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HETEROSIS IN RELATION TO COMBINING ABILITY IN HYBRIDS BETWEEN MULTIVOLTINE AND BIVOLTINE BREEDS OF THE SILKWORM, *BOMBYX MORI* L.

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Combining ability and hybrid vigour analysis for twelve economic characters was carried out in hybrids between multivoltine and bivoltine silkworm breeds of the silkworm, *Bombyx mori* L. General combining ability (GCA) effects revealed that among the lines, 96H was found good general combiner exhibiting significant GCA effects for eight characters. Among testers, CSR2 and CSR4 were found good combiners exhibiting significant GCA effects for seven characters each. Out of thirty-one multivoltine x bivoltine hybrids, two hybrids *viz*. 96A x NB4D2 and 96E x CSR3 showed their superiority by manifesting significant specific combining ability (SCA) effects for four characters each. Five hybrids *viz*. BL67 x CSR2, BL67 x NB4D2, 96A x CSR4, 96E x CSR2 and 96H x CSR17 manifested maximum hybrid vigour for seven characters followed by two hybrids namely BL67 x CSR3, BL67 x CSR4 that manifested significant hybrid vigour for six characters each.

Key words : *Bombyx mori* L., hybrid vigour, combining ability, multivoltine and bivoltine breeds.

INTRODUCTION

India is the second largest silk producing country in the world. Indian silk is both lustrous and elegance and is mainly produced either from multivoltine x multivoltine or multivoltine x bivoltine hybrids. Sometimes, silkworm breeds which the breeder developed with great caution may turn out to be the poor combiners. Therefore, it is essential to determine the combining ability of the silkworm breeds in order to produce superior hybrids for commercial exploitation. Earlier Krishnaswami *et al.* (1964) studied the expression of economic characters in a diallel analysis involving five multivoltine silkworm breeds. Studies on the genetic variability in multivoltine silkworm breeds were conducted (Chatterjee *et al.*, 1993). Sen *et al.* (1995) observed the importance of both additive and additive gene action for the amelioration of multivoltine silkworm breeds. Datta & Pershad (1988) have indicated that additive gene play an important role in the inheritance of several economic characters. In the present study an attempt has been made to evaluate general combining ability of parental silkworm breeds, specific combining ability and magnitude of hybrid vigour in F1 hybrids between newly developed multivoltine and bivoltine silkworm breeds of the silkworm, *Bombyx mori* L.

MATERIALS AND METHODS

Five multivoltine silkworm breeds *viz*. BL67, BL68, 96A, 96E and 96H and six bivoltine silkworm breeds *viz*. CSR2, CSR3, CSR4, CSR12, CSR17 and NB4D2 were identified on the basis of multiple traits evaluation index method (Mano *et al.*, 1993) and utilized as lines and testers, respectively. Crosses were made between multivoltine and bivoltine breeds raising 31 hybrids. F1hybrids along with parents were reared during April-May, 2004. After third moult, 300 larvae were retained and replicated thrice. Data were recorded for fecundity, total larval duration, pupation rate, cocoon yield/10,000 larvae both by weight and number, cocoon weight, cocoon shell weight and cocoon shell ratio including post cocoon parameters like filament length,

Table I : Per cent contribution of Lines, testers and lines x testers for different characters in the silkworm, *Bombyx mori* L.

Source	Fecundity	Larval span	Pupation Rate	Yield/ 10,000 larvae	Cocoon weight	Cocoon shell weight	Cocoon shell ratio	Reel-ability	Filament length	Raw silk (%)	Denier	Neat-ness
Lines	62.18	56.62	46.52	47.09	42.63	51.41	69.43	25.34	38.47	43.93	28.83	12.33
Testers	1.85	7.23	10.20	16.29	18.37	17.78	10.68	10.86	16.05	17.53	6.34	13.53
Lines x testers	36.03	36.15	43.28	36.67	38.99	30.81	19.89	63.80	45.48	38.54	64.81	74.14

denier, reelability, raw silk percentage and neatness. Data were analyzed using line x tester analysis suggested by Kempthorne (1957).

RESULTS

Per cent contribution of lines, testes and line x tester is given in Table I. Lines exhibited maximum percent contribution for shell ratio (69.43%) followed by fecundity (62.18%) and larval span (56.62%). Contribution of tester was maximum for cocoon weight (18.37%) followed by cocoon shell weight (17.73%) & raw silk (17.53%). Lines x testers exhibited maximum percent contribution for neatness (74.14%) followed by denier (64.81%) & reelability (63.80%).

General combining ability (GCA) : General combining ability (GCA) effects in five lines and six testers are given in Table II. The Line 96H exhibited significant GCA effects for eight characters *viz.* cocoon yield/ 10,000 larvae, cocoon shell weight, cocoon shell ratio, filament length, reelability, raw silk percentage, denier and neatness followed by BL67, BL68 and 96E which showed significant GCA effects for seven characters. Among the six testers, CSR2 and CSR4 exhibited significant GCA effects for six characters each followed by NB4D2 that showed significant GCA effects for five characters *i.e.* yield/ 10,000 larvae, cocoon shell weight, cocoon shell ratio, filament length and raw silk percentage.

Specific combining ability (SCA) effects : Specific combining ability (SCA) effects in some promising multivoltine x bivoltine hybrids are given in Table III. Among thirty-one F1 hybrids, two hybrids *viz.* 96A x NB4D2 and 96H x CSR3 were found promising which expressed significant SCA effects for four characters each.

Hybrid vigour : Hybrid vigour in some promising multivoltine x bivoltine hybrids over mid parental value is shown in Table IV. Five multivoltine x bivoltine hybrids *viz.* BL67 x CSR2, BL67 x NB4D2, 96A x CSR4, 96E x CSR2 and 96H x CSR17 manifested maximum hybrid vigour for seven characters followed by two hybrids namely, BL67 x CSR3, BL67 x CSR4 that exhibited hybrid vigour for six characters each.

DISCUSSION

In the present study, among the lines, 86H was found the best general combiner exhibiting significant GCA effects for eight characters indicating that additive genes are playing major role in the inheritance of these characters. The results are in conformity with that of Gamo & Hirabayashi (1983),

Table II : General combining ability effects of lines and testers utilized in the study.

Line/ Testers	Fecun- dity	Larval span	Pupation rate	Yield/ 10,000 larvae	Cocoon weight	Cocoon shell weight	Cocoon shell ratio	Filament length	Reel- ability	Raw silk	Denier	Neat- ness
Lines												
BL67	5.06	-6.83**	1.52**	0.99**	0.11**	0.02*	0.256**	8.37*	0.32	0.04	0.08	0.32
BL68	2.26	0.17	1.34**	0.60**	0.03**	0.01**	3.15*	21.80**	0.28	0.41**	0.07	0.20
96A	73.76**	0.17	2.66**	0.56**	0.00	0.00	0.01	12.13**	-0.11	0.28**	0.01	0.09
96E	7.45	0.17	0.38	0.64**	0.09**	0.01**	0.66**	15.87**	-0.69	1.03**	0.16	1.18**
96H	43.23	0.17	-0.25	0.09**	0.01	0.02**	1.06**	67.41**	1.36**	0.41**	-0.16**	0.35*
Testers												
CSR2	3.10	1.17	0.38	0.53**	0.08**	0.02**	0.13	23.58**	0.03	1.13**	0.05	1.41**
CSR3	6.51	0.17	0.68	0.16**	0.003	0.00	0.20	9.13	0.49	0.21	-0.02	0.04
CSR4	4.94	1.17		0.07**	0.08	0.01**	0.58**	30.85**	0.30	0.00	-0.11**	0.76**
CSR12	11.56	1.83	1.01	0.01**	0.001	0.00	0.11	9.32	-0.90	0.17	0.04	0.02
CSR17	5.99	1.17	0.76	0.70**	0.08**	0.02**	0.12	1.35	0.25	0.19	0.07	0.43
NB4D2	4.05	1.83	0.56	0.07**	0.01	0.01*	0.48**	55.60**	-0.17	0.88**	0.03	0.20

*, ** = Significantly different at 5% and 1% level respectively.

Table III : Specific combining ability effects of some multivoltine x bivoltine hybrids.

Line/testers	Fecun-dity	Larval span	Pupation rate	Yield/ 10,000 larvae	Cocoon weight	Shell weight	Shell ratio	Filament length	Reel-ability	Raw silk (%)	Denier	Neat-ness
BL67 x CSR4	20.51	5.83	0.17	0.61	0.08	0.01	-0.40	53.76**	79.6	1.72**	0.48	1.15
BL68 x CSR17	1.21	-1.17	1.23	-0.98	-0.07	-0.014	-0.04	-30.57	83.4	0.92**	-2.29**	-2.96
96A x CSR17	48.05	-1.17	2.37	0.53	0.07	0.011	-0.15	63.43**	82.3	-0.51	-0.23*	0.59
96A x NB4D2	20.90	1.83	1.64	1.18**	0.08	0.024*	0.54*	10.96	80.0	-0.78*	0.11	1.63
96E x CSR2	68.73	-1.17	0.64	0.50	0.07	0.021*	0.37	48.20**	77.1	-0.04	0.13	0.48
96H x CSR3	20.89	-0.17	1.14	-0.15	0.01	0.020*	1.00**	58.04**	80.9	2.13**	0.23	0.43

*, ** = Significantly different at 5% and 1% level respectively.

Pershad *et al.* (1986), Subba Rao & Sahai (1989), Ravindra Singh (2000 & 2001). BL67 showed significant GCA effects for larval span, pupation rate, cocoon yield, cocoon weight, cocoon shell ratio and filament length. Among testers, CSR2 and CSR4 were found good general combiners exhibiting significant GCA effects for six characters each. Similar results have been reported by several workers (Satenahalli *et al.*, 1989; Rajalakshmi *et al.*, 1997). Importance of additive and non-additive gene action for fecundity, larval span, cocoon yield, cocoon shell ratio and filament length has been reported by Pershad *et al.* (1986) whereas major role of additive and non-additive gene action for the expression of filament length and effective rate of rearing has been observed by Kumar *et al.* (1994).

The specific combining ability effects for thirty-one multivoltine x bivoltine hybrids demonstrated that two hybrids viz. 96A x NB4D2 and 96H x CSR3 exhibited significant SCA effects for four characters each. Krishnaswami *et al.* (1964), Datta & Pershad (1988) have observed predominent role of non-additive gene action for the expression of cocoon weight, cocoon shell weight and cocoon shell ratio observed (Rajlakshmi *et al.*, 1997; Ravindra Singh *et al.*, 2000).

Analysis of hybrid vigour in thirtyone hybrids demostrated that five hybrids showed their superiority by exhibiting significant hybrid vigour for seven economic characters followed by two hybrids which exhibited significant hybrid vigour for six characters each. Significant hybrid vigour for cocoon yield by weight, cocoon weight and cocoon shell weight has been observed in multivoltine x bivoltine hybrids (Rao *et al.*, 1998; Raghavendra Rao *et al.*, 2002).

From this study, it is concluded that the lines 96H showed its superiority by exhibiting significant GCA effects for eight characters out of the twelve characters studied. Among the testers, CSR2 and CSR4, exhibiting significant GCA effects for six characters each, were found good general combiners. Five hybrids *viz.* BL67 x CSR2, BL67 x NB4D2, 96A x CSR4, 96E x CSR2 and 96H x CSR17 were found promising on the basis of manifestation of significant hybrid vigour for seven characters each.

Table IV : Hybrid vigour over mid parental value (MPV) and better parental value (BPV) in multivoltine x bivoltine hybrids.

Hybrid/ Heterosis (%)	Fecundity	Pupation Rate	Yield/ 10,000 larvae	Cocoon weight	Shell weight	Shell ratio	Filament length	Raw silk	Denier	Neat- ness
BL67 x CSR2										
MPV	12.88*	4.33*	37.14**	33.05**	39.25**	8.13**	47.92**	11.29	-2.06	-1.68
BPV	8.97	-1.49	31.53**	22.21**	13.10**	-5.16	25.87**	-4.47	-11.31**	-2.58
BL67 x CSR3										
MPV	13.45*	3.76	46.02**	52.00**	63.87**	9.17**	33.18**	3.56	-1.16	0.93**
BPV	9.83	-1.49	41.17**	40.25**	34.59**	-3.96	12.16**	-9.98	-7.66**	0.37**
BL67 x CSR4										
MPV	17.76*	0.53	45.10**	48.56**	69.54**	15.68**	48.94**	17.10	10.66	-1.12
BPV	13.72	-2.23	36.82**	34.67**	41.75**	5.63**	25.37**	3.13	-0.73	-2.21
BL67 x NB4D2										
MPV	16.19*	1.54	45.02**	50.54**	66.15**	10.85**	29.16**	1.36	-13.87**	-0.19
BPV	12.56	-1.78	42.66**	44.11**	47.66**	2.38	12.23**	-9.45	-20.77**	-1.11
96A x CSR										
4 MPV	50.91**	9.38**	28.06**	42.11**	63.48**	16.04**	50.14	2.93	-6.25**	-0.37
BPV	36.64**	-12.00**	19.10**	27.64**	39.45**	9.60**	23.21**	-6.58	-20.06**	1.47**
96E x CSR2										
MPV	31.31**	2.18	35.00**	37.16**	43.53**	5.71**	57.50**	11.44	3.67	2.42**
BPV	23.27**	-4.17*	23.56**	18.39**	17.66**	0.45	26.05**	-0.31	-9.61**	-1.48
96H x CSR17										
MPV	22.33**	-0.38	47.01**	47.56**	63.16**	11.47**	34.34**	-328	-2.01	2.05**
BPV	5.94	-2.83	31.02**	25.52**	32.59**	5.30**	3.05	-13.35**	-11.38**	0.74

*, ** = Significantly different at 5% and 1% level respectively.

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REFERENCES

CHATTERJEE. S.N.. RAO. P.R.M.. JAYASWAL. K.P.. RAVINDRA SINGH & DATTA. R.K. 1993. Genetic variability in mulberry silkworm. *Bombyx mori* L. breeds with low silk yield. *Indian J. Seric.* **32** : 69-86.

CRUSIO. W.E. 1987. A note on the analysis of reciprocal effects in diallel crosses. *J. Genetics*. **66** : 177-185.

DATTA. R.K. & PERSHAD. G.D. 1988. Combining ability among multivoltine x bivoltine silkworm (*Bombyx mori* L.) hybrids. *Sericologia*. **28** : 21-29.

FALCONER. D.S. & MACKAY. T.F.C. 1996. *Introduction to Quantitative Genetics*. 4th edn.. Longman. London.

GAMO. T. & HIRABAHASHI. T. 1983. Genetic analysis of growth rate. pupation rate and some quantitative characters by diallel cross in silkworm, *Bombyx mori* L. *Japan J. Breed.* **33** : 178-190.

KALPANA. G.V. & SREERAMA REDDY. 1998. Studies on the combining ability of the new multivoltine race MU 953 with tropical bivoltine races. *Sericologia*. **38** : 309-316.

KEMPTHORNE. O. 1957. *An Introduction to Genetic Statistics*. John Wiley and Sons, Inc.. New York.

KRISHNASWAMI. S.. JOLLY. M.S. & SUBBA RAO. G. 1974. Diallel analysis of quantitative characters in multivoltine races of silkworm. *Indian J. Genet.* **34** : 231-222.

KUMAR. P.. BHUTIA. R. & AHSAN. M.M. 1994. Combining ability analysis for filament length and some quantitative traits in bivoltine mulberry silkworm (*Bombyx mori* L.). *Indian J. Genet.* **54** : 253-257.

MANO. Y.. NIRMAL KUMAR. S.. BASAVARAJA. H.K.. MAL REDDY. N. & DATTA. R.K. 1993. A new method to select promising silkworm breeds/ combinations. *Indian Silk*. **31** : 53.

PERSHAD. G.D.. DATTA. R.K.. VIJAYKUMAR. H.V.. BHARGAVA. S.K. & JOLLY. M.S. 1986. Combining ability in multivoltine races of silkworm. *Bombyx mori* L. *Sericologica*. **26** : 307-315.

RAGHAVENDRA RAO. D.. PREMLATHA. V.. RAVINDRA SINGH. KARIAPPA. B.K.. JARASWAL. K.P.. RAMA MOHANA RAO. P. & DATTA. R.K. 2001. Studies on manifestation of hybrid vigour in polyvoltine x bivoltine crosses of silkworm. *Bombyx mori* L. *J. Expt. Zool.* **4** : 219-232.

RAGHAVENDRA RAO. D.. RAVINDRA. SINGH.. PREMLATHA. V.. KARIAPPA. B.K.. REKHA. M. & JAYASWAL. K.P. 2002. Manifestation of hybrid vigour and combining ability in polyvoltine x bivoltine hybrids of silkworm. *Bombyx mori* L.. *Int. J. Indust. Entomol.* **4** : 23-30.

RAJLAKSHMI. E.. CHAUHAN. T.P.S.. THIAGRAJAN. V.. LAKSHMANAN. V. & KAMBLE. C.K. 1997. Line x tester analysis of combining ability in new genotypes of bivoltine silkworm (*Bombyx mori*). *Indian J. Agric. Sci.* **67** : 287-290.

RAO. P.R.M.. RAVINDRA SINGH. JAYASWAL. K.P.. CHATTERJEE. S.N. & DATTA. R.K. 1998. Evaluation of some Indian and exotic low yielding silkworm (*Bombyx mori* L.) breeds through diallel cross and its significance for sericulture in dry zones. *J. Ent. Res.* **22** : 23-33.

RAVINDRA SINGH. KALPANA. G.V.. RAO. P.S.. AHSAN. M.M.. DATTA. R.K. & REKHA. M. 2000. Studies on combining ability and heterosis in the silkworm. *Bombyx mori* L. *Indian J. Seric.* **39** : 43-48.

RAVINDRA SINGH. RAGHAVENDRA RAO. D.. PREMLATHA. V.. KARIAPPA. B.K.. JAYASWAL. K.P. & DATT. R.K. 2001. Evaluation of combining ability in hybrids between low. medium and high cocoon weight polyvotine and bivoltine breeds of silkworm. *Bombyx mori* L. *Sericologia*. **41** : 57-64.

SATENAHALLI. S.B.. GOVINDAN. R. & GOUD. J.V. 1989. Genetic analysis of some quantitative traits by diallel cross in silkworm. *Bombyx mori* L. *Sericologia*. **29** : 333-342.

SEN. S.K.. DAS. S.K.. RAO. P.R.T.. GHOSH. B.DAS. N.K.. CHATTOPADHYAY. S.. ROY. G.C. & SINHA. S.S. 1995. Studies on some important genetic parameters in the silkworm (*Bombyx mori* L.). *Indian J. Plant Breed.* **55** : 238-242.

SPRAGUE. G.F. & TATUM. L.A. 1942. General vs specific combining ability in single crosses of corn. *J. Am. Soc. Agron.* **34** : 923-932.

SUBBA RAO. G. & SAHAI. V. 1989. Combining ability and heterosis studies in bivoltine strains of the silkworm. *Bombyx mori* L. *Uttar Pradesh J. Zool.* **9** : 152-164.