G.J.B.B., VOL.4 (1) 2015: 12-16 ISSN 2278 – 9103

GLOBAL JOURNAL OF BIO-SCIENCE AND BIOTECHNOLOGY

www.scienceandnature.org

ESTIMATES OF GENE INTERACTION IN FOUR BIVOLTINE HYBRIDS OF *BOMBYX MORI* L.

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ABSTRACT

Gene interaction of various genetic components of four bivoltine hybrids was studied by carrying out generation mean analysis. Four crosses *viz*. Pam_{101} x NB_4D_2, Pam_{109} x YS_3, Pam_{109} x CC_1 and Pam_{111} x SF_{19} were selected on the basis of significant specific combining ability estimates and heterosis expression. The analysis indicates predominance of additive x dominance gene interaction besides presence of epistasis in two crosses *viz*. Pam_{101} x NB_4D_2 and Pam_{111} x SF_{19}.

KEY WORDS: Non allelic interaction, scaling test, epistasis, heterosis, *Bombyx mori* L.

INTRODUCTION

Silkworm (*Bombyx mori* L.) is economically the most important sericigenous insect. Volumes of works have been reported on silkworm as it is considered to be a convenient insect for the genetical studies in the field of genetic and molecular and molecular biology (Tanzima, 1978, Gopinathan, 1992, Rajalakshmi *et al*., 2000., Rehman *et al*., 2008., Ramesh and Subramanaya, 2009, Vijayan *et al*., 2010 and Suresh Kumar *et al*., 2011). Ever since the introduction of F_1 hybrids for commercial exploitation in 1922, the polyvoltine hybrids reared in the India did not express much heterosis as both the parents involved possessed polyvoltine blood coupled with poor qualitative and quantitative traits. In J & K state, only one commercial rearing is conducted during spring season. To maximize the cocoon crop, efforts are made to introduce one more commercial rearing during autumn season by introducing hardy hybrids. In this direction fourteen heterotic crosses were studied (Razdan *et al*., 1994) and four region specific crosses were indentified for further studies for their gene and non-allelic interactions. In order to know their heterotic manifestations combining ability estimates were also studied.

MATERIALS & METHODS

The study material included seven bivoltine silkworm parental races *viz*. Pam_{101}, Pam_{109}, Pam_{111}, NB_4D_2, YS_3, SF_{19} and CC_1 and four crosses (F_1^s) viz. Pam_{101} x NB_4D_2, Pam_{109} x YS_3, Pam_{109} x CC_1 and Pam_{111} x SF_{19} with F_2^s and back crosses of F_1^s. The material was reared cellular in the three replications (1 replication: 1Dfl) in autumn season (Krishnaswamy, 1978). Data on economic parameters included; larval weight, larval duration, cocoon yield/10,000 larvae brushed, single cocoon weight, single shell weight and shell ratio percentage. The generation mean analysis was carried out by estimating various genetic components like mean (m), additive effect (d), dominance effect (h), additive x additive genic interaction (i), additive x dominance genic interaction (j) and dominance x dominance genic interaction (l) by Jinks & Jones (1958) and Haymen (1958) methods. To detect the type of epistasis present, scaling test was performed as prescribed by Mather (1949), Haymen & Mather (1955).

RESULT & DISCUSSION

The data n generation means of various characters are presented in Table 1. The estimates of six genetic components *viz*, m, d, h, i, j, and l representing various types of interactions are presented in Table 2. In the present study, additive-dominance effect were evidenced in Pam_{101} x NB_4D_2 (d and h significant) in cocoon yield and shell percentage characters. Larval weight is one of the important parameters which determine not only the health of the larvae but also the quality of the cocoons spun (Matsumura and Takuchi, 1950). In the present study larval weight shows, only dominance (h significant) and this observation supports the view point of Nacheva (1980) and Rayur & Govindan (1990). The estimation of interaction parameters reveal either one of the parameter or two or all the three significantly different from zero for the characters studied. This is in agreement with the scaling test in which either A or both A and C have significant values for all the characters studied. Kurian and Peter (1995) have reported additive genetic variance for the qualitative characters and non-additive variance for the yield component. Gamo and Hirabayashi (1983) recorded additive gene interaction as an important factor for growth rate of fifth instar larvae in silkworms. They have also reported that single cocoon weight was predominantly controlled by additive gene effect to a less extent by non-additive gene action and epistasis. In the present study, larval weight and larval duration, additive x additive (i) type of gene interaction is responsible while as for cocoon yield, cocoon weight, shell weight and shell percentage additive x dominance (j) gene interaction is making contribution. However, dominance (h) effect is significantly positive and additive x additive (i) interaction is significantly negative for larval weight, cocoon yield and shell percentage. This interaction therefore appears to be predominantly of duplicate type and is in conformity with the findings of Sengupta *et al.* (1974) and Nanjunda swamy (1980).

TABLE–1: Mean data on parents, their F_1s, F_2s back crosses and parents, heterosis in *Bombyx mori* L.

Characters	Generation Mean	Pam_{101} x NB_4D_2	Pam_{109} x YS_3	Pam_{109} x CC_1	Pam x SF_{19}
Larval weight (g)	P1	38.67 ± 0.67	47.33 ± 2.33	47.33 ± 2.33	40.67 ± 0.67
	B1	45.67 ± 2.33	39.00 ± 3.21	42.67 ± 1.67	44.00 ± 1.15
	F1	50.33 ± 0.33	46.00 ± 0.58	46.33 ± 1.86	46.33 ± 0.88
	F2	39.33 ± 1.20	41.33 ± 1.76	44.67 ± 1.76	48.00 ± 0.58
	B2	48.00 ± 0.58	45.67 ± 1.20	45.00 ± 1.53	47.00 ± 0.33
	P2	47.33 ± 1.45	44.00 ± 1.00	40.00 ± 0.33	41.00 ± 0.58
Heterosis Over MP		17.05**	0.73	-5.70**	13.49**
Heterosis Over SP		6.34**	-2.82	-2.11	13.01**
Larval duration (days)	P1	25.07 ± 0.06	25.09 ± 0.51	25.09 ± 0.51	24.71 ± 0.34
	B1	23.72 ± 0.35	25.71 ± 0.31	25.40 ± 0.30	25.17 ± 0.57
	F1	23.38 ± 0.33	24.72 ± 0.32	24.72 ± 0.32	24.74 ± 0.90
	F2	23.47 ± 0.27	25.80 ± 0.36	23.52 ± 0.30	26.15 ± 0.07
	B2	23.69 ± 0.33	25.41 ± 0.31	24.75 ± 0.85	25.77 ± 0.27
	P2	25.41 ± 0.62	25.78 ± 0.28	25.36 ± 0.33	26.41 ± 0.35
Heterosis Over MP		-7.37**	-4.03**	-1.98	-3.23**
Heterosis Over SP		-6.74**	-2.70	-1.45	0.09
Cocoon yield/ 10,000 larvae brushed (kg)	P1	48.63 ± 1.09	44.63 ± 1.84	14.63 ±1.84	49.83 ± 4.80
	B1	93.47 ± 2.62	49.07 ± 8.19	100.50±10.20	44.07 ± 0.85
	F1	64.50 ± 7.56	67.63 ± 7.47	57.00 ± 7.72	63.80 ±5.43
	F2	43.33 ± 7.19	77.57 ± 8.93	83.03 ± 9.23	108.33 ±9.73
	B2	61.23 ±13.26	53.13 ± 7.39	45.30 ± 5.20	42.00 ± 4.82
	P2	52.53 ± 6.98	62.83 ± 2.24	59.83 ± 6.66	49.73 ± 3.44
Heterosis Over MP		15.70**	25.87**	15.76	28.16**
Heterosis Over SP		9.38**	7.64	5.88	28.03*
Cocoon Weight (g)	P1	1.57 ± 0.01	1.44 ± 0.02	1.44 ± 0.02	1.37 ± 0.01
	B1	1.93 ± 0.04	1.50 ± 0.10	1.74 ± 0.04	1.63 ± 0.02
	F1	1.84 ± 0.00	1.72 ± 0.04	0.67 ± 0.02	1.50 ± 0.02
	F2	1.54 ± 0.12	1.57 ± 0.04	1.91 ± 0.05	0.42 ± 0.06
	B2	1.51 ± 0.22	1.64 ± 0.05	1.55 ± 0.14	1.55 ± 0.03
	P2	1.72 ± 0.05	1.58 ± 0.06	1.56 ± 0.13	1.47 ± 0.10
Heterosis Over MP		11.76**	13.79**	11.28**	5.30*
Heterosis Over SP		6.93*	8.92*	7.12*	1.77
Shell weight (g)	P1	0.28 ± 0.003	0.32 ± 0.010	0.32 ± 0.010	0.28 ± 0.001
	B1	0.39 ± 0.003	0.30 ± 0.025	0.35 ± 0.010	0.36 ± 0.022
	F1	0.34 ± 0.006	0.37 ± 0.010	0.32 ± 0.014	0.32 ± 0.006
	F2	0.25 ± 0.014	0.32 ±0.010	0.39 ± 0.014	0.27 ± 0.020
	B2	0.26 ± 0.047	0.32 ±0.017	0.31 ± 0.037	0.31 ± 0.025
	P2	0.31 ± 0.006	0.30 ±0.014	0.30 ± 0.017	0.28 ± 0.033
Heterosis Over MP		15.21**	20.26**	4.21	12.28*
Heterosis Over SP		8.56	17.71**	1.06	10.77
Shell Percentage(g)	P1	17.57 ± 0.10	21.79 ± 0.62	21.79 ± 0.62	20.76 ± 0.06
	B1	20.24 ± 0.22	20.21 ± 0.22	19.87 ± 0.64	21.76 ± 1.39
	F1	18.44 ± 0.36	21.54 ± 0.13	19.03 ± 0.69	21.08 ± 0.10
	F2	16.18 ± 0.42	20.33 ± 0.18	20.52 ± 0.61	19.13 ± 0.77
	B2	17.50 ± 0.74	19.78 ± 0.78	20.15 ± 0.70	13.93 ± 139
	P2	18.71 ± 0.29	19.07 ± 0.27	19.08 ± 1.03	18.72 ± 1.04
Heterosis Over MP		3.18	5.42*	-6.89**	6.78**
Heterosis Over SP		1.49	-1.16	-12.70**	1.57

Where MP – Mid parent and SP – Superior Parent

ISSN 2278 – 9103

TABLE 2. Estimates of additive, dominance and interaction for the means of six characters in respect of four crosses of Bombyx *mori* L. and sealing tests.

Characters	Crosses	a(mean of F2)	d(Add.)	h(Dom)	i(Add x Add)	j (Add x Dom)	l(Dom x Dom)	Sealing Tests A	Sealing Tests B	Sealing Tests C	Type of Epistasis
Larval duration	Pam-101 x NB_4D_2	23.47**	0.03	-0.92	6.20**	0.20	1.48	*	-	*	D
	Pam-109 x YS_3	25.80**	0.30	-1.99	0.10	0.65	-1.59	**	-	*	C
	Pam-109 x CC_1	23.52**	0.65	5.72	1.90	0.79	-6.63	-	-	**	D
	Pam-111 x SF_{19}	26.15**	-0.60	-3.54	-0.84	0.25	1.44	-	-	*	D
Larval Weight	Pam-101 x NB_4D_2	39.33**	-2.33	37.35**	-20.00**	2.00	30.70**	-	-	**	D
	Pam-109 x YS_3	41.33**	-6.67	4.36	-0.02	-8.34*	9.97	*	-	*	C
	Pam-109 x CC_1	44.67**	-2.33	-0.84	-4.68	-5.83*	8.32	*	-	-	D
	Pam-111 x SF_{19}	48.00**	-3.33*	-3.85	-25.98**	-3.17*	1.01	-	*	**	D
Yield by weight(100dfls)	Pam-101 x NB_4D_2	43.33**	32.24*	150.00**	-42.60	34.19*	-215.30*	**	-	-	D
	Pam-109 x YS_3	77.57**	-4.06	-91.98*	2.40	5.04	144.20*	-	-	-	-
	Pam-109 x CC_1	83.03**	55.20**	-35.75	27.72	62.80*	-32.62	**	-	**	C
	Pam-111 x SF_{19}	108.30**	2.07	-247.20**	31.12	2.02	361.20**	**	*	**	D
Cocoon weight	Pam-101 x NB_4D_2	1.54**	0.42	0.92	0.54	0.50*	-0.63	**	-	-	D
	Pam-109 x YS_3	1.57**	-0.14	0.21	-0.52	-0.07	0.18	-	-	-	-
	Pam-109 x CC_1	1.91**	0.19	-0.89	-0.20	0.25	0.82	**	-	**	D
	Pam-111 x SF_{19}	1.42**	0.08	0.76**	-0.52	0.13**	-1.20**	**	-	-	D
Shell weight	Pam-101 x NB_4D_2	0.25**	0.13**	0.35	0.14	0.15**	-0.33	**	-	**	D
	Pam-109 x YS_3	0.32**	-0.02	0.02	-0.04	-0.03	0.16	-	-	-	-
	Pam-109 x CC_1	0.39**	0.04	-0.23	0.00	0.03	0.18	*	-	-	D
	Pam-111 x SF_{19}	0.27**	0.05	0.30*	-0.12	0.05	-1.40*	**	-	-	D
Shell percentage	Pam-101 x NB_4D_2	16.18**	2.74**	11.33*	1.48	3.04**	-13.62**	**	-	**	D
	Pam-109 x YS_3	20.33**	0.43	-0.23	2.60	-0.93	5.30	**	-	**	D
	Pam-109 x CC_1	20.52**	-0.28	-3.45	1.14	-1.64	0.93	-	-	-	-
	Pam-111 x SF_{19}	19.13**	1.83	8.20	-0.76	0.81	-8.60	-	-	-	-

*significant at 5%, **significant at 1%, C- Complementary and D - Duplicate

Mather and Jinks (1982) advocates that dominance (h) effect must be positive and greater than additive (d) effect. The scrutiny of the estimates reveals that heterosis is present in the larval weight, cocoon yield, cocoon weight and shell percentage in Pam_{101} x NB_4D_2 since the ratio h/d > 1 for this particular cross. This can be considered either due to super dominance or over dominance at some or all loci besides being unidirectional. That was conformity with the findings of Nagalakshmamma and Jyothi (2009). In cross Pam_{111} x SF_{19} cocoon characters show presence of dominance (h significant) is noticed. Rajara and Maheshwari (1996) have observed the importance of additive and non- additive gene actions for improvements in wheat yield. In present study for non allelic interactions, additive x additive (i) and additive x dominance generic interaction (j) are responsible for larval weight. For cocoon weight all the three types *viz*. additive x additive (i), additive x dominance (j) and dominance x dominance (1) gene interactions are noticed. In larval weight only additive x additive (i) and additive x dominance (j) interactions are observed while cocoon yield show dominant x dominant (1) type of interaction. The findings observed are in conformity with those of Mirhosiene *et al*. (2004). Narasimhana and Rajashekhar Shetty (1979) have reported that additive gene action is important for cocoon yield in bivoltine silkworms. These interactions have been further confirmed by scaling tests. For cocoon yield dominance effect (h) is significantly negative and dominance x dominance (1) effect significantly positive. Reverse is the case for cocoon and shell weight and therefore interaction were considered to be predominantly of duplicate type. Further scrutiny of the estimates (Table 2) reveals that dominance effect (h) is positive and greater than additive effect (d) for cocoon characters. As such the heterosis manifestation can be attributed to the presence of dominance for this cross. Estimates of additive effect (d) and dominance effect (h) for the cross Pam_{109} x YS_3 are non significant for all the characters except cocoon yield wherein evidence of dominance (h) is present. Interaction parameters *viz.* additive x additive (i), additive x dominance (j) and dominance x dominance (1) are non-significant for all the characters except cocoon yield and larval weight for which dominance x dominance (1) and additive x dominance (j) type of interactions are responsible, although the same is not confirmed by scaling tests. The cross does not show any heterosis since h/d < 1 and dominance is not positive in most of the characters. Therefore this cross has no evidence of non-allelic interactions. For the cross Pam_{109} x CC_1, both additive and dominance effects are absent for all the characters except cocoon yield in which additive effects are responsible (Table 2). The study of non-allelic interactions reveal that additive x dominance (j) type of genic interaction is responsible for larval weight and cocoon yield which is further confirmed by the scaling tests in which A or A and C have shown significance. For rest of the characters, evidence of non-allelic interactions are absent. Heterosis is absent for the characters studied.The gene action studies of four crosses have revealed that hybrids Pam_{101} x NB_4D_2 and Pam_{111} x SF_{19} give ample evidence of presence of additive-dominance and heterosis manifestation and hence could provide broad genetic base with higher probabilities of selection of variants which could be channelized into productive derivatives by adapting suitable breeding strategies.

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