkit *et al.*, 1992). Line X tester analysis is an useful procedure for the evaluation of genetic stock in determining the gene action of different characters. Keeping this in view, an experiment was initiated during 1991 to improve the survival in bivoltine races. The combining ability of 24 lines and 48 F_1's was noted for cocoon yield and other economic characters.

MATERIALS AND METHODS

A total of 24 genetically diverse inbred lines and 2 testers (Table 2) of silkworm (*Bombyx mori*) were involved in a line X tester crossing programme. Thus, 48 F_1's and their 26 parents (24 lines and 2 testers) were reared together with the control (PM×NB4D2). The experiment was conducted during September-October 1994, as per the method of Krishnaswami (1978). The observations were made on five economic characters namely cocoon yield per 10,000 larvae brushed (by number and weight), single cocoon weight, single shell weight and shell ratio. Data recorded on these characters were subjected to line X tester analysis (Kempthorne, 1957).

RESULTS AND DISCUSSION

1. Analysis of variance

Mean squares (Table 1) were significant for lines (in single cocoon weight, single shell weight and shell ratio), testers (all the characters except cocoon yield by number) and lines X testers (in single cocoon weight and shell ratio). The larger mean

Table 1. *Analysis of variance of combining ability and eatimates of variance components for economic characters in silkworm, Bombyx mori L.*

Source of Variation	Degree of freedom	Mean sum of squares				
		Cocoon yield		single cocoon weight	Single shell weight	Shell ratio
		Number	Weight			
Lines	23	168425.7	2.233	0.030**	0.002**	3.607**
Testers	1	28672.0	3.664**	0.015**	0.004**	7.133
Lines × testers	23	207426.8	2.599	0.021**	0.0009	1.624*
Error	146	465892.0	1.715	0.009	0.0006	0.864
Predictability ratio	-	0.0025	-0.005	0.001	0.0499	0.037

*Significant at 5% level; **Singnificant at 1% level

squares of single cocoon weight for lines compared to testers and lines X testers indicated more diversity in lines for single cocoon weight.

2. General combining ability (GCA) effects

Original sampled data (shown in parentheses) and the estimates of GCA of 24 lines and 2 testers is shown in Table 2. None of the parents showed significant GCA for cocoon yield by number. However, 934D1 (9500), 934B (9789), 934A1 (9855) and 934A2 (9533) could be chosen for cocoon yield by number according to their high GCA. Based on GCA the lines

Table 2. *Entimates of general combining ability (GCA) and original sampled data ($\bar{x}$) for economic characters of 24 lines and 2 testers of silkworm, Bombyxmori L.*

Lines & Testers	Cocoon yield per 10000 larvae brushed				Single cocoon weigh		Single shell weight		Shell ratio	
	Number		Weight							
	x	GCA	x (Kgs.)	GCA	x (g)	GCA	x (g)	GCA	x (%)	GCA
Lines										
930A	9388	-291.590	15.787	-0.128	1.663	0.056	0.332	0.011	19.96	0.036
930A1	8699	-69.257	14.483	-0.200	1.530	-0.033	0.297	-0.028	19.41	-1.408
930B	9089	-269.257	16.800	-0.237	1.571	0.004	0.320	-0.012	20.37	-0.456
930E	9566	63.910	18.060	0.302	1.796	0.069*	0.317	-0.003	17.65	-0.069
930F	9100	-15.424	16.377	0.123	1.668	0.063	0.343	-0.013	20.56	-1.404
930G	7975	41.743	14.997	0.574	1.682	0.050	0.301	-0.002	17.89	-0.806
931B	9722	102.743	18.197	-0.109	1.860	0.047	0.342	0.007	18.39	-0.039
931C	9311	-36.257	16.997	-0.343	1.517	0.093*	0.260	0.016	17.14	-0.053
931D	7500	225.076	14.040	1.168	1.717	0.126**	0.314	0.016	18.29	-0.738
932A	8789	-163.757	15.963	-0.459	1.720	-0.070	0.311	-0.007	18.08	0.332
932B	8767	-247.090	16.240	-0.348	1.765	0.042	0.330	0.038**	18.70	1.592**
932D	9166	-52.924	15.867	0.291	1.597	-0.007	0.299	-0.014	18.72	-0.746
932F	8266	190.743	15.043	-0.176	1.635	-0.002	0.306	-0.005	18.72	-0.226
933A	8888	41.576	14.977	0.192	1.585	-0.047	0.299	0.016	18.86	1.489**
933B	7073	63.910	12.217	-0.121	1.705	-0.048	0.284	-0.010	16.66	-0.088
934A1	9855	186.076	17.377	0.113	1.470	-0.068	0.272	-0.004	18.50	0.306
934A2	9533	158.410	16.140	-0.009	1.592	-0.041	0.314	0.010	19.72	0.562
934B	9789	219.576	15.687	0.429	1.376	0.021	0.247	0.021*	17.95	0.947*
934D	7655	58.410	11.333	-0.659	1.481	-0.021	0.295	-0.009	19.92	-0.294
934D1	9500	252.910	15.643	0.980	1.569	0.044	0.309	0.007	19.69	-0.039
935A	8788	-352.590	13.710	-1.531	1.453	-0.092	0.289	0.002	19.89	1.164
935B	8244	-35.924	13.917	-1.009	1.284	-0.183	0.234	-0.040	18.22	-0.414
935C	9166	2.910	16.173	0.135	1.530	-0.079	0.302	-0.012	19.74	0.182
935F	8100	-13.924	17.023	1.024	1.528	0.074*	0.294	0.017	19.24	0.171

Table 2. *Continued.*

Lines & Testers	Cocoon yield per 10000 larvae brushed				Single cocoon weigh		Single shell weight		Shell ratio	
	Number		Weight							
	$\bar{x}$	GCA	(Kgs.)	GCA	(g)	GCA	(g)	GCA	(%)	GCA
Testers										
KA	7033	–	11.35	–	1.608	–	0.301	–	18.72	–
NB4D2	6988	–	11.54	–	1.609		0.305		18.96	
l.s.d. 5%	–	447.615	–	1.587	–	0.066	–	0.017	–	0.650
l.s.d. 1%	–	696.638		2.315	–	0.096	–	0.025	–	0.948

*Significant at 5% level; **Significant at 1% level; l.s.d=least significant difference $\bar{x}$=mean of 3 replications.

found to be superior for other characters are as follows : 931D (14.040 Kgs.), 935E (17.023 Kgs)., 934D1 (15.643 Kgs.) and 934B (15.687 kgs.) for cocoon yield by weight; 931D (1.717 g), 931C (1.517 g) and 930E (1.796 g) for single cocoon weight; 932B (0.330 g) for single shell weigh; 930B (18.70%), 933A (18.86%) and 935A (19.89%) for shell ratio.

3. Specific combining ability (SCA) effects

Original sampled data and the estimates of GCA of 48 F_1's is shown in Table 3. The results showed that both original sampled data and SCA were high in

Table 3. *Entimates of general combining ability (SCA) and original sampled data (x) for economic characters of 48 F_1s and control (PM × NB4D2) of silkworm, Bombyxmori L.*

Crosses	Cocoon yield per 10000 larvae brushed				Single cocoon weigh		Single shell weight		Shell ratio	
	Number		Weight							
	x	SCA	x (Kgs.)	SCA	x (g)	SCA	x (g)	SCA	x (%)	SCA
933A × KA	9389	174.743	16.340	0.480	1.744	-0.003	0.335	0.009	19.21	0.541
930A × NB4D2	9011	-174.743	15.699	-0.480	1.771	0.003	0.329	-0.009	18.58	-0.541
930A1 × KA	9144	-291.924	15.000	-0.788	1.585	-0.074	0.290	0.003	18.30	0.794
930A1 × NB4D2	9700	291.924	16.896	0.788	1.753	0.074	0.295	-0.003	16.83	-0.794
930B × KA	8900	-336.590	15.378	-0.373	1.736	0.040	0.320	0.016	18.43	0.253
930B × NB4D2	9544	336.590	16.444	0.373	1.676	-0.040	0.297	-0.016	17.72	-0.253
930E × KA	9355	-214.090	16.367	0.077	1.759	-0.002	0.325	0.012	18.48	0.586
930E × NB4D2	9755	214.090	16.533	-0.077	1.782	0.002	0.312	-0.012	17.51	-0.586
930F × KA	9185	-304.757	16.399	0.287	1.840	0.085	0.312	0.010	16.96	-0.272
930F × NB4D2	9766	304.757	16.144	-0.287	1.690	-0.085	0.303	-0.010	17.93	0.272
930G × KA	9488	-58.924	16.833	0.271	1.778	0.037	0.332	0.019	18.67	0.546
930G × NB4D2	9578	58.924	16.611	-0.271	1.725	-0.037	0.306	-0.019	17.74	-0.546
931B × KA	9644	35.743	16.655	0.777	1.850	0.112*	0.330	0.008	17.84	-0.721
931B × NB4D2	9544	-35.743	15.422	-0.777	1.648	-0.112	0.325	-0.008	19.72	0.721
931C × KA	9122	-347.590	17.077	1.432*	1.911	0.126*	0.341	0.010	17.84	-0.724
931C × NB4D2	9788	347.590	14.533	-1.432	1.679	-0.126	0.332	-0.010	19.77	0.724
931D × KA	9766	35.743	17.377	0.221	1.839	0.022	0.331	-0.001	18.00	-0.536
931D × NB4D2	9666	-35.743	17.255	-0.221	1.816	-0.022	0.343	0.001	18.89	0.536
932A × KA	9255	-86.424	14.444	-1.084	1.545	-0.077	0.287	-0.022	18.58	-0.406
932A × NB4D2	9400	86.424	16.933	1.084	1.719	0.077	0.341	0.022	19.84	0.406
932B × KA	9300	41.243	15.244	-0.395	1.646	-0.088	0.340	-0.013	20.66	0.471
932B × NB4D2	9186	-41.243	16.355	0.395	1.841	0.088	0.377	0.013	20.48	-0.471
932D × KA	9822	369.077	16.255	-0.023	1.701	0.016	0.314	0.013	18.46	0.576
932D × NB4D2	9055	-369.077	16.622	0.023	1.689	-0.016	0.300	-0.013	17.76	-0.576
932F × KA	9744	107.743	16.744	0.932	1.711	0.022	0.307	-0.003	17.94	-0.361
932F × NB4D2	9500	-107.743	15.200	-0.932	1.689	-0.022	0.324	0.003	19.18	0.361

Table 3. *Continued.*

Crosses	Cocoon yield per 10000 larvae brushed				Single cocoon weigh		Single shell weight		Shell ratio	
	Number		Weight							
	x	SCA	x (Kgs.)	SCA	x (g)	SCA	x (g)	SCA	x (%)	SCA
933A × KA	9711	163.577	16.055	-0.124	1.621	-0.024	0.324	-0.007	19.99	-0.159
933A × NB4D2	9355	-163.577	16.624	0.124	1.689	0.024	0.350	0.007	20.72	0.159
933B × KA	9588	18.909	15.166	-0.701	1.566	-0.077	0.297	-0.008	18.97	0.494
933B × NB4D2	9522	-18.909	16.888	0.701	1.142	0.077	0.323	0.008	18.54	-0.494
934A1 × KA	9877	185.743	15.411	-0.690	1.553	-0.070	0.313	0.001	20.15	0.651
934A1 × NB4D2	9477	-185.743	17.111	0.690	1.713	0.070	0.321	-0.001	18.74	-0.651
934A2 × KA	9755	91.409	15.300	-0.679	1.595	-0.056	0.308	-0.017	19.31	0.131
934A2 × NB4D2	9544	-91.409	16.978	0.679	1.727	0.056	0.353	0.017	20.44	-0.131
9934B × KA	9744	18.910	16.311	-0.107	1.679	-0.034	0.311	-0.025	18.52	-1.011
9934B × NB4D2	9678	-18.910	16.844	0.107	1.767	0.034	0.371	0.025*	21.00	1.011*
934D × KA	9755	191.409	16.255	0.927	1.665	-0.006	0.304	-0.003	18.26	-0.076
934D × NB4D2	9344	-191.409	14.722	-0.927	1.697	0.006	0.320	0.003	18.86	0.076
34D1 × KA	9800	41.243	17.233	0.265	1.752	0.017	0.331	0.008	18.89	0.286
34D1 × NB4D2	9689	-41.243	17.022	-0.265	1.739	-0.017	0.325	-0.008	18.69	-0.286
935A × KA	9277	124.409	14.989	0.532	1.603	0.004	0.312	-0.005	19.46	-0.347
935A × NB4D2	9000	-124.409	14.244	-0.532	1.615	-0.004	0.333	0.005	20.62	0.347
935B × KA	9433	-36.590	13.922	-1.057	1.464	-0.045	0.259	-0.017	17.69	-0.579
935B × NB4D2	9478	36.590	16.355	1.057	1.574	0.045	0.303	0.017	19.29	0.579
935C × KA	9633	124.576	15.811	-0.312	1.627	0.015	0.303	-0.001	18.62	-0.239
935C × NB4D2	9355	-124.576	16.755	0.312	1.618	-0.015	0.315	0.001	19.47	0.239
935E × KA	9389	-47.590	17.144	0.132	1.825	0.060	0.345	0.013	18.90	0.099
935E × NB4D2	9011	47.590	17.200	-0.132	1.725	-0.060	0.330	-0.013	19.13	-0.099
Control (PM × NB4D2)	9522	-	15.550		1.580	-	0.284		17.97	-
l.s.d. 5% level	-	648.257	-	1.244	-	0.090	-	0.023	-	0.882
l.s.d. 1% level	-	916.625	-	1.758	-	0.127	-	0.033	-	1.248

*Significant at 5% level; **Significant at 1% level; l.s.d=least significant difference $\bar{x}$=mean of 3 replications.

some F_1's. These were 932D × KA for cocoon yield by number; 932A × NB4D2 for cocoon yield by weight; 931C × KA for single cocoon weight; 934B × NB4D2 for single shell weight and shell ratio (Table 3). Furthermore, 934B × NB4D2 involving parents with high GCA had good SCA for single shell weight and shell ratio, indicating preponderance of additive gene action whereas 931C × NB4D2; 930B × NB4D2; 930F × NB4D2 and 930A1 × NB4D2 with high SCA involved low × low GCA parents indicating dominace × dominance gene effects for cocoon yield by number.

The choice of parents for hybridization depends upon the original sampled data of parents (Bhargava, 1995a; Thiagarajan *et al.*, 1993), the performance of F_1's (Bhargava *et al.*, 1993) and GCA (Bhargava, 1995b; Bhargava *et al.*, 1993). Thus, the results of the present study has helped in identifying both parents and F_1's. The fact that the predictability ratio ($\sigma^2A/\sigma^2A+\sigma^2D$) calculated by using the Baker's (1978) formula was less than unity for all the five characters indicating non-additive gene action in them. Krishnaswami *et al.* (1964) and Sengupta *et al.* (1974) observed non-additive gene action to be operating in the genetic control of cocoon weight and shell weight. The non-additive gene action observed by them for effective rate of rearing is in conformity with our results on cocoon yield by number. However, the deviation in our results on cocoon weight from the work of Bhargava (1995b) and on shell ratio from the previous reports (Sengupta *et al.*, 1974; Pershad *et al.*, 1986) may be due variations in the genatic make up of the silkworm races empolyed. At last it may be concluded that the crosses found to be superior will be exploited commercially. The promising lines could be utilized as genetic resource material for improving the productivity. The information from the results of this study has helped in programming further testing of superior crosses at regional research stations and sericultural farms of this institute.

적 요

가잠 2화성의 5개 실용형질에 대하여 일반 조합능력(GCA)과 특수 조합능력(SCA) 효과가 Line X tester(24계통과 2검정계)로 분석되었다. 그 결과 934D 1(9500), 934B(9789) 및 934A1(9855)가 부화유충 10,000두당 수견량에 있어서 바람직한 일반 조합능력 효과가 인정되었다. 마찬가지로, 다른 실용형질에 있어서도 일반 조합능력 효과가 뛰어난 몇가지 계통들이 있었는데 다음과 같다, 즉 수견량에서 931D(14.040 kg), 935E(17.023 kg), 930E(2.796 kg), 견층중에서 932B(15.687 kg), 단견중에서 931D(1.717 g)과 930E (1.796 kg), 견층중에서 932B(0.330 g) 그리고 견층비율에서 932B(18.7%), 933A(18.86%) 및 935A(19.89 %)이었다.

특수조합능력 효과는 부화유충 10,000두당 수견수에서 932D × KA(9,822개), 동 수견량에서 932A × NB4D2(0.371 g과 21.0%)이 뛰어난 결과를 보였다.

분석결과 5개 형질 모두에서의 유전자 영향은 비상가적으로 나타났다.

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