APPENDIX

Uttar Pradesh J. Zool. 12 (2) : 133-139, 1992 ISSN 0256-971X

VARIATION IN THE PERFORMANCE OF SOME INDIGENOUS MULTIVOLTINE MULBERRY SILKWORM BREEDS OF *BOMBYX MORI* L. IN TWO ENVIRONMENTS

P.R.T. RAO, B. GHOSH, S. CHATTOPADHYAY, B.P. NAIR, S.K. DAS, G.C. ROY, AND S.K. SEN

SILKWORM BREEDING & GENETICS SECTION, CENTRAL SERICULTURAL RESEARCH & TRAINING INSTITUTE, BERHAMPORE-742101, INDIA.

A total of 8 indigenous multivoltine silkworm breeds have been reared during two favourable and two unfavourable seasons per year from 1988 to 1991 to evaluate the essence of economic triats of different breeds on varied environmental conditions. Statistical analysis of the rearing performance (ANOVA) reveal that the indigenous breeds NISTID possess high survival; TAMILNADU (W) has better ERR.WT., SCW, SSW and SR%; MORIA has longest FIL.LENG. and fine DN.; SARUPAT(W) has highest WT. of ML. which clearly indicate that these breeds can be utilised as better breeding materials for further hybridization studies.

INTRODUCTION

Maintenance of genetic stocks is the primary requisite of sericulture industry for commercial exploitation of mulberry silkworm *Bombyx mori* L. (Chikusi, 1972). Since the silkworm has been domesticated for many centuries, they are, by nature, quite delicate and sensitive to the environmental factors like temperature, humidity and photoperiod which, to a great extent, affect the expression of quantitative characters (Sakaguchi, 1978). A specific difference of environment may have a great effect on some genotypes than on others or there may be a change in the ranking of genotypes when measured in diverse environments. This interplay of genetic and non-genetic effect on the phenotypic expression is called genotype environment (GE) interaction (Jain, 1982).

Therefore, the production of cocoon crops require optimum environmental conditions at the time of rearing for reaping good quantity of cocoons with high silk contents (Krishanaswamy, 1978). India, being a vast country, experience very wide range of fluctuation in agroclimatic conditions which can certainly be tolerated by indigenous multivoltine breeds with high survival as compared to improved multivoltine or bivoltine silkworm breeds (Subba Rao *et al.*, 1989; Jayaswal *et al.*, 1990; Goldsmith, 1991).

In West Bengal too, the climatic conditions facilitate the rearings of multivoltine silkworm breeds that can sustain with high temperature and excess humidity in the tropics of the province. Rearing of indigenous multivoltine silkworm breeds and their hybrids are in practice (Sidhu, 1967; Sengupta *et al.*, 1971 & 1974; Noamani *et al.*, 1990) since time immemorial.

A comparative study of 8 indigenous breeds *viz.* NISTARI, NISTARI (P), NISTID, SARUPAT (W), MORIA, PURE MYSORE, TAMILNADU(W) and RAJ was made during favourable and unfavourable seasons to ascertain the efficacy of the gene interaction of different breeds with environmental conditions of different seasons for the expression of economic triats which may further lead to pure line selection and other breeding plans.

MATERIAL AND METHODS

A list of 8 indigenous breeds, their origin/source and salient morphological characters is detailed below :

Name of Breed	Origin/Source	Cocoon characters	
		Colour	Shape
NISTARI	West Bengal	Yellow	Spindle
NISTARI [P]	West Bengal	Yellow	Spindle
NISTID	West Bengal	Yellow	Spindle
SARUPAT [W]	Assam	White	Spindle
MORIA	Assam	White	Ellipticle
PURE MYSORE	CSR & TI, Mysore	Light green	Spindle
TAMILNADU [W]	Tamil Nadu	White	Spindle
RAJ	Bangladesh	White	Spindle

As such, rearing of all these breeds were conducted following the rearing technology suggested by Krishnaswamy (1978 & 1979). 10 Dfls of each of the breeds were brushed *en masse* and after 2nd moult larvae were distribiuted in 3 replications, each with 300 worms. In West Bengal, silkworms are reared during favourable seasons (October to March) and in unfavourable seasons (April to September) (Jayaswal *et al.*, 1990). During former period the silkworm genes are fully expressible for better quantitative and qualitative characters whereas in the later season, the interaction of genes become passive and thus resulting into poor performance. Hence, two favourable - January to February (Flagun) and Novermber to December (Agrahaian) and two unfavourable - May to June (Jaistha) and August to September (Bhadra) indentical seasons have been considered consecutively from 1988 to 1991.

Observations were recorded for weight of 10 mature larvae in grams (WT. 10 ML.), effective rate of rearing per 10,000 larvae by number (ERR. No.) and by Weight (ERR. WT.) in grams, average single cocoon weight in grams (SCW), average single shell weight in grams (SSW), cocoon-shell ratio in per cent (SR. %), average filament length in metres (FIL.LENG.) and denier (DN).

RESULTS AND DISCUSSION

Analysis of varience (ANOVA) for statistical significance of various characters in 8 breeds during two seasons are discussed below. Significant difference was found for all the characters within seasons and within breeds. Interaction between seasons and breeds was significant in all except SCW, SSW and FIL.LENG.

WT. 10 ML. : Significant difference was recorded for WT. 10 ML. among breeds, inbetween the seasons and seasons x breeds ($P \leq 0.05$). Highest larval weight was recorded in SARUPAT(W) (25.6 g) followed by MORIA (24.9 g). The minimum larval weight was noticed in PURE MYSORE (17.1 g).

ERR No. & WT. : Highest survival No. was recorded in NISTID (8792) and by WT. in TAMILNADU(W) (8810.94 g). Both the characters are significant at 1% level. Minimum ERR. No. was noted in PURE MYSORE (6675) and WT. in MORIA (7360.13 g).

Cocoon characters : Remarkable breeding difference and seasonal differences were recorded at 1% level. High SCW, SSW and SR.% were observed as 1.072 g, 0.153 g and

Table I. Mean rearing performance of 8 multivoltine silkworm breeds.

BREED	WT. 10 ML.	ERR. NO.	ERR. WT.	SCW	SSW	SR. %	FIL. LENG	DENIER
NISTARI	20.1	8199	7399.44	0.899	0.112	12.50	366.5	1.98
NISTARI (P)	20.4	8699	7929.06	0.901	0.109	12.08	403.3	1.86
NISTID	20.9	8792	8401.94	0.949	0.111	11.75	404.4	1.96
SARUPAT (W)	25.6	8079	8691.19	1.068	0.145	13.63	530.2	2.02
MORIA	24.9	7340	7360.13	1.024	0.139	13.61	558.4	1.72
PURE MYSORE	17.1	6675	5668.56	0.832	0.098	11.76	382.9	1.76
TAMILNADU (W)	24.1	8326	8810.94	1.072	0.153	14.26	553.8	1.90
RAJ	24.4	7488	7571.06	1.040	0.144	13.76	493.6	1.98
CD ($P \leq 0.05$)	1.572	970.916	996.674	0.063	0.012	0.931	41.452	0.175
SE	0.794	490.362	503.371	0.032	0.000	0.470	20.935	0.089

Table II. Rearing performance of 8 multivoltine breeds during favourable and unfavourable seasons.

BREED	WT. 10ML.	ERR. NO.	ERR. WT.	SCW	SSW	SR. %	FIL. LENG	DENIER
FAVOURABLE SEASON								
NISTARI	21.8	8970	8711.00	0.974	0.127	13.18	361.3	1.99
NISTARI (P)	21.3	9159	8800.63	0.928	0.113	12.23	404.3	1.90
NISTID	21.9	9251	9401.50	1.009	0.115	11.42	394.3	2.11
SARUPAT (W)	28.2	8834	10934.63	1.188	0.165	13.93	567.8	2.09
MORIA	26.6	8408	8974.63	1.105	0.147	13.30	544.0	1.95
PURE MYSORE	18.1	7858	6903.13	0.874	0.105	11.95	375.0	1.81
TAMILNADU (W)	26.7	9013	10512.00	1.187	0.172	14.48	625.8	2.00
RAJ	26.8	8743	9297.50	1.123	0.165	14.75	492.4	2.16
UNFAVOURABLE SEASON								
NISTARI	18.4	7428	6087.88	0.823	0.098	11.82	371.8	1.98
NISTARI (P)	19.5	8238	7057.50	0.875	0.105	11.93	402.3	1.83
NISTID	19.9	8332	7402.38	0.889	0.108	12.08	414.1	1.81
SARUPAT (W)	23.1	7323	6447.75	0.948	0.126	13.32	492.6	1.95
MORIA	23.2	6272	5745.63	0.943	0.132	13.91	572.8	1.49
PURE MYSORE	16.1	5491	4434.00	0.789	0.091	11.57	390.8	1.70
TAMILNADU (W)	21.5	7638	7109.88	0.956	0.134	14.04	481.9	1.80
RAJ	22.0	6234	5844.63	0.957	0.123	12.77	494.8	1.79
CD ($P \leq 0.05$)	2.224	1373.08	1409.51	NS	NS	1.316	NS	0.248

Table III. Characterwise performance of silkworm breeds in two seasons.

SEASON	WT. 10 ML.	ERR. NO.	ERR. WT.	SCW	SSW	SR. %	FIL. LENG	DENIER
FAVOURABLE	23.9	8780	9191.88	1.049	0.139	13.15	470.6	2.00
UNFAVOURBALE	20.5	7120	6266.20	0.898	0.114	12.68	452.6	1.79
CD ($P \leq 0.05$)	0.786	485.458	498.337	0.0310	0.006	0.465	20.726	0.088

14.26%, respectively in TAMILNADU(W) alone. The minimum SCW (0.832 g)and SSW (0.098 g) were noted in PURE MYSORE. The least SR.% was noted in NISTID (11.75%).

Yarn characters : The post cocoon characters pertaining to quality of fibers are also important for the evolution of breeds (Dutta, 1984). The longest FIL.LENG. (558.4 metres) and finest DN (1.72) were noticed in MORIA. The shortest FIL.LENG. in NISTARI (366.5 metres) and highest DN in SARUPAT (W) (2.02) were recorded.

Table I shows that SARUPAT (W), MORIA, TAMILNADU(W) and RAJ were performing better than the rest for cocoon characters like WT. 10 ML., SCW, SSW, SR.% and FIL.LENG; whereas SARUPAT (W), NISTARI, RAJ, NISTID AND TAMILNADU(W) were better for DN; NISTID, NISTARI, NISTARI(P) and TAMILNADU(W) showed better performance for ERR. No.; TAMILNADU(N), SARUPAT(N) and NISTID were better for ERR. WT.

During favourable season, SARUPAT(W) showed high values for WT. 10 ML., ERR. WT. and SCW; TAMILNADU(W) for SSW, SR.% and FIL.LENG.; NISTID for ERR. No. and PURE MYSORE for DN (Table II). During unfavourable season, MORIA performed better than other breeds for WT. 10 ML., FIL.LENG. and DN; NISTID for ERR. No. and ERR. WT.; TAMILNADU(W) for SSW, & SR.% and RAJ for SCW (Table II). Favourable season is found to be better in all character but for denier as compared to unfavourable season (Table III).

The over all performance thus shows that indigenous breed NISTID possessed high survival; TAMILNADU(W) contain better ERR. WT., SCW, SSW and SR.%; MORIA has longest FIL.LENG.and fine DN and SARUPAT(W) has more weight for mature larvae. Therefore, NISTID, TAMILNADU(W), SARUPAT(W) and MORIA can be exploited as useful breeding material either in pure form or for hybridization studies.

ACKNOWLEDGEMENTS

Authors are thankful to all the Staff members of Silkworm Breeding and Genetics Section of CSR&TI, Berhampore for helping in conducting the rearings.

REFERENCES

CHIKUSI,H. 1972. *Genes and genetics stocks of the silkworm*. Keigaku Publishing Company, Tokyo, Japan, 67-68.

DUTTA R.K. 1984. Improvement of silkworm races (*B. mori* L.) in India. *Sericologia*. 24 (3) : 393-415.

1986. Mulberry silkworm breeding in India. Lectures on Sericulture. Swamy Publishers, Bangalore. pp. 150–156.

GOLDSMITH, M.R. 1991. Silkworm breeding for the 90's : New Molecular and genetic tools to meet the challenge of the tropics. *Sericologia*. 31 (1) :145-155.

JAIN, B.P. 1982. *Statistical Techniques in Quantitative Genetics*. Tata McGraw - Hill Pub. Company Ltd., New Delhi. pp. - 257.

JAYASWAL, K.P., DAS, S.K. & SEN,SUDIP KUMAR. 1990. Nistari (*Bombyx mori*) is an excellent breeding material. *Indian Silk*. pp. 33.

KRISHNASWAMY, S. 1978. New Technology of silkworm rearing, Bulletin 2; CSR&TI, Mysore. 1-10.

1978. FAO Agricultural Service Bulletin, Sericulture Manuals - 2.Silkworm rearing.

1979. Improved method of rearing young aged (Chawki) silkworms Bulletin 3, CSR&TI, Mysore, pp. 23.

1990. What ails our Bivoltine Silk production programme. *Indian Silk*. 29 : 6-14.

NOAMANI, M.K.R., SENGUPTA, K., NAGARAJ, J., VIZAYARAGHAVAN, K., PREMLATHA, V., RAVINDRA SINGH. RAM MOHAN RAO, P. 1990. Preference of multivoltine breeds of the silkworm, *Bombyx mori*. L. for high cocoon weight and shell weight. *Ind. Jour. Seric.* 29 (2) : 227-232.

SATYANARAYAN RAJU, CH.CHANDRASHEKHARIAH & VENUGOPALA PILLAI, S. 1990. Preference of Bivoltine breeds of silkworm *Bombyx mori* L. as influenced by mulberry varieties in high altitude. *Ibid:* 29 (2) : 162-167.

SAKAGUCHI, B. 1978. Postembryonic development of silkworm. In : *The silkworm -An important Laboratory tool* (Tazima, Y.Ed.) Nat. Inst. of Genetics Mishima Japan, Kodansha Ltd., Tokyo. pp. 31-49.

SENGUPTA,K., DUTTA, R.K., BISWAS, S.N. & SINGH, B.D. 1971. Heterosis in Multivoltine silkworm *Bombyx mori*, L. yield performance of F_1 hybrids of NISTARI and from evolved multivoltine breeds. *Ind. Jour. Seric.* 10 : 6-13.

SENGUPTA, K., YUSUF, M.R. & GROVER, S.P. 1974. Hybrid vigour and genetic analysis of quantitative traits in silkworm. *Ind. Jour. Genetics. Sabrao.* 34 : 249-256.

SIDHU, N.S. 1967. A multivoltine breed of silkworm, *Bombyx mori*. L., for tropics in evolution. *Ind. Jour. Seric.* 6 : 63-66.

SUBBA RAO, G., DAS, S.K. & GHOSH, B. 1989. Heterosis effect on some New silkworm hybrids evolved in three way cross. *Perspective in Cytology and Genetics.* 6 : 373-378.

Environment & Ecology 10 (4) : 845—848, 1992
 ISSN 0970-0420

Analysis of Quantitative Traits in Some Evolved Multivoltine Silkworm Breeds of *Bombyx mori* L. Under Two Environments

S. CHATTOPADHYAY, B. GHOSH, P. R. T. RAO, SUDIP SEN, S. K. GUPTA, G. C. ROY, S K. SEN AND S. K. DAS

Central Sericultural Research & Training Institute

Berhampore 742101, India

Abstract

The performance of five evolved multivoltine silkworm breeds of *Bombyx mori* L., was studied during two favorable and unfavorable seasons to evaluate the quantitative traits during different environments. Statistical analysis depicts that the additive gene-effect has a vital role in expressing the quantitative traits in varied environments. Further, CB-5 being better in respect of survival can be exploited and OS-616 having better cocoon characters, also may be utilized for hybridization programs.

The yield of good quality silk is mostly dependent on the genetic potentiality of silkworm breeds and the climatic conditions to which they are exploited (1). Multivoltine indigenous breeds are dominating in the tropical belt of eastern and north-eastern India. These breeds can tolerate different environmental conditions and give a crop reliability but their yield and the silk quality is virtually poor (2—6). Therefore, attempts have been made to evolve high yielding multivoltine silkworm breeds that can withstand high temperature and high humidity (7—10) and their maintenance is also of paramount importance for the development of sericulture industry. Moreover, the heretability and genotype-environmental interactions (G×E) are influencing the genotypic expression of economic traits (11, 12). To fulfill the above requirements, a number of high yielding multivoltine silkworm breeds were evolved from time to time from different indigenous breeds through several breeding techniques (13).

In the present study, a comparative performance of five evolved multivoltine breeds, namely, G, CB-5, Oval, S-1> and OS-616 was made with different environmental conditions. The breed×seasonal interactions of all these breeds were estimated statistically in respect of survival and other economic quantitative traits.

(Authors are grateful to all the staff members of silkworm breeding and genetic section of CSR & TI, Berhampore, WB for assistance in rearings, and thanks are also due to B. P. Nair, SRO, statistics for statistical analysis.)

Methods

The detailed morphological features of five evolved multivoltine breeds and their mode of evolution are given in Table 1. Maintenacc of multivoltine silkworm breeds is a continuous process. For the present study, 10 DFLS each of five evolved multivoltine breeds were brushed en masse and the rearings were conducted as per the standard rearing technology (14, 15). After second moult the larvae were distributed in three replications each with 300 larvae. In the tropical plains of eastern and north-eastern India from October to March and April to September are known as favorable and unfavorable seasons respectively for silkworm rearings.

As such, for the present study the rearings of two favorable seasons *falgooni* (January-

February) and *agrahayani* (October-November) and two unfavorable seasons *jaistha* (May-June) and *bhaduri* (August-September) have been considered consecutively.

Observations were recorded for number of eggs laid, larval period in days (Lar. pd.) survival percentage (Sur %), yield per 10,000 larvae brushed in kilograms (yield in kg), average single cocoon weight in grams (SCW), average single shell weight in grams (SSW) and average filament length in meters (Fil. l.). Cocoon and shell weights were taken on the sixth day from the date of mounting the worms for spinning. Data were statistically analyzed.

Results and Discussion

Analysis of variance (ANOVA) for statistical significance of various characters in five evolved multivoltine breeds during two seasons are discussed. Significant difference ($P \leqslant 0.05$) was found for all the characters except number of eggs laid and filament length for seasons. Significant difference was also observed in different breeds for all the characters except number of eggs laid and yield in kg. Interaction between breeds and seasons was not significant (Table 2).

Number of eggs Laid by Female Moth. No significant difference was observed among the breeds between the seasons and their interaction.

Larval Period in Days. Significant difference ($P \leqslant 0.05$) was observed among the breeds and between seasons. Interaction between seasons and breeds was not significant. Shortest larval period was noticed in oval (21 days) followed by CB-5 and S-15 (22 375 days).

Survival Percentage. Significant differences were observed for seasons and breeds in respect of survival percentage. Highest survival percentage was observed in CB-5 (86 07) followed by oval (83.40) ; lowest survival percentage was noted in OS-616 (71.16).

Yield in Kilograms per 10,000 Larval Brushed. Breed differences in yield, were not significant but seasons differences were found significant at 5% level. Highest yield was recorded in OS-616 (9.691 kg) followed by G (9.609 kg).

Cocoon Characters. Significant differences were recorded among breeds and seasons for SCW, SSW, OS-616 showed high values for SCW (single cocoon weight) (1.361 g), SSW single shell weight) (0.204 g). Lowest values were recorded in CB-5 for SCW (1.124 g) and in S-15 for SSW (0.154 g).

Filament Length in Meters. Significant difference in breeds and seasons were recorded at 5% level, OS-416 contained the longest filament length (635.4 m) followed by CB-5 (585.2 meters). Shortest filament length was recorded in S-15 (517.3 m).

During unfavorable season OS-616 showed better performance for number of eggs laid, SCW, SSW and filament length, oval showed shortest larval period, CB-5 was better for survival percent and G for high yield.

During favorable season OS-616 was found better for number of eggs laid, SCW, SSW, yield and filament length, shortest larval period was noticed in oval and better survival was noticed in CB-5.

Overall performance of the breeds showed that OS-616 was better for number of eggs, yield, SCW, SSW and filament length, shortest larval period was found in oval and CB-5 stands for better survival percent.

The significant interaction effect between seasons and breeds indicate that the additive gene-effect of these evolved breeds has a significant role in expressing the quantitative traits in varied environment. Absence of $G \times E$ interaction implies that the breeds which are performing well in one season are likely to do so

Table 1. Morphological features of five multivoltine breed and their mode of evolution.

Name of the breed	Evolved at CSR & TI	Mode of evolution	Larval marking	Cocoon color	Cocoon shape
O	CSR & TI, Berhampore (WB)	Mutation and hybridization	Marked	Yellow	Oval
CB-5	,,	,,	,,	,,	,,
Oval	,,	,,	,,	,,	,,
S-15	,,	,,	,,	,,	Ellyptical
OS-616	,,	Hybridization	,,	,,	Oval

in the other seasons also.

Thus, it can be seen from the Table 2 that CB-5 was the only breed which gave essentially higher survival rate both in favorable and unfavorable seasons. Cocoon characters of CB-5 was also not inferior to other except OS-616. This breed may be exploited in both favorable and unfavorable seasons. Although OS-616 has marked by high cocoon and shell weight its survival during favorable and unfavorable seasons was quite low. This breed may be used as one of the components in hybridization program.

Table 2. Mean performance of evolved multivoltine breeds in two environments. Unfav, Unfavorable season ; Fav, favorable season ; NS, not significant.

Breed	Season	No. of eggs laid	Lar. pd.	Surv %	Yld/ 10,000 larvae (kg)	SCW	SSW	Fill. Leng.
O	Unfav	446	21.250	75.82	8.142	1.150	0.151	560.750
	Fav	469	24.375	88.84	11.077	1.277	0.181	574.250
	Mean	458	22.813	82.33	9.610	1.213	0.166	567.500
CB5	Unfav	450	20.625	78.52	7.570	1.031	0.144	553.250
	Fav	459	24.125	93.63	11.107	1.217	0.171	617.250
	Mean	454	22.375	86.07	9.338	1.124	0.157	585.250
Oval	Unfav	448	20.250	73.72	7.668	1.108	0.150	518.875
	Fav	451	23.625	93.09	10.611	1.237	0.175	578.375
	Mean	449	21.938	83.40	9.139	1.172	0.162	548.625
S15	Unfav	445	20.750	67.92	7.205	1.099	0.143	521.750
	Fav	466	24.000	93.22	10.470	1.191	0.166	512.750
	Mean	455	22.375	80.57	8.838	1.145	0.154	517.250
OS-616	Unfav	479	21.625	64.79	7.603	1.205	0.173	595.000
	Fav	525	24.750	77.53	11.780	1.517	0.236	675.875
	Mean	502	23.188	71.16	9.691	1.361	0.204	635.438
CD AT 5%	Season :	NS	0.548	5.58	0.850	0.053	0.010	NS
	Breed :	NS	0.867	8.82	NS	0.084	0.016	70.795
	SEXBR :	NS	NS	NS	NS	NS	NS	NS
	SE	43.617	0.859	8.74	1.330	0.083	0.016	70.094

References

1. Sreerama Reddy G. 1986. Genetics and breeding of silkworm *Bombyx mori* L. Lectures on sericulture. Swamy Publishers, Bangalore, India, pp. 70—80.
2. Sengupta K., R. K. Dutta, S. N. Biswas, and B. D. Singh. 1976. Heterosis in multivoltine silkworm (*Bombyx mori* L.) yield performance of F-1 hybrids of Nistari and four evolved multivoltine breeds. Indian J. Seic. 10 : 6—1 .
3. Sengupta K. and R. K. Dutta. 1973. Studies on the evolution of superior multivoltine breeds of silkworms, *Bombyx mori* L. 12th International Silk Congress, Bercelona, pp. 1—16.
4. Sengupta K., R. K. Dutta and S. N. Biswas. 1974. Effect of multiple crossing on the population pattern of progeny in silkworm. Indian J. Genetics, Plant Breeding. 34 : 241—248.
5. Dutta R. K. 1986. Mulberry silk worm breeding in India. Lectures on sericulture. Swamy Publishers, Bangalore, India, pp. 150—156.
6. Noamani M. K. R., K Sengupta, J. Nagaraj, K. Vijayaraghavan, V. Premlatha, Ravinder Singh, P. Rammohan Rao. 1990. Performance of multivoltine breeds of silkworm, *Bombyx mori*, L., for high cocoon weight and shell weight. Indian J. Seric. 29 : 227—232.
7. Sidhu M. S. 1967. A multivoltine breed of silkworm, *Bombyx mori* L., for tropics in evolution. Indian J. Seric. 6 : 63—66.
8. Sakaguchi B. 1978. Post-embryonic development of silkworm. The silkworm, an important laboratory tool. *In* Y. Tazima, editor. National Institute of Genetics. Kodansha Mishima, Japan. Ltd., Tokyo.
9. Krishnaswami S. 1978. Sericultural manuals—2, Silkworm rearing. 15/2, FAO Agricultural Service Bulletin, Rome, Italy.
10. Goldsmith M. R. 1991. Silkworm breeding for the 90's :New molecular and genetic tools to meet the challange of tropics. Sericologia 31 : 145—155.
11. Jain B. P. 1982. Statistical techniques in quantitative genetics. Tata Mc. Graw Hill Pub. Comp. Ltd., New Delhi, India.
12. Sharma S. K., K. S. Gill and G. S. Nanda. 1985. Genotype-environment interaction and heritability estimates for some quantitative characters in triticale. Indian J. Genetics 45 : 75—80.
13. Dutta R. K. 1984. Improvement of silkworm races (*B. mori* L.) in India. Sericologia 24 : 393—415.
14. Krishnaswami S. 1978. New technology of silkworm rearing. Bull. 2, CSR & TI, Mysore, India.
15. Krishnaswami S. 1979. Improved method of rearing young aged (Chawki). Silkworms Bull. 3, CSR & TI, Mysore, India.

Environment & Ecology 11 (3): 548—552, 1993
 ISSN 0970-0420

Heterosis Effect on Multivoltine Silkworm Hybrids *Bombyx mori* L. Suitable to Tropics of Eastern India

B. GHOSH, S. K. DAS, P. R. T. RAO, S. K. SEN AND S. S. SINHA
Central Sericultural Research & Training Institute
Berhampore 742101, India

Abstract

The heterosis on the quantitative traits of some multivoltine silkworm hybrids of *Bombyx mori* L. was studied during two unfavorable seasons of West Bengal. Statistical analysis of data revealed high heterosis in May—June than August—September seasons. Data further depicted that the hybrids N×PM, PM×S and S×PM can be exploited for commercial rearing.

The developement of sericultural industry in any country depends much on the availability of disease resistant silkworm breeds and their proper utilization for the production of silk (1). The plains of West Bengal is dominated by indigenous multivoltine silkworm breeds as they can withstand the local climatic conditions with shorter larval period. But their silk yield is less and quality is poor (2). With a view to replace the indigenous multivoltine pure breeds at field level during most unfavorable seasons of West Bengal when temperature (28 to 37 c) and relative humidity (80 to 98%) are high, some hybrids and their reciprocals have been evaluated. The introduction of hybrid silkworm by Toyama (3), that has stimulated extensive studies (4—15) and the design has increased the efficiency of breeding operation in silkworm, *Bombyx mori* L.

(Authors are thankful to Mr. B. P. Nair, SRO, Statistics, of this Institute for statistical analysis of data.)

Methods

Three hybrids namely, Nistari x Pure Mysore (N×PM), Pure Mysore×Sarupat (W) (PM×S) and Sarupat (W)×Tamil Nadu (W) (S×TN) and their reciprocal crosses along with their parents were reared with five replications each. Rearings were conducted during two unfavorable commercial seasons of West Bengal namely, May—June (Jaistha) and August—September (Bhaduri). The standard schedule of rearing was followed as advocated by Krishnaswami (16). Data on nine important commercial traits, namely, fecundity (Fecund), larval period in days (Lar Pd), weight of 10 mature larvae (Wt10Ml), survival percent (Surv %). yield per 10,000 worms in grams (ERR Wt), single cocoon weight (SCW), single shell weight (SSW), filament length in meter (Fil Leng) and denier were recorded. Heterosis over mid parent value (MPV) and better parent value (BPV) were determined as per standard statistical method.

Percentage of heterosis over MPV=(Fl—BP)/MP×100

S Ed (Fl—MPV)=/3 EMS/2r

CD=S Ed × t 0.05, error df

Percentage of heterosis over BPV = (Fl—BP)/BP×100

S Ed (Fl—BPV)= /2 EMS / r

CD=S Ed × t 0.05, error df

where MPV, mid parent value ; BPV, better parent value; EMS, error mean square ; t 0.05, error df Student t values 5% level corresponding to eroor ; df, degree of freedom; CD, critical difference and r, replication.

Results and Discussion

Season-wise performance of six hybrids and their parents in respect of nine quantitative traits are presented in Table 1. Analysis of varience (ANOVA) revealed significant difference ($P \leq 0.05$) for seasons and race. Interaction between season and race was also found significant.

May-June months of West Bengal are considered as the dry summer with high temperature and less humidity. During this season the hybrids have performed better than their parents whereas in August-September when the temperature and humidity both are high, the performance of hybrids was not so good. Therefore, the degree of heterosis was more pronounced in the former season than the later one (Tables 2 and 3). The prime reason for less heterosis in the later season is the combination of high relative humidity along with high temperature during which the interaction of genes are not expressed. The variation in the performance of these hybrids from season to season can be explained due to the influence of environment (17).

Season-wise heterosis over mid parent value (MPV) and better parent value (BPV) are presented in Tables 2 and 3. The results of both the seasons are discussed seperately.

May-June (*Jaistha*). For fecundity no significant positive heterotic effect was found in all the hybrids over MPV and BPV. The desirable negative value for Lar Pd was noticed in all the hybrids over both parental values except three hybrids, nemely, N × PM, PM × S and S × PM over BPV. Heterotic effects for Wt 10 Ml were found positive and significant in all the hybrids over MPV and BPV except PM × N (4.56). The maximum heterotic value was recorded in TN × S (MPV 41.10 and BPV 40.42) followed by PM × S (MPV 35.65 and BPV 29.88). For Surv percent of most of the heterotic values was found positive over MPV and BPV. Highest heterosis value was recorded in S × PM (MPV 84.16; BPV 40.97) followed by PM × S (MPV 79.85; BPV 37.67). Significant positive heterosis values were noticed for ERR Wt in all the hybrids over MPV except S × TN over BPV. The maximum value was found in PM × S (MPV 137.93; BPV 88.01) followed by S × PM (MPV 131.69; BPV 83.08). For SCW and SSW significant positive heterotic effects were noticed in all the hybrids over MPV and BPV. Maximum heterosis for SCW was recorded in TN × S (MPV 30.19; BPV 30.05) followed by PM × S (MPV 27.51; BPV 26.83); PM × S showed highest value for SSW followed by its reciprocal over MPV and BPV. Filament length has shown positive and significant heterosis in all the hybrids except S × TN over MPV and BPV. Highest values were observed in TN × S (MPV 29.78; BPV 26.02) followed by S × PM (MPV 28.53: BPV 24.53). Most of the heterotic values for denier were recorded positive and highest value was observed in S × PM over MPV (19.64) and BPV (18.24).

August-September (*Bhaduri*). Negative heterosis for fecundity over MPV and BPV was found except N × PM (MPV 14.78; BPV 10.81) and TN × S (only MPV 5.60) (Table 3). Desirable negative significant heterosis for Lar Pd was observed in all the hybrids only over MPV. Heterotic effect for Wt 10Ml was found positive in all hybrids except in S × PM over BPV (−5.71) and TN × S for MPV (−0.40) and BPV (−4.76). Positive and significant heterosis was noticed except in N × PM (BPV 6.93) and PM × S (BPV 5.17). The heterosis for Surv percent was found to be positive in all hybrids except PM × N (BPV 11.34). Positively

Table 1. Performance of parents and hybrids. NS, Not significant; PM, Pure Mysore; N, Nistari; S, Sarupat (W); TN, Tamilnadu (W); Fecund, fecundity; Lar pd, larval period in days; Wt 10 MI, weight of 10 mature larvae in g; Surv. % survival percent; ERR Wt: yield per 10,000 worms in g; SCW: single cocoon weight in g; SSW: single shell weight in g; Fil. ln, filament length in meter.

Race/ Comb	Fecund	Lar Pd	Wt 10 MI	Surv %	ERR Wt	SCW	SSW	Fil Ln	Denier
May-Jun									
N	302	19.00	24.96	77.36	7711.80	0.970	0.140	403.40	2.53
PM	301	21.00	21.30	64.66	5680.80	0.943	0.119	392.20	2.09
S	321	19.00	23.28	34.33	3297.00	0.933	0.129	367.80	2.14
TN	256	19.00	23.51	61.02	5609.80	0.935	0.119	390.40	2.38
N×PM	306	19.00	27.39	89.36	10010.80	1.174	0.163	495.00	2.39
PM×N	265	19.00	26.10	90.56	10048.00	1.124	0.163	465.60	2.40
PM×S	270	18.00	30.24	89.02	10680.40	1.196	0.170	469.00	2.48
S×PM	304	19.00	27.06	91.16	10400.20	1.112	0.162	488.40	2.53
S×TN	321	18.00	29.57	64.83	7224.40	1.119	0.161	407.00	2.67
TN×S	313	18.00	33.01	57.43	6890.80	1.216	0.158	492.00	2.57
Aug-Sep									
N	451	18.00	20.35	47.36	4382.20	0.999	0.134	484.00	2.00
PM	420	23.00	15.77	71.40	5252.80	0.806	0.108	388.00	1.69
S	564	20.00	25.16	47.11	4746.40	1.002	0.129	424.00	2.51
TN	489	21.00	22.91	55.19	4841.60	0.948	0.128	469.00	2.27
N×PM	500	20.00	21.76	72.69	7328.20	1.036	0.146	493.00	2.27
PM×N	396	20.00	22.78	63.30	6539.80	1.008	0.145	477.00	2.42
PM×S	422	20.00	26.46	72.57	7788.00	1.079	0.158	500.00	2.16
S×PM	479	20.00	23.72	74.08	7636.60	1.028	0.140	474.00	2.33
S×TN	473	20.00	28.10	65.37	7124.60	1.135	0.166	430.00	2.41
TN×S	556	20.00	23.94	82.98	8182.00	1.005	0.147	399.00	2.55
Average									
N	377	18.50	22.66	62.36	6047.00	0.984	0.137	443.70	2.26
PM	361	22.00	18.54	68.04	5466.80	0.874	0.113	390.10	1.89
S	443	19.50	24.22	40.72	4021.70	0.967	0.129	395.90	2.32
TN	373	20.00	23.21	58.11	5225.70	0.941	0.123	429.70	2.33
N×PM	403	19.50	24.58	81.02	8669.50	1.105	0.154	494.00	2.33
PM×N	331	19.50	24.44	76.93	8293.90	1.066	0.154	471.30	1.41
PM×S	346	19.00	28.35	80.80	9234.20	1.137	0.164	484.50	2.32
S×PM	392	19.50	25.39	82.62	9018.40	1.070	0.151	481.20	2.43
S×TN	397	19.00	28.84	65.10	7174.50	1.127	0.163	418.50	2.54
TN×S	435	19.00	28.48	70.21	7536.40	1.110	0.153	445.50	2.56
CD At 5%									
Season (SE)	14.380	0.00	0.467	5.205	565.14	0.026	0.004	NS	0.09
Race (RA)	2.156	0.00	1.043	11.64	1263.69	0.058	0.009	37.97	0.19
SE×RA	45.475	0.00	1.476	16.46	1787.13	0.082	0.013	53.67	0.27

significant heterosis was found in TN×S (MPV 62.23 and BPV 50.36). Most of the hybrids exhibited positively significant heterosis in respect of ERR Wt. except PM×N (MPV 35.75; BPV 24.50). In respect of SCW, the BPV are not significant for the hybrids N×PM, PM×N, S×PM and TN×S containing only positive values. In SSW, all the hy-

Table 2. Heterosis over mid parent and better parent (May-June). Values are significant at 5% level (*); MP, mid parent; BP, better parent.

Combination		Fecund	Lar Pd	Wt 10 Ml	Surv %	ERR Wt	SCW	SSW	Fil Ln	Denier
N×PM	MP	1.63	−5.00	18.40*	25.83	49.50*	22.74*	25.87*	24.43*	3.42
	BP	1.46	0.00	9.72*	15.51	29.81*	21.03*	16.43*	22.71*	−5.54
PM×N	MP	−11.98	−5.00	12.83*	27.53*	50.05*	17.51*	25.87*	17.04*	4.12
	BP	−12.13	0.00	4.56	17.06	30.29*	15.88*	16.43*	15.42*	−4.91
PM×S	MP	−13.13	−10.00	35.65*	79.85*	137.93*	27.51*	37.10*	23.42*	17.27*
	BP	−15.84*	−5.26	29.88*	37.67*	88.01*	26.83*	31.78*	19.58*	15.90*
S×PM	MP	−2.25	−5.00	21.40*	84.16*	131.69*	18.55*	30.65*	28.53*	19.64*
	BP	−5.30	0.00	16.23*	40.97*	83.08*	17.92*	25.58*	24.53*	18.24*
S×TN	MP	11.37	−5.26	26.38*	35.97	62.22*	19.81*	29.84*	7.36	18.05*
	BP	0.19	−5.26	25.78*	6.23	28.78	19.68*	24.81*	4.25	12.01*
TN×S	MP	8.52	−5.26	41.10*	20.47	54.73*	30.19*	27.42*	29.78*	13.89*
	BP	−2.37	−5.26	40.42*	−5.88	22.84*	30.05*	22.48	26.02*	8.06

brids possess significantly positive both for MPV and BPV. In Fil. Leng. negative heterotic values were observed for the hybrids PM×N (BPV—1.45). S×TN(MPV—3.70;BPV —8.32) and TN×S(MPV—10.64)but its BPV was insignificant (—14.93);maximum positively significant heterosis was observedin PM×S(MPV 23.15; BPV 17.92). Positive and significant value for denier was noticed in the hybrid PM ×N over MPV and BPV; significantly negative heterosis was noticed over BPV in PM×S (—13.65).

Considering season-wise and average per'se performance, three hybrids, namely, S×PM, PM×S and N×PM have been found better during unfavorable seasons of West Bengal. Since, heterotic values of the above hybrids were high and significant for survival percentage, ERR Wt., SCW, SSW, filament length and desired negative larval period, it can be inferred that Fl hybrids have more adoptibility and can successfully be exploited at the field level.

Table 3. Heterosis over mid parent and better parent (August-September). Values are significant at 5% level; MP, mid parent; BP, better parent.

Combination		Fecund	Lar Pd	Wt 10 Ml	SURV %	ERR Wt	SCW	SSW	Fil Ln	Denier
N×PM	MP	14.78*	−2.44	20.50*	22.40	52.12*	14.77*	20.80*	13.07	23.01*
	BP	10.81	11.11	6.93	1.80	39.51*	3.70	8.97*	1.86	13.60
PM×N	MP	−9.13	−2.44	26.14*	6.60	35.75	11.73*	20.13*	9.40	31.24*
	BP	−12.27*	11.11	11.93*	−11.34	24.50	0.96	8.37*	−1.45	21.20*
PM×S	MP	−14.20*	−6.98	29.31*	22.46	55.77*	19.30*	33.95*	23.15*	3.05
	BP	−25.16*	0.00	5.17	1.64	48.26*	7.64*	23.02*	17.92*	−13.65*
S×PM	MP	−2.66	−6.98	15.92*	25.01	52.74*	13.68*	18.20*	16.75*	10.86
	BP	−15.10*	0.00	−5.71	3.75	45.38*	2.57	8.55*	11.79	−7.10
S×TN	MP	−10.09	−2.44	16.91*	27.80	48.61*	16.44*	29.43*	−3.70	0.96
	BP	−16.12*	0.00	11.68*	18.45	47.15*	13.29*	28.93*	−8.32	−3.83
TN×S	MP	5.60	−2.44	−0.43	62.23*	70.67*	3.05	14.75*	−10.64	7.00
	BP	−1.49	0.00	−4.86	50.36*	68.99*	0.26	14.31*	−14.93*	1.92

References

1. Sengupta K. and R. K. Datta. 1973. Studies on the evolution of superior multivoltine breeds of silkworms, *Bombyx mori* L. 12th International Silk Congress, Bercelona, pp. 1—16.
2. Goldsmith M. R. 1991. Silkworm breeding for the 90's : New molecular and genetic tools to meet the challange of tropics. Sericologia 31 : 145—155.
3. Toyama K. 1906. Studies on hybridology of insects. In some silkworm crosses with special reference to Mendel's Law of Heridity. Bull. Coll. Agric. Tokyo Univ. 7 : 259—293.
4. Hirobe T. 1956. An analysis of heterosis, made with the silkworm. Proc. Int. Genet. Symp. Suppl. Vol. Cytologia, pp. 357—361.
5. Sidhu N. S., B. L. Tikko, Kamala Singh and R. Srinivasan. 1969. Determination of superior hybrid combinations for commercial exploitation in *Bombyx mori* L. Silkworm Inf. Bull. 1 : 33—40.
6. Sengupta K., R. K. Datta, S. N. Biswas and B. D. Singh. 1971. Heterosis in multivoltine silkworm *Bombyx mori* L., yield performance of Fl hybrids of Nistari and four evolved multivoltine breeds. Ind. J. Seric. 10 : 6—13.
7. Sengupta K., M.R. Yusuf and S. P. Grover. 1974. Hybrid vigor and genetic analysis of quantitative traits insilkworm. Ind. J. Genet. SABRAO 34 : 249—256.
8. Yokoyama T. 1974. Utilization of heterosis in Japan sericulture. Ind. J. Genet. SABRAO 34 : 206—210.
9. Petkov and A. Yolove. 1979. Influence of cocoon size and weight on heterosis effect in silkworm *Bombyx mori* L. Genet. Sel. 12 : 286—291.
10. Jolly M. S. 1983. Silkworm genetics and breeding. National Seminar on Silk Res. and Developement (Lead Paper), Bangalore India, pp. 1—19.
11. Gamo T. and T. Hirabayashi. 1983. Genetic and analysis of growth rate, population rate and some quantitative characters by diallel cross in the silkworm *Bombyx mori* L. Jap. J. Breed. 33 : 178—190.
12. Subba Rao G., S. K. Das, B. Ghosh and K. P. Jayaswala. 1987. A study on the heterosis of two hybrids of mulberry silkworm. Nat. Symp. on heterosis exploitation : Accomplishment and prospect. Marathwada Agric. Univ., Parbhani, p. 59.
13. Subba rao G., S. K. Das and B. Ghosh. 1989. Heterosis effect on some new silkworm hybrids evolved by three-way cross. Pages 373—378. *in* G. K. Manna and U. Sinha, editors. Perspective in cytology and genetics volume 6. Kalyani press, New Delhi, India.
14. Subba Rao G., S. K. Sen, B. Ghosh and S. K. Das. 1990. Heterosis in some hybrids of indigenous and bivoltine races of mulberry silkworm. Proc. 7th. All India Cong. of Cyto. Genet. Kalyani, India, p. 4.
15. Tayade D. S. 1987. Heterosis effect on economic traits of new hybrids of silkworm, *Bombyx mori* L. under Marathawada conditions. Sericologia 27 : 301—307.
16. Krishnaswami S. 1978. New technology of silkworm rearing. Bull. C. S. R. & T. I., Mysore. 2 : 1—10.
17. Allard R.W. 1956. The analysis of environmental interaction by means of diallel cross. Genetics pp. 5—318.

Indian J. Genet., 55 (3): 238–242 (1995)

STUDIES ON SOME IMPORTANT GENETIC PARAMETERS IN SILKWORM (*BOMBYX MORI* L.)

S. K. SEN, S. K. DAS, P. R. T. RAO, B. GHOSH, N. K. DAS, S. CHATTOPADHYAY, G. C. ROY AND S. S. SINHA

Silkworm Breeding and Genetics Section, Central Sericultural Research & Training Institute, Berhampore, West Bengal 742101

(Received: January 20, 1994; accepted: December 15, 1994)

ABSTRACT

A study on genetic variability was made with 5 x 5 diallel of genetically divergent multivoltine lines to determine the importance of quantitative traits of mulberry silkworm, *Bombyx mori* L. Data were collected from rearings made during four commercial seasons of West Bengal. The study of phenotypic and genotypic variation, coefficient of variation, heritability and genetic advance for 10 quantitative traits indicated additive and nonadditive effects of genes which facilitates selection for the amelioration of breeds.

Key words: Genotypic and phenotypic variation, heritability, genetic advance, *Bombyx mori* L.

Studies on genotypic and phenotypic variability, heritability and genetic advance play an important role in planning the selection scheme for the improvement of economically important traits in plants and animals as well. Extensive review, on the agreement between estimated and realised genetic parameters has been made on various animals, which showed difference between the realised and estimated genetic parameters. Further, accuracy of selection index can be improved by considering the realised heritability estimate and depending on the selection response, the traits can also be adjusted [1, 2]. Heritability estimates have been worked out on the hoarding of sugar syrup in honey bee using cumulative selection differential and a considerable gain has been achieved [3]. In tasar silkworm, *Antheraea mylitta* D. genotypic and phenotypic variability and correlations, heritability (broad and narrow sense) genetic advance, environmental effects etc., have been reported earlier [4–6]. In mulberry silkworm, *Bombyx mori* L., some authors [7–9] have estimated a few of the above parameters sporadically. Narasimharaju et al. [10] worked extensively on genetic variability in different types of hybrids only.

The present study, has been undertaken to understand the nature and extent of phenotypic and genotypic variability, heritability (broad sense) and genetic advance of

10 quantitative traits in 5 multivoltine silkworm breeds and their possible hybrids for adopting a suitable selection criterion for further improvement through breeding.

MATERIALS AND METHODS

The genetic divergence of multivoltine silkworm parental stock of this institute was measured by using Mahalanobis' D^2 statistics [11]. The breeds were grouped into 5 clusters. Five multivoltine breeds, Nistari, Raj, CB_5, G and B, one from each cluster, were selected and crossed in 5 x 5 diallel. Rearings were conducted during two favourable (Falgooni and Agrahayani) and two unfavourable (Jaistha and Bhaduri) commercial rearing seasons of West Bengal as per the standard schedule. Data were collected on 10 quantitative traits of economic importance (Table 1).

The phenotypic and genotypic variance and coefficient of variation were calculated following Burton and De Vane [12]. Heritability in broad sense was estimated as per the formula given by Lush [13] and Allard [14], ($h^2 = \sigma g^2/\sigma p^2$). The genetic advance (percentage of mean) was worked out using the method of [15].

RESULTS AND DISCUSSION

The mean, range, standard error, CD and SD for different traits are presented in Table 1. Analysis of variance (ANOVA) revealed that the pure breeds or hybrids were significant for all traits ($P \geq 0.01$). The maximum range was found in shell weight, followed

Table 1. Phenotypic variability of ten traits in silkworm

Trait	Range	Mean	SE	CD, 5%	S.D.
Fecundity (No.)	367.0 – 472.7	420.6	5.76	33.4	28.8
Hatching (%)	90.3 – 96.5	93.8	0.31	3.0	1.6
Larval period (days)	21.0 – 22.2	21.4	0.06	0.2	0.3
Weight of 10 mature larvae (g)	20.2 – 31.7	27.4	0.53	1.1	2.7
Survival (%)	78.0 – 93.4	87.1	0.87	5.0	4.3
Yield / 10,000 larvae (kg)	8.0 – 12.1	10.3	0.20	0.7	1.0
Single-cocoon wt. (g)	0.9 – 1.4	1.2	0.03	0.1	0.1
Single-shell wt. (g)	0.1 – 0.2	0.2	0.00	0.0	0.0
Cocoon-shell ratio	13.2 – 15.9	15.0	0.12	0.5	0.7
Filament length (m)	412.5 – 691.2	573.1	15.61	55.3	78.1

by filament length and cocoon weight, and minimum for larval period and hatching percentage. Phenotypic and genotypic variabilities, heritability and genetic advance of different traits are presented in Table 2.

Table 2. Estimates of phenotypic and genotypic variability, heritability and genetic advance in silkworm

Trait	Variance		PCV	GCV	Heritability	G.A.
	phenotypic	genotypic			(%)	(%)
Fecundity	4030	2881	15.1	12.8	71.5	22.2
Hatching	14.5	5.4	4.1	2.5	37.2	3.1
Larval period	0.4	0.4	3.0	2.9	88.9	5.6
Weight of larvae	30.0	28.9	20.0	19.6	96.3	39.6
Survival	90.8	65.1	11.0	9.3	71.7	16.2
Yield/10,000 larvae	4.2	3.7	19.9	18.7	88.0	36.2
Single-cocoon wt.	0.08	0.17	23.4	22.9	95.5	46.1
Single-shell wt.	0.00	0.00	30.2	29.5	95.9	59.6
Cocoon–shell ratio	2.1	1.8	9.6	8.9	86.2	17.1
Filament length	26971	23824	28.7	26.9	88.3	52.1

The difference between phenotypic and genotypic variances was highest for hatching percentage, depicting maximum environmental influence. Minimum differences were observed in most of the economic traits except survival and fecundity, indicating less environmental effect. The phenotypic and genotypic coefficients of variations (PCV, GCV) were lowest in larval period and highest in single-shell weight, followed by filament length and single-cocoon weight. The PCV was higher than GCV for all the traits. The difference between them was less for hatching percentage and larval duration.

The heritability expresses the proportion of the total variance that is attributable to the average effect of genes and determines the degree of resemblance between relatives [15]. With the exception of hatching percentage, broad sense heritability was high for all the traits and ranged from 71.5% (fecundity) to 96.2% (larval period) (Table 2). Therefore, the reliability of selection through phenotypic values of these traits is high. Heritability alone is not enough to describe the additive and nonadditive gene action for selection criterion. For this, estimation of genetic advance, in addition to heritability, is important. The observed genetic advance (GA) was high for shell weight (59.6%), filament length (52.1%), cocoon weight (46.1%), larval period (39.6%) and E.R.R. wt. (36.1%). For other traits GA was low in the range of 3.1% (hatching %) and 22.2% (fecundity).

It can be concluded from the above observations that mature larval wt., E.R.R. wt., cocoon wt., shell wt. and filament length, for which heritability as well as GA were high, are the traits governed by additive gene action, suggesting high selection value for these traits which can be improved through mass selection [16]. The other traits, except hatching percentage, have high heritability but low in genetic advance indicating prevalence of nonadditive gene actions. As such, progeny/family testing is to be practised for the improvement of these traits.

REFERENCES

1. A. K. Sheridan. 1988. Agreement between estimated and realised genetic parameters. Animal Breed. Abstr., 58: 877–889.

2. H. W. Johnson, H. F. Robinson and R. E. Comstock. 1955. Estimates of genetic and environmental variability in soyabean. Agron. J., 47: 314–418.

3. Anita M. Collins. 1986. Quantitative genetics. *In*: Bee Genetics and Breeding (eds. Thomas E. Rinderer). Academic Press, Inc., New York.

4. S. K. Sen, A. K. Sengupta and M. S. Jolly. 1976. Studies on genetic variability, correlation and path coefficient analysis, discriminate function in *A. mylitta* D. Indian J. Seric., 15: 9–14.

5. A. A. Siddiqui, A. K. Sengupta and K. Sengupta. 1985. Variability and correlation studies of shell weight and their contributing traits in *A. mylitta* D. Sericologia, 25: 45–50.

6. A. A. Siddiqui, A. K. Sengupta, Ajit Kumar and K. Sengupta. 1988. Genotypic and phenotypic variability of some quantitative characters in *Antheraea mylitta* D. Sericologia, 28: 187–192.

7. T. Gamo and T. Hirabayashi. 1983. Genetic analysis of growth rate, pupation rate and some quantitative characters by diallel cross in the silkworm, *Bombyx mori* L. Japan J. Breed., 33: 191–194.

8. S. B. Satenahalli, R. Govindan and J. V. Goud. 1990. Studies on gene action for some quantitative traits in silkworm, *Bombyx mori* L. Entomon, 15: 227–230.

9. A. Sarkar, N. K. Das and B. C. Das. 1991. A diallel cross analysis of the cocoon weight in the silkworm, *Bombyx mori* L. Sericologia, 31: 301–306.

10. R. Narasimharaju, R. Govindan, J. Asoka and S. G. Rayar. 1990. Genetic variability for quantitative traits in silkworm, *Bombyx mori* L. Entomon, 15: 197–201.

11. G. Subba Rao, S. K. Das and N. K. Das. 1991. Genetic divergence among 15 multivoltine genetic stocks of silkworm, *Bombyx mori* L. Indian J. Seric., 30: 72–74.

12. G. W. Burton and E. M. De Vane. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. Agron. J., 45: 478–481.

13. J. L. Lush. 1949. Animal Breeding Plans (3rd edn.). The Collegiate Press, Iowa, U.S.A.

14. R. W. Allard. 1960. Principles of Plant Breeding. John Willey and Sons, New York, U.S.A.: 485.

15. D. S. Falconer. 1981. Introduction to Quantitative Genetics (2nd edn.). Longman, London: 281.

16. V. G. Panse. 1957. Genetics of quantitative characters in relation to plant breeding. Indian J. Genet., 17: 318–328.

Uttar Pradesh J. Zool. 13(1) : 47-51, 1993 ISSN 0256-971X

ANALYSIS OF QUANTITATIVE TRAITS OF MULTIVOLTINE SILKWORM, *BOMBYX MORI* L. (LEPIDOPTERA : BOMBYCIDAE) IN VARIED ENVIRONMENTS

B. GHOSH, S. CHATTOPADHYAY, P.R.T. RAO, S.K. DAS, G.C. ROY, S.K. SEN AND S.S. SINHA.
CENTRAL SERICULTURAL RESEARCH AND TRAINING INSTITUTE, BERHAMPORE- 742101. INDIA.

The quantitative performance of 10 evolved multivoltine silkworm breeds of *Bombyx mori* L. were studied under varied environmental condition to evaluate different quantitative traits. Statistical analysis (ANOVA) revealed that the overall performance of AB_5, O yellow (Oval), NJB(Y), M_2 and BC_5 (C) were better and may be utilised through hybridization.

INTRODUCTION

The multivoltine indigenous breeds are dominated in the tropical belt as they can withstand different environmental conditions but their yield and quality of silk is very poor (Sengupta & Datta, 1973; Sengupta *et al.*, 1974 & 1976; Datta, 1984 & 1986; Nomani *et al.*, 1990; Goldsmith, 1991). As such, attention is being given from time to time to evolve high yielding multivoltine silkworm breeds by many workers (Jolly, 1983; Sidhu, 1967 & 1984; Narasimhanna *et al.*, 1976; Raju & Krishnamurthy, 1984; Sreerama Reddy, 1984) through different breeding techniques and thus a number of breeds have been evolved. To exploit genotype - environmental interaction, the ecological races are required to be identified. It is also important to find out the congenial and optimum environmental conditions for expression of quantitative traits of genotypes that are controlled by additive and non-additive genes (Sharma *et al.*, 1985).

The maintenance of germplasm and evaluation of the breeds under varied environmental conditions are most essential parameters for silkworm breeding plan. This can be achieved through analysis of the quantitative performance of silkworm breeds in both favourable and unfavourable seasons. The performance of silkworm breeds were studied by several workers (Krishnaswami & Tikoo, 1971; Sidhu, 1974; Sengupta *et al.*, 1976; Tayade, 1987; Nomani *et al.*, 1990; Haque & Barman, 1991).

The present study is dealing with the analysis of quantitative performance of 10 evolved multivoltine breeds *viz.* $A_{14}d$(Y); AB_5; O-yellow (Oval); O; B; NJB (Y); CB_2; M_2; BC_5 (C) and S_{10} (P) reared to evaluate the efficacy of these breeds under different environmental conditions.

MATERIAL AND METHODS

The distinct morphological features of 10 evolved multivoltine breeds and their mode of evolution are furnished below :

Name of Breeds	Evolved at	Mode of evolution	Larval marketing	Coccon shape	Cocoon colour
$A_{14}d(Y)$	CSR&TI, Berhampore	Hybridization	Marked & plain	Oval	Yellow
AB_5	-do-	Mutation & Hybridization	Marked	-do-	-do-
O yellow (Oval)	-do-	Hybridization	-do-	-do-	-do-
O	-do-	-do- & mutation	-do-	Elliptical	-do-
B	-do-	-do-	Plain	-do-	-do-
NJB (Y)	-do-	Hybridization	Marked & plain	-do-	-do-
CB_2	-do-	Mutation & hybridization	Marked	Oval	-do-
M_2	-do-	-do-	-do-	-do-	-do-
BC_5 (C)	-do-	-do-	-do-	Elliptical	-do-
S_{10} (P)	-do-	Hybridization	Plain	Spindle	-do-

For the present study 10 dfls of each of the evolved multivoltine breeds were crushed and standard schedule of rearing was followed (Krishnaswami, 1978 & 1979). After second moult, larvae were distributed in 3 replications, each with 300 larvae. Every year three rearings during favourable seasons (October - March) and three rearings during unfavourable seasons (April - September) were conducted. Observations were recorded for number of eggs laid/female (Fecun.); larval period (LAR Pd.) in days; survival percentage (Surv. %); yield per 10,000 worms (ERR Wt.); single cocoon weight (SCW); single shell weight (SSW); Cocoon shell ratio (SR%) and filament length (Fil. Leng.) in metres and the last 4 years data were statistically analysed.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) for statistical significance of different quantitative traits of 10 evolved multivoltine silkworm breeds during favourable and unfavourable seasons, their mean values and C.D. values are presented in Table I.

Significant difference ($P \leq 0.05$) was observed for all characters except filament length for year and season, but their interaction was significant except fecundity, survival percentage and single cocoon Wt.; significant difference ($P \leq 0.05$) was also noticed among different breeds for all characters except fecundity, survival percentage and ERR wt.; interaction between breed & environment was not significant which depict that additive gene effect of these evolved breeds has a significant role for expressing quantitative traits under varied environment.

Fecundity: (No. of eggs laid by female moth) : No significant difference was observed among the breeds and between season and breed. Maximum fecundity was found in AB_5 (462) and minimum in $A_{14}d(Y)$ (432).

Larval period in days (Lar. Pd.): Shortest larval period was noted in A_{14} d(Y) (21.38) followed by O and NJB (Y) (21.79) and longest larval period in S_{10} (P) (23.33).

Table I. Performance of the evolved multivoltine breeds.

Breed	Season	Fecund	Lar.Pd.	Surv%	ERR.Wt.	SCW	SSW	SR%	Fil.Leng.
$A_{14}d$(Y)	UNFAV	409	19.92	77.35	7031.67	0.996	0.137	13.74	553.33
	FAV	456	22.83	90.18	9621.00	1.101	0.149	13.49	543.33
	MEAN	432	21.38	83.77	8326.33	1.049	0.143	13.61	548.46
AB_5	UNFAV	423	20.42	76.99	7558.58	1.103	0.159	14.45	582.92
	FAV	501	23.42	90.47	9955.58	1.143	0.168	14.75	577.42
	MEAN	462	21.92	83.73	8757.08	1.123	0.164	14.60	580.17
O Yel(O)	UNFAV	434	20.33	67.40	7444.75	1.172	0.156	13.29	602.17
	FAV	465	23.50	90.11	10717.83	1.236	0.172	13.54	624.92
	MEAN	449	21.92	78.76	9081.29	1.204	0.164	13.41	613.54
O	UNFAV	422	20.25	67.31	7282.92	1.106	0.158	14.34	589.83
	FAV	460	23.33	90.54	10548.92	1.128	0.161	14.21	592.50
	MEAN	441	21.79	78.93	8915.92	1.117	0.160	14.28	591.17
B	UNFAV	414	20.58	65.03	6134.08	0.975	0.126	12.97	492.00
	FAV	484	23.75	88.54	9271.92	1.041	0.146	14.00	486.92
	MEAN	449	22.17	76.78	7703.00	1.008	0.136	13.49	489.46
NJB(Y)	UNFAV	423	20.17	67.93	7263.08	1.133	0.150	13.22	604.08
	FAV	470	23.42	89.79	11061.00	1.247	0.170	13.60	631.67
	MEAN	447	21.79	78.86	9162.04	1.190	0.160	13.41	617.88
CB_2	UNFAV	421	20.25	68.57	6976.25	1.095	0.151	13.91	599.42
	FAV	473	23.42	92.83	10630.75	1.191	0.171	14.47	578.42
	MEAN	447	21.83	80.70	8803.50	1.143	0.161	14.19	588.92
M_2	UNFAV	430	20.33	67.65	6842.25	1.127	0.155	13.75	633.33
	FAV	473	23.33	91.61	10548.08	1.212	0.176	14.55	652.33
	MEAN	452	21.83	79.63	8695.17	1.170	0.166	14.15	642.83
BC_5(C)	UNFAV	417	21.00	80.01	7031.42	0.916	0.116	12.71	474.33
	FAV	458	23.75	90.07	8586.83	1.006	0.130	12.97	487.25
	MEAN	438	22.38	85.04	7809.13	0.961	0.123	12.84	480.79
S_{10}(P)	UNFAV	422	22.00	72.75	7133.67	0.997	0.127	12.67	409.75
	FAV	470	24.67	90.91	9638.08	1.074	0.146	13.62	366.00
	MEAN	446	23.33	81.83	8385.88	1.035	0.136	13.15	387.88
CD at 5%									
for	A:	19.015	.550	4.764	524.065	.039	.006	.381	NS
	B:	13.446	.389	3.368	370.570	.028	.005	.270	NS
	C:	NS	.870	NS	NS	.062	.010	.603	47.825
	A x B:	NS	.778	NS	741.139	NS	.009	.539	42.776
	B x C:	NS	NS	NS	NS	NS	NS	NS	NS
	SE:	30.523	.883	7.647	841.237	.063	.010	.612	48.553

A: Year; B: Season (UNFAV / FAV) and C: Breed; NS : Not significant.

Survival percentage (Surv. %): Significant difference was observed for season and highest surv. % was recorded in BC_5 (C) (85.04) followed by A_{14}d (Y) (83.77) and AB_5 (83.73), minimum surv.% was notice in B (76.78).

Yield per 10,000 worms (ERR Wt.): The highest ERR Wt. was found in NJB (Y) (9162.04 gms) followed by O-yellow (Oval) (9081.29 gms) and lowest in B (7703.00 gms).

Cocoon characters : Maximum average single cocoon weight was noticed in O-yellow (Oval) (1.204 gms) followed by NJB (Y) (1.190 gms) and M_2 (1.170 gms). The highest single shell weight was observed in M_2 (0.166 gms) followed by O yellow (Oval) and AB_5 (0.164 gms). SR% was found in AB_5 (14.60) followed by O (14.28). The average maximum filament length was recorded in M_2 (642.83) which is significant among breeds.

During unfavourable season O yellow (Oval) showed better performance for fecundity and single cocoon wt.; maximum survival percentage and filament length were recorded in BC_5 (C) and M_2 respectively and AB_5 exhibits highest value for ERR Wt., SSW and SR% and shortest larval period noted in A_{14} d(Y).

During favourable season AB_5 was found better for fecundity and SR%; NJB (Y) showed better ERR Wt. and single cocoon Wt., M_2 for single shell wt. and filament length; shortest larval period and maximum surv. % were recorded in A_{14}d (Y) and CB_2 respectively.

The overall performance of all the breeds showed that AB_5 was better for fecundity and SR%, A_{14}d (Y) for shortest larval period, BC_5 (C) for highest surv. %, NJB(Y) for ERR Wt., O Yellow (Oval) for SCW and M_2 for SSW and filament length. (Table I). Therefore, AB_5, O Yellow (Oval), NJB(Y), M_2 and BC_5(C) may be commercially exploited subjected to their combining ability studies followed by field trials.

ACKNOWLEDGEMENTS

Authors are thankful to Mr. B.P. Nair, SRO, Statistics for analysis of data, Staff members of S.B.G. Section CSR&TI, Berhampore for helping in conducting rearing and Mr. S. Ghosh, Stenographer for typing the manuscript.

REFERENCES

DATTA, R.K. 1984. Improvement of silkworm races (*Bombyx mori* L.) in India. *Sericologia.* 24(3): 393-415.

1986. *Mulberry silkworm breeding in India, Lectures on Sericulture.* Swamy Publishers, Bangalore.

GOLDSMITH, M.R. 1991. Silkworm breeding for the 90's: New molecular and genetic tools to meet the challenge of the tropics. *Sericologia.* 31(1): 145-155.

HAQUE, T. & BARMAN, A.C. 1991. Some observation on the performance of Indian multivoltine silkworm, *Bombyx mori* L. Under Bangladesh condition. *Bull. Seric. Res.* 2: 99-102.

JOLLY, M. S. 1983. Silkworm genetics and breeding. Lead paper. *Nat. Semi. On Silk Res. & Dev.*, Bangalore. pp. 19.

KRISHNASWAMI, S. 1978. New technology of silkworm rearing. *Bulletin* 2: CSR&TI, Mysore. pp. 10.

1979. Improved method of rearing young aged (Chawki) Silkworm. *Bulletin* - 3: CSR&TI, Mysore. pp.23.

KRISHNASWAMI, S. & TIKOO, B.L. 1971. A comparative study of performances of Pure races currently under rearing in Mysore State. *Ind. J. Seric.* 10: 66-71.

NARASIMHANNA, M.N., CHANDRASEKARAIAH, GEETHADEVI, R.G. & PRABHA, G. 1976. Ecogenetic attributes of the newly evolved bivoltine hybrid 'Nandi' in *Bombyx mori L. Dunn & Dobzhanski Symp. Genet.*: 379-386.

NOMANI, M.K.R., SENGUPTA, K., NAGRAJ, J., VIZAYARAGHAVAN, K., PREMLATHA, V., RAVINDRA SINGH & RAM MOHANRAO, P. 1990. Performances of multivoltine breeds of the silkworm, *Bombyx mori* L., for high cocoon weight and shell weight. *Ind. J. Seric.* 29: 227-232.

RAJU, P.J. & KRISHNAMURTHY, N.B. 1984. Evolution of high yielding multivoltine races of silkworm *Bombyx mori* L. by selective hybridization. *Sericologia.* 24: 430.

SENGUPTA, K. & DATTA, R. K. 1973. Studies on the superior multivoltine breeds of silkworm. *Bombyx mori* L. *XII Int. Silk. Cong. Barcelona.* 1-16.

SENGUPTA, K., DATTA, R.K. & BISWAS, S.N. 1974. Effect of multiple crossing on the population pattern of progeny in silkworm. *Ind. J. Genet. & Plant Breed.*, SABRAO. 34(A): 241-248.

SENGUPTA, K., DATTA, R.K. BISWAS, S.N. & SINGH, B.D. 1976. Heterosis in multivoltine Silkworm (*Bombyx mori* L.) yield performance of F1 hybrids of Nistari and four evolved multivoltine breeds. *Ind. J. Seric.* 10: 6-13.

SHARMA, S.K., GILL, K.S. & NANDA, G.S. 1985. Genotype environment interaction and heritability estimates for some quantitative characters in Triticale. *Ind. J. Genet.* 45: 75-80.

SIDHU, N.S. 1967. A multivoltine breed of Silkworm, *Bombyx mori* L. for tropics in evolution. *Ind. J. Seric.* 6: 63-66.

1974. Performance of newly evolved multivoltine breed in southern states of India. *Ind. J. Genet.*, SABRAO. 34(A): 237-240.

1984. Performance of the CSR&TI I to VIII multivoltine breeds of silkworm *Bombyx mori* L. for tropics. *Sericologia.* 24: 434-433.

TAYADE, D.S. 1987. Performance of different races of silkworm, *Bombyx mori* L. Under Marathawada conditions. *Ibid.* 27: 381-389.

RELATIONSHIP BETWEEN THE DEGREE OF HETEROSIS AND GENETIC DIVERGENCE IN THE SILKWORM, *BOMBYX MORI* L.

S.K. SEN, B.P. NAIR*, S.K. DAS, G.C. ROY, B. GHOSH**, P.R.T. RAO & S.S. SINHA****

Central Sericultural Research and Training Institute, Berhampore 742 101, West Bengal, India.

The present experiment was carried out to predict the distribution frequency of hybrids and magnitude of heterosis by crossing various genetically divergent parents. The multivoltine and bivoltine parental stocks were grouped into five clusters each. Five multivoltine breeds, i.e., N (Nistari), Raj, CB_5, G and B, and five multivoltine breeds, i.e., P_5, NB_{18}, JD_6, SF_{19} and KSO, were selected for this study, one from each cluster. The selected parents were crossed in a diallel fashion separately and reared during two favourable (autumn and spring) and two unfavourable (dry summer and late monsoon) seasons. The genetically divergent parents were grouped into four classes, i.e., DC_1 (> m + s), DC_2 (m to m + s), DC_3 (m − s to m) and DC_4 (> m − s), where m and s are mean and standard deviation of the divergence, respectively (Arunachalam and Bandyopadhyay, 1984). Heterosis was calculated in per cent improvement over mid-parent for six important characters, i.e., larval duration, larval weight, survival percentage, single cocoon weight, single shell weight and filament length. The analysis revealed that crosses involving the divergent group falling in DC_3 had a higher probability of producing more heterosis as compared to other classes in both multivoltine and bivoltine silkworm breeds.

Keywords: *Bombyx mori* L., multivoltine, bivoltine, genetic divergence, heterosis.

INTRODUCTION

The silkworm provides one of the earliest and best example of hybrid vigour. F_1 silkworm hybrids are in many respects superior to their parents (Toyama, 1906; Hirobe, 1956; Sengupta *et al.*, 1971, 1974; Jolly, 1983; Subba Rao *et al.*, 1989, 1990; Das *et al.*, 1994). Evaluation and choice of the parents is an important part of heterosis breeding programmes for any crop improvement. Where the germplasm collection is large it becomes difficult to identify parental stocks (Holden, 1984) and it is difficult to compare all possible breeds and crosses in the laboratory or at field level. Hence, it would be useful for the breeders to predict the heterosis that may occur in different hybrids. Provided there is no epistasis, heterosis generally depends on the difference in gene frequency between the populations or equivalently, the increase in heterozygosity in the F_1 (Ehiobu and Goddard, 1990) hybrids. Goddard and Ahmed (1982) defined a statistic F' to measure this, where

$$F' = (HF_1 - Hp)/Hp$$

Hp = Heterozygosity of the parent
HF_1 = Heterozygosity in the F_1 hybrid

Heterosis and specific combining ability are most important parameters of selection in F_1 hybrids. Ramanujam *et al.* (1984), Singh and Ramanujam (1981), Arunachalam and Bandyopadhyay (1984),

* Silkworm Seed Technology Laboratory, Carmelram Post, Kodathi, Bangalore 560 035, India.
** Central Tasar Research and Training Institute, Central Silk Board, P.O. Piska Nagri, Ranchi 835 303, Bihar, India

Arunachalam *et al.* (1984), Gallias (1988), Troyer *et al.* (1988), Main and Bahl (1989) and Thakur and Zarger (1989) have reported different aspects of relationship between genetic divergence and heterosis in different agricultural crops.

Arunachalam and Bandyopadhyay (1984) reported that two parents whose genetic divergence falls between (m + s) and (m – s), when crossed, will have higher chances of high frequency and magnitude of heterosis when compared to a cross whose parental divergence falls outside the limit (m + s, m – s) where m and s are mean and standard deviation, respectively. The concept of limit to parental divergence for optimum expression of heterosis was studied in hybrids of geographically divergent parents in maize (Moll *et al.*, 1965).

The object of this paper is to determine and predict the frequency and magnitude of heterosis in F_1 hybrids raised from genetically divergent parents in the silkworm, *Bombyx mori* L.

MATERIALS AND METHODS

The genetic divergence among 15 multivoltine and 17 bivoltine silkworm breeds was measured by using D^2 statistics (Subba Rao *et al.*, 1991; Sen, 1993) separately. The multivoltine and bivoltine silkworms from the germplasm collection were grouped separately into five clusters. Five multivoltine breeds, i.e., Nistari (N), Raj, CB5, G and B, and five bivoltine breeds, i.e., P_5, NB_{18}, JD_6, SF_{19} and KSO, were selected from each cluster, separately. The breeder's choice was also considered while selecting parents from each cluster. The selected parents of multivoltine and bivoltine silkworms were crossed in a diallel fashion separately. All the possible hybrids of multivoltine and bivoltine were reared during four commercial rearing seasons of West Bengal, i.e., two favourable seasons (autumn and spring) and two unfavourable seasons (dry summer and late monsoon). A standard schedule of silkworm rearing was followed with three replications for each hybrid and parent. The performance data on six important quantitative traits, i.e., larval duration (LD), larval weight (LW), survival percentage (SURV %), single cocoon weight (SCW), single shell weight (SSW) and filament length (FILL), were recorded. The heterosis was calculated over mid-parental values season-wise for multivoltine and bivoltine silkworms, separately.

The D^2 values were grouped into four classes, i.e., DC_1, DC_2, DC_3 and DC_4, as suggested by Arunachalam and Bandyopadhyay (1984). The four divergence classes are defined as follows:

DC_1: $D^2 \geq (m + s)$
DC_2: $D^2 < (m + s)$ and $< m$
DC_3: $D^2 \geq (m - s)$ and $< m$
DC_4: $D^2 < (m - s)$

where m and s are mean and standard deviation of D^2 values.

All the crosses were grouped into the above four divergence classes. The following parameters were considered as defined by Arunachalam and Bandyopadhyay (1984).

n: number of crosses falling in different divergent classes
p: proportion of crosses showing heterosis
q: proportion of crosses showing heterosis greater than k
x: mean of each character over such crosses with positive heterosis
y: mean of such crosses showing heterosis greater than k
k: mean of all positive heterosis over all the four seasons

The above parameters were estimated for each divergent class and ranked for p, q, x and y separately. A sum of ranks across all the characters was calculated for each class.

RESULTS AND DISCUSSION

The means, standard deviation and the range of the genetic divergence values (D^2) were calculated and are presented in Table I. In multivoltine breeds the range of D^2 was greater than in bivoltine breeds.

The frequency of distribution of silkworm hybrids and their positive heterosis, average heterosis and average magnitude of positive heterosis observed in the different divergent classes are presented in Table II for multivoltine and bivoltine silkworms for fitness and cocoon characters. None of the multivoltine hybrids fell in the DC_4 divergent class. However, the bivoltine hybrids were distributed in all the four classes. The maximum number of hybrids belonged to the DC_3 for all the six characters in both the multivoltine and the bivoltine silkworms (Table II). The overall performance of different divergent classes was evaluated on the basis of the scoring process. The scoring was done over all six characters and four parameters p, q, x and y.

Table I. Mean, standard deviation and range of genetic divergence values in silkworms.

Tableau I. Moyenne, écart type et fourchette des valeurs de divergence chez les vers à soie.

Race *Race*	Mean of divergence values *Moyenne des valeurs de divergence*	Standard deviation *Ecart type*	Range of divergence values *Fourchette des valeurs de divergence*
Multivoltine / *Polyvoltine*	21.80	13.46	9.0-47.0
Bivoltine	24.89	4.09	16.8-32.0

The results revealed that the divergent class DC_3 topped in the list of multivoltine and bivoltine crosses and were closely followed by the divergent class DC_1.

The magnitude of heterosis occurred in the different divergent classes is presented in Tables III and IV for multivoltine and bivoltine silkworms, respectively. It is evident from the data that the magnitude of heterosis found in DC_3 is higher than the rest of the divergence classes in multivoltine hybrids irrespective of the season. However, in the case of bivoltine silkworms, the highest heterosis for each character was recorded among the hybrids belonging to either DC_1 or DC_3. During the spring and dry summer seasons, the highest heterosis was recorded in DC_1 whereas during autumn and late monsoon, the maximum heterosis was found in DC_3. The result obtained in multivoltine and bivoltine hybrids revealed a close relationship between the genetic diversity and heterosis values, as reported by Arunachalam and Bandyopadhyay (1984) and Srivastava and Arunachalam (1977).

Table II. Frequency of silkworm hybrids falling in different divergent classes (DC) with their mean values having positive heterosis.

Tableau II. Fréquence de présence des hybrides de vers à soie présentant une hétérosis positive dans les différentes classes de divergence (DC) avec leurs valeurs moyennes.

R	C	NF n	Larval duration *Durée larvaire*				Larval weight *Poids larvaire*				Survival % *Taux de survie*				Cocoon weight *Poids du cocon*				Shell weight *Poids de la coque*				Filament length *Longueur de la bave*				Score *Score*
			p	q	x	y	p	q	x	y	p	q	x	y	p	q	x	y	p	q	x	y	p	q	x	x	
M	DC_1	8	25.0	25.0	19.7	19.8	85	60	27.6	27.8	75	38	8800	8944	100	38	1.20	1.22	100	38	0.18	0.19	60	12	545	349	47
	DC_2	4	7.5	25.0	19.5	19.0	100	75	25.5	26.1	100	50	9279	9333	75	50	1.03	1.01	75	25	0.14	0.14	50	25	498	616	60
	DC_3	28	35.0	18.0	20.2	20.6	89	99	28.1	27.8	99	40	8805	8631	98	40	1.21	1.21	98	40	0.19	0.19	61	32	578	617	32
B	DC_1	8	38.0	38.0	22.7	23.2	98	25	38.1	38.0	100	25	6173	3278	100	38	1.44	1.46	100	38	0.29	0.29	100	38	943	1040	46
	DC_2	8	75.0	38.0	24.4	23.8	100	38	34.2	31.1	99	25	5498	1611	99	38	1.30	1.33	99	50	0.26	0.26	50	25	911	892	73
	DC_3	20	60.0	15.0	23.6	23.6	99	35	36.3	34.4	100	40	6232	3775	100	50	1.42	1.40	90	45	0.28	0.28	75	40	918	948	43
	DC_4	4	25.0	25.0	24.6	24.0	100	50	36.4	35.2	100	50	7003	5161	100	25	1.49	1.60	100	50	0.29	0.30	75	25	965	951	63

R: race. C: class. NF: Number of F1's. M: Multivoltine. B: Bivoltine. n: number of crosses falling in different divergent classes; p: proportion of crosses showing heterosis; q: proportion of crosses showing heterosis greater than K; x: mean of each character over such crosses with positive heterosis; y: mean of such crosses showing heterosis greater than K.

R : race. C : classe. NF : nombre de F1. M : Polyvoltine. B : Bivoltine. n : *nombre de croisements dans la classe de divergence concernée ; p : proportion de croisements présentant une hétérosis ; q : proportion de croisements présentant une hétérosis supérieure à k ; x : moyenne de chaque caractère pour les croisements présentant une hétérosis positive ; y : moyenne des croisements présentant une hétérosis supérieure à K.*

The magnitude of heterosis was recorded highest in DC_3 in multivoltine hybrids. But in the case of bivoltine hybrids DC_1 was found top rank for spring and dry summer seasons and DC_3 was top for the other two seasons. The evaluation and importance of divergent classes, i.e., DC_1 and DC_3, would become clear if the results were based on a large number of crosses. Although DC_1 recorded the highest heterosis over DC_3, the difference in magnitude was very marginal.

The scoring process of different divergent classes with the help of the parameters p, q, x and y showed that the divergent class DC_3 is superior to DC_2 and DC_4 and this was closely followed by DC_1. The present study revealed that the right frequency and magnitude of heterosis recorded in the hybrids belonged to the divergent class DC_3. The parents of the hybrids belonging to the class DC_3 were with an intermediate genetic distance (m to m – s) in multivoltine and bivoltine silkworms. A few exceptions were recorded in bivoltines during the spring and summer seasons but the degree of heterosis did not decrease remarkably in the intermediate divergent class (DC_3) in these seasons.

Table III. Magnitude of heterosis observed in different divergent classes of multivoltine silkworm hybrids.

Tableau III. Amplitude de l'hétérosis observée dans différentes classes de divergence chez les hybrides de ver à soie polyvoltins.

Class *Classe*	**Season** *Saison*	**LD**	**LW**	**SURV**	**SCW**	**SSW**	**FILL**
DC_1	Autumn / *Automne*	-3.60	5.64	-	8.96	10.06	29.52
	Spring / *Printemps*	-5.56	13.28	5.06	11.53	18.75	-
	Dry summer / *Eté sec*	-2.44	11.99	1.66	12.46	18.51	-
	Late monsoon / *Fin de mousson*	-2.63	14.02	7.81	15.06	17.28	-
DC_2	Autumn / *Automne*	-2.44	15.60	4.79	4.97	5.09	6.93
	Spring / *Printemps*	-3.11	11.69	10.30	-	-	-
	Dry summer / *Eté sec*	1.68	3.52	11.59	5.94	2.42	-
	Late monsoon / *Fin de mousson*	0.00	12.26	4.27	2.74	1.98	8.59
DC_3	Autumn / *Automne*	-4.76	15.93	7.39	14.95	18.92	22.22
	Spring / *Printemps*	-7.41	21.39	16.73	16.10	23.25	16.68
	Dry summer / *Eté sec*	-2.44	23.20	19.48	34.22	35.27	19.75
	Late monsoon / *Fin de mousson*	-2.63	13.05	18.61	23.53	33.95	3.05

LD: larval duration; **LW**: larval weight; **SURV**: survival percentage; **SCW**: single cocoon weight; **SSW**: single shell weight; **FILL**: filament length.
LD : durée larvaire ; LW : poids larvaire . SURV : taux de survie : SCW : poids du cocon ; SSW : poids de la coque : FILL : longueur de la bave

Table IV. Magnitude of heterosis observed in different divergent classes of bivoltine silkworm hybrids.

Tableau IV. Amplitude de l'hétérosis observée dans différentes classes de divergence chez les hybrides de ver à soie bivoltins.

Class *Classe*	Season *Saison*	LD	LW	SURV	SCW	SSW	FILL
DC_1	Autumn / *Automne*	0.71	23.01	45.59	13.85	32.00	7.79
	Spring / *Printemps*	-3.05	2.19	4.98	10.07	14.84	5.79
	Dry summer / *Eté sec*	-4.50	14.53	188.65	26.80	53.50	23.69
	Late monsoon / *Fin de mousson*	-0.80	8.30	175.21	26.67	61.42	4.11
DC_2	Autumn / *Automne*	3.56	12.65	46.65	17.79	36.12	20.13
	Spring / *Printemps*	0.00	5.43	6.96	2.94	0.75	-
	Dry summer / *Eté sec*	-0.72	6.86	-	24.07	40.76	12.73
	Late monsoon / *Fin de mousson*	-2.93	15.64	213.42	6.60	27.93	-
DC_3	Autumn / *Automne*	-0.71	21.63	51.61	28.43	50.82	24.96
	Spring / *Printemps*	-1.84	9.02	7.51	3.81	6.33	0.43
	Dry summer / *Eté sec*	-1.52	10.48	155.70	25.72	42.52	18.18
	Late monsoon / *Fin de mousson*	-2.93	22.87	242.28	26.23	68.36	13.20
DC_4	Autumn / *Automne*	2.08	7.14	33.21	9.27	22.78	2.57
	Spring / *Printemps*	0.00	1.28	3.66	1.20	3.42	-
	Dry summer / *Eté sec*	0.00	7.30	210.60	23.72	27.86	14.15
	Late monsoon / *Fin de mousson*	-3.74	8.67	105.79	8.48	9.29	12.08

LD: larval duration; **LW:** larval weight; **SURV:** survival percentage; **SCW:** single cocoon weight; **SSW:** single shell weight; **FILL:** filament length.
LD : durée larvaire ; LW : poids larvaire ; SURV : taux de survie ; SCW : poids du cocon ; SSW : poids de la coque ; FILL : longueur de la bave.

REFERENCES

ARUNACHALAM V., BANDYOPADHYAY A. (1984) Limit to genetic divergence for occurrence of heterosis — Experimental evidence from crop plants. Indian J. Genet., 44(3), 548-554.

ARUNACHALAM V., BANDYOPADHYAY A., NIGAM S.N., GIBBONS R.W. (1984) Heterosis in relation to genetic divergence and specific combining ability in groundnut (*Arachis hypogaca* L.). Euphytica, 33-39.

DAS S.K., PATTNAIK S., GHOSH B., SINGH T., NAIR B.P., SEN S.K., SUBBA RAO G. (1994) Heterosis analysis in some three-way crosses of *Bombyx mori* L. Sericologia, 34(1), 51-61.

EHIOBU N.G., GODDARD M.E. (1990) Heterosis in crosses between geographically separated populations of *Drosophila melanogaster*. Theo. Appl. Genet., 80, 569-575.

GODDARD M.E., AHMED A.M. (1992) The use of genetic distance between cattle breeds to predict heterosis in crosses. Proc. 2nd World Cong. Genet. Appl. Livestock Prod., Madrid, Spain, pp. 377-382.

GALLIAS A. (1988) Heterosis: its genetic basis and its utilization in plant breeding. Euphytica, 39, 95-104.

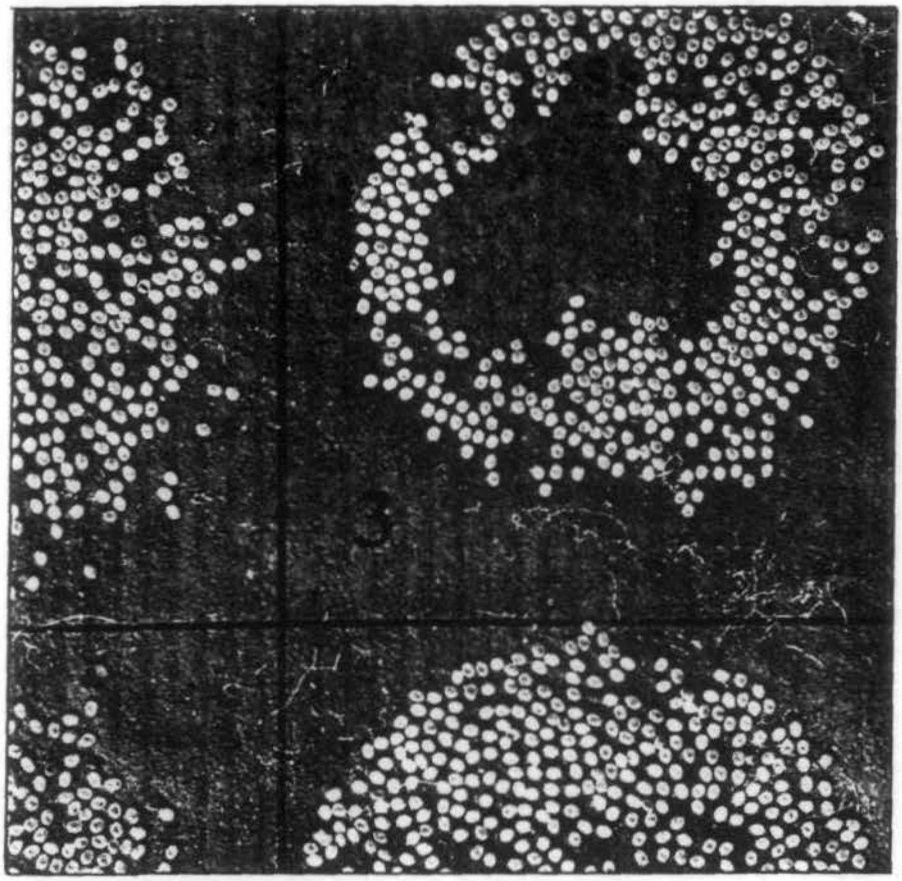
HIROBE T. (1956) Analysis of heterosis made with the silkworm. Proc. Internat. Genet. Symp. Suppl. Vol. Cytologia, 357-361.
HOLDEN J.H.W. (1984) The second ten years. *In* Crop Genetic Resources: Conservation and Evaluation. pp. 276-285. Holden J.H.W. and William J.T. (Eds), Allen and Uwin Inc., Winchester.
JOLLY M.S. (1983) Silkworm genetics and breeding. Lead paper. National Seminar on Seric. Research and Development, Session III, 10-13 March, Bangalore, 1-19.
MAIN M.A.K., BAHL P.N. (1989) Genetic divergence and hybrid performance in chickpea. Indian J. Genet., 49(1), 119-124.
MOLL R.H., LONNQVIST J.H., FORTUNO J.V., JOHNSON E.C. (1985) The relationship of heterosis and genetic divergence in maize. Genetics, 52, 139-144.
RAMANUJAM S., TIWARI A.S., MEHRA R.B. (1974) Genetic divergence and hybrid performance in mungbean. Theor. Appl. Genet., 45, 211-214.
SEN S.K. (1993) On some aspects of improvement of mulberry silkworm, *Bombyx mori* L. Ph.D. thesis, Dept. of Zoology, Univ. of Ranchi, India.
SENGUPTA K., DATTA R.K., BISWAS S.N., SINGH B.D. (1971) Heterosis in multivoltine silkworm (*Bombyx mori* L.). I. Yield performance of F_1 hybrids of Nistari and four evolved multivoltine breeds. Indian J. Seric., 10, 6-13.
SENGUPTA K., YUSUF M.R., GROVER S.P. (1974) Hybrid vigour and genetic analysis of quantitative traits in silkworm. Indian J. Genet. SABRAO, 34(4), 249-256.
SINGH S.P., RAMANUJAM S. (1981) Genetic divergence and hybrid performance in *Cicer arietinum* L. Indian J. Genet., 41, 268-276.
SRIVASTAVA P.S.L., ARUNACHALAM V. (1977) Heterosis as a function of genetic divergence in triticale. Z. Pflanzenzuchtung, 78, 269-275.
SUBBA RAO G., DAS S.K., GHOSH B. (1989) Heterosis effect on some new silkworm hybrids evolved by three-way cross. Perspective in Cytology and Genetics, 6, 373-378.
SUBBA RAO G., SEN S.K., GHOSH B., DAS S.K. (1990) Heterosis in some hybrid indigenous and bivoltine races of mulberry silkworm, *Bombyx mori* L. Perspective in Cytology and Genetics, 7, 1043-1054.
SUBBA RAO G., DAS S.K., DAS N.K. (1991) Genetic divergence among 15 multivoltine genetic stock of silkworm (*Bombyx mori* L.). Indian J. Seric., 30(1), 72-74.
THAKUR H.L., ZARGER M.A. (1989) Heterosis in relation to genetic divergence and specific combining ability in Indian mustard, *Brassica juncea* L. Czern. Indian J. Genet., 49(2), 223-226.
TOYAMA K. (1906) Studies on hybridology of insects. In some silkworm crosses with special reference to Mendel's law of heredity. Bull. Coll. Agric. Tokyo Univ., 7, 259-293.
TROYER A.F., OPENSHAW S.J., KNITTLE K.H. (1988) Measurement of genetic diversity among popular commercial corn hybrids. Crop Sci., 28, 431-485.

Utilization of Hybrid Vigour – An Approach

B. Ghosh, P.R.T. Rao, A.K. Sengupta, S.K. Sen and B. Saratchandra

The seed organization in sericulturally advanced countries has been developed systematically through a three tier seed multiplication system *viz.*, P_3, P_2 and P_1. The research institutes here, play a vital role in evolving quantitatively and qualitatively superior silkworm breeds and maintain "breeder's stock" without losing its vigour. P_3 stations being the heart of this entire seed organisation system, known as "breeding stations", work like a bridge between the research institute and the seed multiplication system, headed by experienced breeders. P_2 is known as "breeding farm", responsible for the multiplication of grand parents and thus, produce P_1 seed. P_1 station known as commercial grainage, should be equipped with modern facilities and skilled technicians (Narasimhanna, 1984 and 1986). During last decade, India also has adopted the above technology but, without studying the degree of adaptability under Indian climatic conditions. Hence, even after sincere efforts made by the sericultural scientists it has not been possible to produce the required quantity of elite seeds owing to some basic gaps as well as unsuccessful P_1 seed crop rearing especially during unfavourable climatic conditions (April–Sept.) when the temperature and R.H. remain high (Fig. 1).

A systematic three tier seed multiplication system is also essential to realise the full potentials of the developments made by the research institutes in maintaining breeder's stock. Hence, production of required quantity of elite commercial seed following an intermediate technology for utilization of hybrid vigour becomes an important step, opines author.



Present practices and problems

During late seventies, exploitation of hybrid vigour in the form of multi x multi and multi x bi at commerical level has been introduced especially for spring and autumn seasons of eastern and north-eastern states and it became popular among the farmers, reelers and weavers (Datta, 1986). Since, the production of hybrid seed is not sufficient to meet the requirement

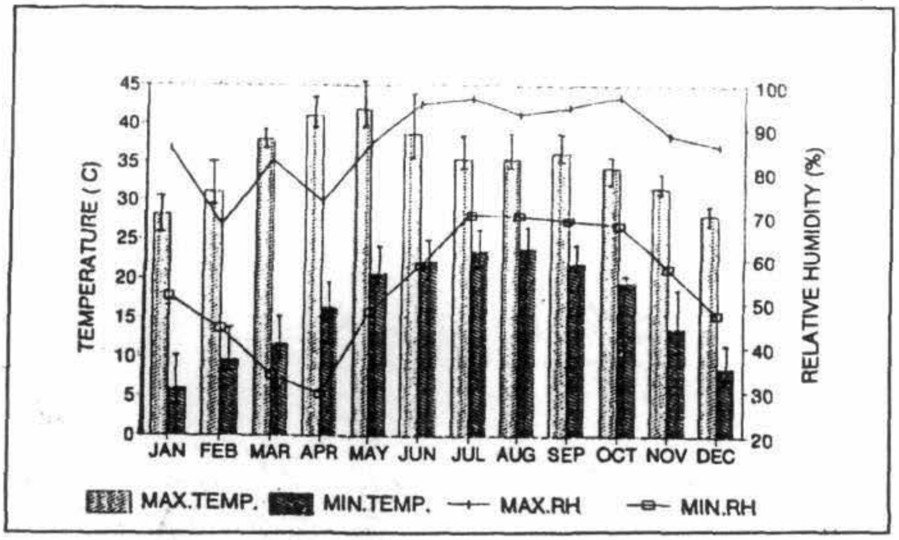


Fig. 1 : Maximum and minimum temperature and relative humidity during last 5 years at Berhampore (WB)

even for favourable seasons, the farmers are compelled to depend on the local races like Nistari, Pure Mysore, Sarupat etc., ignoring the source of layings and their quality (sometimes commercial cocoons of one area are also being used as seed cocoons for other areas). This type of practice has become one of the primary reasons for commercial crop failure that leads to low yield with poor quality.

Another cause of crop deterioration is the three tier system of basic seed multiplication and pure breeds being reared at all the three levels. This virtually affects the crop reliability particularly in P_1 seed crop specially during unfavourable seasons *i.e.*, in the seed crop for Jaistha, Bhaduri and Agrahayani commercial crops. During dry summer when the silkworms are reared at P_3 and P_2 levels, considerable mortality and male sterility are also usually experienced leaving behind a limited population yielding to genetic drift (Table–1 & Fig. 1). Another contrasting problem (Aug.–Sept.) becomes more crucial when temperature remains moderately high along with a very high humidity which causes high mortality in silkworms when the bivoltines are reared as a P_1 seed crop.

Breeding techniques for seed production

Indian sericulture, with special reference to eastern and north-eastern states, the first and foremost important step is to produce the required quantity of elite silkworm commercial seed following an intermediate technology which envisages the utilization of hybrid vigour to produce commerical seed.

In this venture, it is imperative to study the following points :

i) Necessary to collect the available endemic and exotic breeds of multivoltine as well as bivoltine.

ii) Evaluation and documentation of the collected breeds and their multi

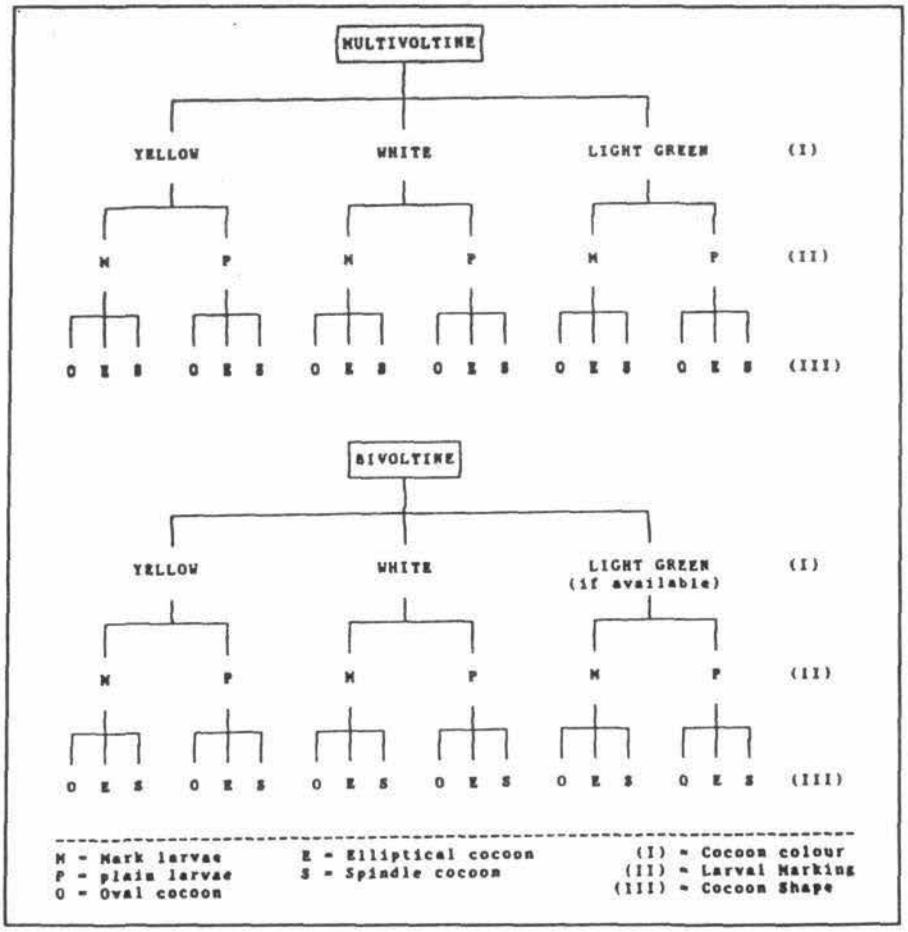
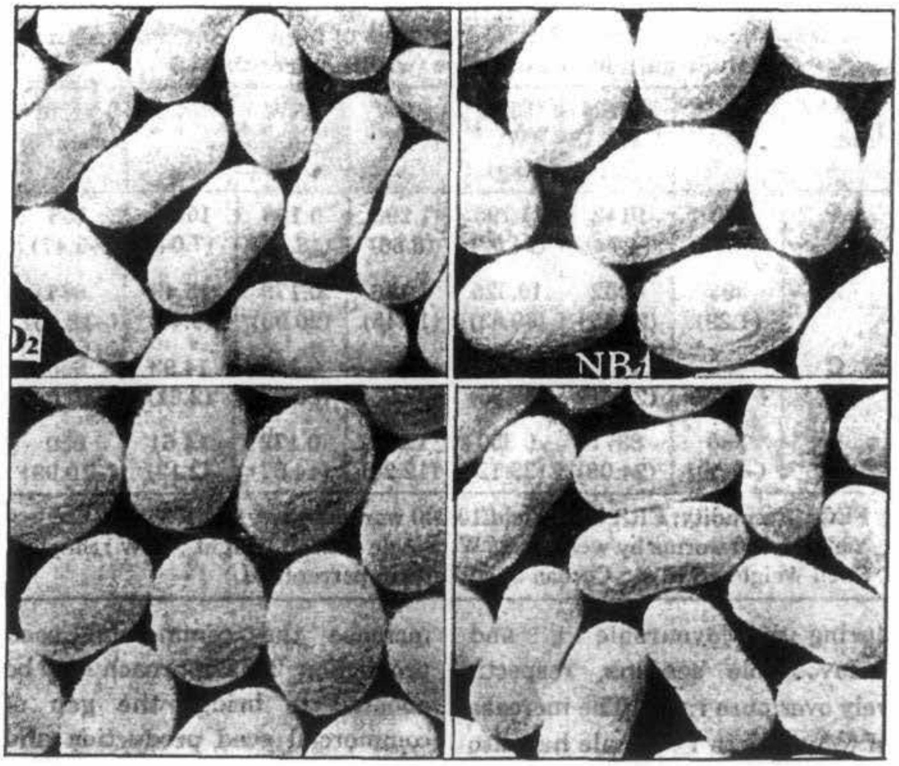


Fig. 2 : Schematic characterization of breeds



environmental tests to be worked out for their genotypic and phenotypic stability.

iii) Clustering/grouping of the breeds to be done morphologically and genetically (both for multi and bivoltine).

iv) Genetic clustering of the races on the basis of their metric traits to be computed and environment-wise and region-wise stability to be worked out.

After collecting and documenting the above information, a breeder can select a few breeds for hybridization to fulfil the demands of the industry.

The silkworm hybrids which show the positive heterosis are either superior over mid parent value or excel the better parent not only in qualitative and quantitative traits but in viability also. Such a situation should properly be exploited in commercial seed production (Toyoma, 1905, 1906a & b). While formulating the breeding programme, a breeder should consider the morphological and genetic background of the races of lines (Fig. 2) especially, for foundation crosses at P_2 station for the purpose of P_1 seed, to produce double hybrids for commercial use. In order to avoid the segregation, parents (both male and female components) of the foundation crosses should be morphologically identical (larval marking, cocoon colour and shape) and genetically compatible (having the moderate genetic distance; Arunachalam, 1974; and Sen *et al.*, 1995) finally to produce a double cross *i.e.*, (A x B) x (C x D) and the reciprocal. While preparing the above seeds, some percentage of inbred layings of foundation crosses may also be produced at commercial grainages. Such layings may be used since higher number of eggs per laying and low degree of inbreeding depression in economic traits will be observed.

Utility of hybrid vigour in seed production

An experiment has been designed to advocate a compact package for framing a balanced seed production system by using hybrid vigour as one of the major tools. Season-wise average rearing performance has been presented in Tables 1 & 2 for pure races and the foundation crosses, respectively. The gain of foundation crosses (hybrids) over pure races is also presented (in parenthesis) in Table. 2.

As mentioned above, three P_1 seed crop seasons *viz.*, A, B, C are unfavourable seasons for silkworm rearing and only one seed crop is raised during

Table. 1 : Season-wise performance of pure races

P_1 crop season	FEC	ERR No.	ERR Wt. (kg)	SCW (g)	SSW (g)	S.R.%	No. of cocoon/ kg.
A	422	8728	10.343	1.185	0.170	14.34	834
B	388	7311	7.384	1.010	0.148	14.65	990
C	384	6566	5.800	0.886	0.129	14.55	1130
D	398	6751	7.080	1.049	0.150	14.30	955

A – Dec.–Jan.: P_1 of Falgooni crop ; B – Sept.–Oct.: P_1 of Agrahayani crop; C – March–April : P_1 of Jaistha crop & D – June–July : P_1 of Bhaduri crop. FEC : Fecundity; ERR No. : Yield/10,000 worms by No. ; ERR Wt. : Yield/10,000 worms by weight ; SCW : Single Cocoon Weight ; SSW : Single Shell Weight ; S.R. % : Cocoon Shell Ratio in percentage.

favourable season *i.e.*, A : season. Better hybrid performance during unfavourable seasons is attributed to heterozygous superiority (Yokoyama, 1974). The P_1 seed crop warranty can, therefore, be increased 22.17 to 24.08% by utilising F_1 hybrid vigour in place of pure races (Table–2). During favourable season (Season : A), the heterotic effect of the foundation crosses over pure races is less, compared to the heterotic effect which is much higher during unfavourable seasons.

Table. 2 : Season-wise mean performance of foundation crosses and their gain over pure race (within parenthesis)

P_1 crop season	FEC	ERR No.	ERR Wt. (kg)	SCW (g)	SSW (g)	S.R.%	No. of cocoon/kg
A	479 (11.92)	9142 (4.74)	11.793 (14.02)	1.290 (8.86)	0.198 (16.47)	15.55 (7.04)	755 (-9.47)
B	393 (1.29)	8932 (22.17)	10.325 (39.83)	1.156 (14.45)	0.179 (20.95)	15.49 (5.73)	865 (–12.63)
C	382 (–0.52)	8100 (23.36)	8.460 (45.86)	1.045 (17.95)	0.156 (20.93)	14.93 (2.61)	960 (–15.04)
D	396 (–0.50)	8377 (24.08)	9.850 (39.12)	1.177 (12.20)	0.172 (14.67)	14.61 (2.17)	850 (–10.99)

FEC : Fecundity; ERR No. : Yield/10,000 worms by No. ; ERR Wt. : Yield/10,000 worms by weight ; SCW : Single Cocoon Weight ; SSW : Single Shell Weight ; S.R. % : Cocoon Shell Ratio in percentage.

The fecundity of different types of silkworm breeds and gain over pure races in foundation crosses and commercial hybrids are presented in Table–3. The fecundity increased in foundation crosses by 13.51% whereas there was no increase over pure races during favourable and unfavourable seasons, respectively. In double crosses or commerical hybrids, the fecundity increased by 20.62% and 33.85% during favourable and unfavourable seasons, respectively over pure races. The increase of fecundity in F_2 female has also been reported by Benchamin and Krishnaswamy (1981), Narashimhanna (1985) and Benchamin *et al.* (1988).

Table. 3 : Mean of fecundity of different types of breeds and their gain over pure races

Type of Breed	Fecundity		
	Mean of favourable season	Mean of unfavourable season	Avg.
Pure Race	**422**	390	406
Foundation Crosses	**479** (13.51)	390 (0.00)	435 (7.14)
Double Cross or Commercial Hybrid	**509** (20.62)	522 (33.85)	515 (26.85)

Data within parenthesis is gain over pure race

Merits of the approach

If foundation crosses are used at P_1 level, it would eventually increase the commercial seed production. This approach may be adopted to bridge the gap of commercial seed production and the quality. The immediate benefits of the approach are :

- Increased crop reliability, if foundation crosses are raised and reared at P_1 level specially in unfavourable seed crop seasons.
- Increase in number of eggs upto an extent of 30% promoting an enhanced production.
- Seed crop rearers will not hesitate to accept the foundation crosses instead of pure breeds because of the crop assurance.

The authors are with Central Sericultural Research & Training Institute, Berhampore, West Bengal.

Readers Write !

The **Letters to the Editor** column is an open forum where anyone who wants to say anything about sericulture and silk industry as well as articles/features published in **Indian Silk** is welcome to do so. Please make your letters brief and to the point. Prizes worth Rs. 50 and Rs. 30 are awarded to the first and second best letters, respectively, whenever such letters are published. Send your letters to the Editor.

Silkworm Breeds and Their Hybrids

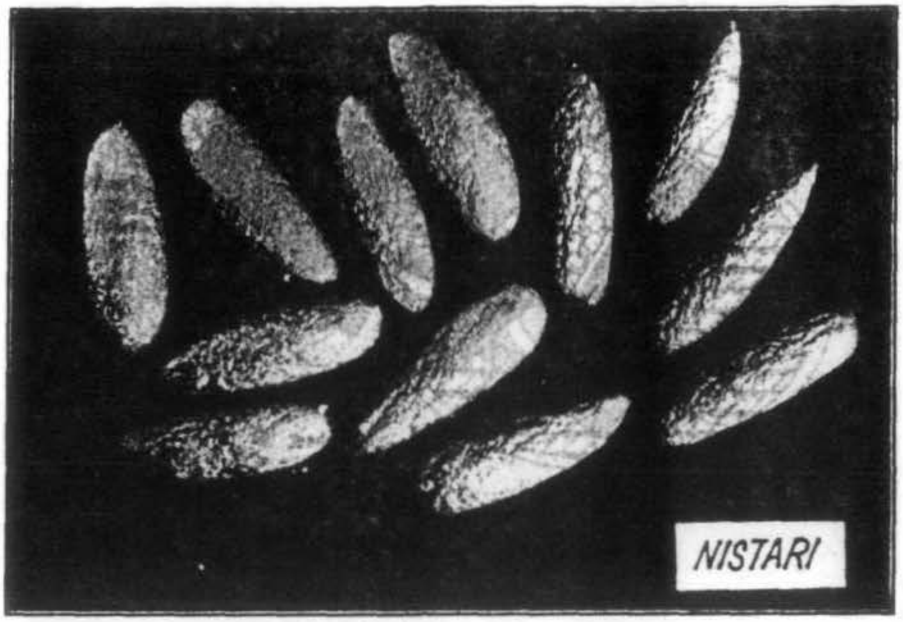
A.K. Sengupta, S.K. Das, P.R.T. Rao, B. Ghosh and B. Saratchandra

India is a vast country with varying climatic conditions in different agro-climatic zones. The precipitation rate, temperature and humidity vary from season to season and zone to zone. Among different zones, the tropical region experiences the highest temperature. The high rain fall areas and the coastal regions also experience high humidity and precipitation during summer and monsoon, respectively.

Evolution of hybrid vigour in silkworms that can withstand the vagaries of summer, has made much head-way in the sericultural front over the past two decades. The article portrays the silkworm races suitable for different regions during summer.

About 97% of the total area under mulberry, covering mainly the traditional states like Karnataka, Andhra Pradesh, West Bengal and Tamil Nadu and the non-traditional states lies in the tropical region.

During summer, the Deccan plateau and the Central India are normally hot and dry while the coastal areas of the peninsula, the Gangetic West Bengal and the Brahmaputra valley of the North-eastern region are hot and humid. In most of the sericulture areas, the temperature reaches as high as 35-45°C which makes silkworm rearing difficult. The room temperature normally lies 2-3°C lower than the ambient temperature and this can be further brought down by another 3-4°C by various simple measures.



Silkworm has no mechanism to regulate its body temperature to suit its physiological requirements. Hence, extreme high temperature and humidity result in the following:

* Affect the growth and development of the silkworm leading to high mortality.

* Facilitate the growth and multiplication of various pathogens causing silkworm diseases.

* Silkworms become weak and susceptible to various diseases which leads to crop losses.

* Mulberry leaves dry quickly and loose nutritive value which in-directly affect rearing performance and reduce yield and quality.

* Provoke hasty spinning resulting in formation of double cocoons and also silkworm waste.

* Reduce the cocoon quality and adversely affect reelability.

* Prevalence of temperature above 32°C during 5th instar and spinning induces male sterility thus affecting egg production in grainages.

Table 1: Performance of indigenous breeds during summer				
Race Breed	Pupation rate (%)	Yield/100 Layings (kg)	Av. Shell (per cent)	Filament length (mtr)
Nistari	76.00	17.00	11.29	367
Sarupat (W)	45.00	16.00	12.82	434
Pure Mysore	55.00	16.00	11.78	342
Moria	58.00	18.00	14.34	523
T. White	70.00	19.00	14.35	517

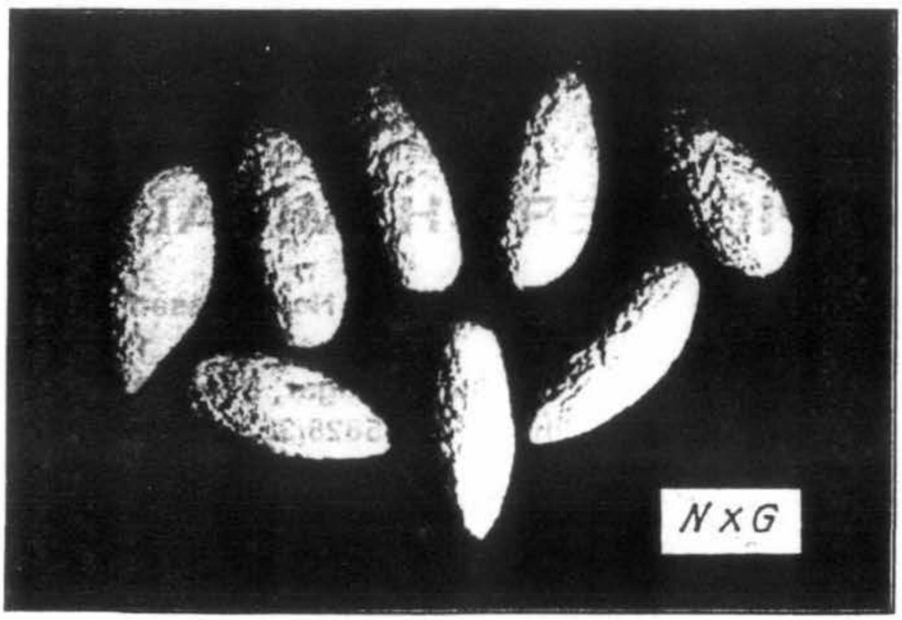
The tropical silkworm races experience the extreme fluctuation of environmental vagaries. These polyvoltine breeds and their hybrids can only withstand the harsh climate of Eastern and North-eastern India. Therefore, a few improved multivoltine breeds and some of their hybrids have been developed for summer. This was followed by the successful introduction of the multivoltine x bivoltine hybrids to a limited extent and have been found useful in summer seasons.

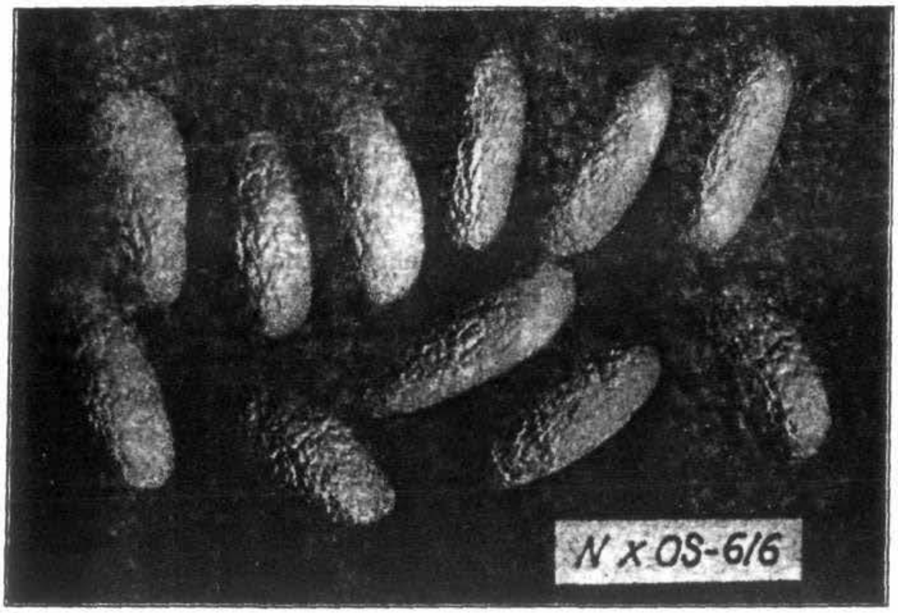
Though it was proved that multivoltine and multi x bivoltine hybrids can be successfully reared in the hot and humid season, the preceding seed crop (P_1) rearing of bivoltine parents in pure form poses a threat, thereby affecting the supply of bivoltine seed cocoons for preparation of multivoltine x bivoltine combinations (commercial hybrid seeds). The difficulty of bivoltine seed (P_1) rearing can be solved by using bivoltine hybrids as male parent, because hybrid rearing is much easier and successful since they can exert harsh climate in a better way by virtue of their heterozygous superiority or broader genetic base.

These problems remain the main bottlenecks for the rearing of the current high yielding, good quality temperate bivoltine varieties during summer. As a consequence, the farmers are compelled to rear traditional polyvoltine races or the age old local races which are poor in many characters and fetch low return due to their weaknesses like shorter filament length (300-500 mtrs.), low cocoon shell percent (11-13%), low reelability, poor neatness and less cohesion.

Therefore, the regional races like Nistari (West Bengal), Sarupat and Moria (Assam and some parts of North-eastern states), Tamil Nadu White and Pure Mysore (Tamil Nadu, Karnataka and Andhra Pradesh) are reared by farmers in summer (Table 1).

The commercial exploitation of hybrid vigour, in silkworm, has already been introduced since the beginning of this century, in most of the sericulturally developed countries. In this context, the use of hybrid vigour





has been initiated in the middle of the century. However, a few silkworm varieties have been evolved *viz..*, Nistid, Nismo, Itan, C. Nichi etc. were reigned for about two decades at commercial level. Simultaneously, a locally developed silkworm variety named "Debra" (Fig.2) became very popular among the farmers and because of its robustness is still in vogue.

During past two decades some more productive silkworm varieties have been evolved for the summer months of this area. With a view to exploit multivoltine breeds in a better way the improved multivoltine races like G and OS-616 were developed by using bivoltine genes. The breeds were crossed with the local variety 'Nistari' and introduced in the field during 1982 onwards, specially during dry and wet summer seasons of West Bengal. The average yield of these hybrids ranged between 25-30 kg against 12-15 kg yield of traditional race 'Nistari' (Figs. 3 and 4).

Table 2: Authorised silkworm hybrids for different states

	Assam, Bihar, Orissa & MP	Uttar Pradesh
Multi X B_i	N x (NB_{18} x P_5) , PM x NB_{18}	P_2D_1 x NB_{18} RD_1 x NB_{18}

Accordingly, to produce better cross breeds local races of the traditional zones were crossed with the above bivoltine breeds to develop cross breed like PM x NB_4D_2, N x KPG-A, N X KPG-B, N x P_5, T. White x NB_4D_2 etc. and yield ranges between 25–30 kg.

The impact of improved crossbreeds (multi x bi) or productivity of cocoon and silk on the spread of the industry was remarkable during the period between 1971 to 1995 and it was made possible with the evaluation of some bivoltine breeds like NB_4D_2, NB_{18}, KPG-B, P_5 and SH_6.

Recently some multivoltine x bivoltine hybrids have been authorised by the Central Silk Board (Table 2) and some more hybrids are under race authorisation trial.

The authors are with Central Sericultural Research and Training Institute, Berhampore, Murshidabad district, West Bengal.