The Bioscan 5(1) : 35 - 40, 2010
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES

DIFFERENTIAL EXPRESSION OF QUANTITATIVE TRAITS IN MULTIVOLTINE RACES AND BIVOLTINE BREEDS OF SILKWORM *BOMBYX MORI* L.

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KEY WORDS
Silkworm
Multivoltine
Bivoltine
Quantitative traits
Season

Received on :
15.12.2009
Accepted on :
21.02.2010

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ABSTRACT

Six multivoltine races and four bivoltine breeds were reared in three replicates each in three different seasons of a year. Thirteen quantitative traits of economic importance were analyzed through analysis of variance to understand the interaction between each races/ breeds, seasons and quantitative traits. The performance of the multivoltine races for the viability traits such as yield by number and pupation rate was highly significant where as among the bivoltine breeds, NB_4D_2 and CSR_2 revealed significant higher values for cocoon weight, shell weight, shell percentage and filament length compared to multivoltine races. All the races irrespective of the voltinism exhibited higher values for productivity traits in the monsoon period of the year. The expression of thirteen quantitative traits of both multivoltine and bivoltine races are discussed in regard to the importance of favourable environment for productivity traits.

INTRODUCTION

Bombyx mori, a silkmoth of great economic values is extensively being used for the production of commercial silk in many countries. Compared to temperate climatic zones, salubrious climate and profuse sunlight through out the year in many parts of our country is considered as very congenial for silkworm rearing and mulberry cultivation (Narasimhanna, 1976). As a result, sericulture is one of the important commercial crop in our country and hence India occupies second prominent position in the global silk production next to china (Datta, 1994). Realizing the importance of tropical environment for the production of quality silk, several studies were undertaken to understand the impact of different seasons on mulberry crop and cocoon production (Narayanan *et al.,* 1964; Kasivishwanathan *et al*., 1970). It is important to note that the introduction of promising bivoltine races during 1970-2000 has resulted in the increase of silk production by many folds (Datta, 2000). The rearing of bivoltines have clearly indicated that they failed to display uniform crop performance in the unfavorable environmental conditions of our country compared to multivoltine and multi x bi hybrids (Kalpana, 1992; Subramanya and Murakami, 1995). As a result multivoltine races and their hybrids are always preferred by the rearers than bivoltine and bivoltine hybrids. In the light of the above, to determine the extent of expression of important economic traits in three different seasons of South India is very essential since a particular environment may be most favourable than the others. Hence, information on the impact of three distinct seasons viz., pre-monsoon, monsoon and post-monsoon are considered for the present studies on the expression of thirteen economically important quantitative traits in six multivoltine and four bivoltine races of silkworm *Bombyx mori*. The results of the above studies are incorporated in this paper.

MATERIALS AND METHODS

The six multivoltine races and four bivoltine breeds were selected for the present investigation. The multivotine races are pre (precocity), npnd (non pigmented non diapause), C. nichi, Pure Mysore and Diazo. Where as, the bivoltine breeds selected are C_{108}, Kalimpong-A, NB_4D_2 and CSR_2. The description of characteristic features of the six multivoltine races and four bivoltine breeds are presented in Table 1. All these two voltine groups are drawn from the germ plasm bank of the department of studies in sericulture science and reared in three replicates feeding quality M_5 mulberry leaves.

The rearing was conducted in three different seasons of the year namely, pre-monsoon, monsoon, and post monsoon. The four months from March to June is considered as pre-monsoon which is characterized by high temperature and low humidity with occasional pre-monsoon showers. The monsoon season includes July to October months which brings heavy rain, fall in temperature and increase in the humidity. The post-monsoon season comprises the months from November to February which brings low temperature and low humidity in an environment. The rearing performances of all the ten races/breeds are critically assessed by conducting cellular rearing. The thirteen important economic traits selected for evaluating the rearing are fecundity, hatching percentage, larval duration, larval weight, yield by number, yield by weight, pupation rate, single cocoon weight, shell weight, shell percentage, length of the filament, denier and renditta. The performance of thirteen parameters from all the three replication are pooled and subjected for the statistical analysis through two- way analysis of variance test.

RESULTS AND DISCUSSION

Six multivoltine races and four bivoltine breeds revealed significant differences ($p<0.05$) between one another for each of the thirteen characters under study during three periods of the year and presented in Tables 2 and 7. It is evident from the data presented in the Tables 2 and 7 that the manifestation of different characters are not uniform in the two voltine groups in the three seasons. In multivoltine races, significant ($p<0.05$) differences are observed for all the characters except hatching percentage, yield by number and pupation rate during pre-monsoon season (Table 2). During monsoon season a similar trend was observed (Table 3) where as, in the post-monsoon season (Table 4) all the races / breeds exhibited significant differences ($p<0.05$) for eleven out of thirteen traits studied, except hatching and pupation rate. The data pertaining to the evaluation of thirteen economic traits among four bivoltine breeds are shown in Tables 5 and 7. It is evident from the results that there are non significant differences ($p>0.05$) for the trait hatching percentage, larval duration, shell percentage, pupation rate and denier during pre-monsoon season (Table 5). However, in monsoon season it is evident that highly significant differences ($p<0.05$) were observed for the traits of fecundity, larval weight, yield by number, yield by weight, shell weight, shell percentage, length of the silk filament, denier and renditta through ANOVA and F- values. A similar trend was observed for the degree of expression of characters studied in post-monsoon seasons by exhibiting significant differences ($p<0.05$) between the breeds for eight economic traits (Table 7).

The knowledge on the genotype and environmental interaction in both plants and animals has helped in understanding the reliable estimates of phenotypic variability

Table 1: Racial characteristic features of multivoltines races and bivoltine breeds

Races	Voltinism	Larval pattern	Cocoon colour
Pre	Multivoltine	Marked	White
npnd	Multivoltine	Marked	White
C.nichi	Multivoltine	Plain	White
Pure Mysore	Multivoltine	Plain	Light green
Nistari	Multivoltine	Marked	Golden yellow
Diazo	Multivoltine	Marked	Green
C_{108}	Bivoltine	Plain	White
Kalimpong-A	Bivoltine	Plain	White
NB_4D_2	Bivoltine	Plain	White
CSR_2	Bivoltine	Plain	White

Table 2: Mean values of the thirteen quantitative traits of six multivoltine races in pre-monsoon season

Economic traits Races	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 larvae brushed By (no)	By wt kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (kg)
Pre	358	94.22	430.67	12.31	9649	6.13	0.72	0.093	11.86	296.00	94.33	1.61	17.16
	±5.77	±1.48	±5.19	±0.04	±5.19	±0.02	±0.02	±0.02	±0.06	±3.46	±0.63	± 0.02	±0.034
npnd	361	95.59	462.34	12.66	9636	6.29	0.81	0.098	12.15	385.00	9 4.74	1.72	16.51
	±2.88	±0.80	±4.15	± 0.03	±6.92	±0.06	±0.02	±0.01	±0.03	±8.66	±0.36	±0.02	±0.29
C.nichi	367	96.69	470.67	16.01	9622	10.24	0.87	0.13	12.48	383.33	95.02	1.74	15.88
	±4.61	±1.21	±4.05	±0.01*	±4.61	±0.13	±0.04	±0.01	±0.05	±10.13	±0.34	±0.03	±0.21
Pure	383	95.79	540.24	16.52	9610	10.69	0.91	0.14	13.56	390.00	95.78	1.76	14.88
Mysore	±4.04	±1.32	±5.90	±0.07*	±2.30	±0.09	±0.06	±0.01	±0.02	±8.08	±0.57	±0.02	±0.21
Nistari	396	96.20	511.12	18.52	9618	11.56	0.93	0.14	13.78	422.00	96.10	1.79	13.84
	±4.61	±1.10	±4.61	±0.34	±5.96	±0.14	±0.02	± 0.02	±0.05	±92.3	± 0.63	±0.03	±0.11
Diazo	460	95.94	525.67	22.67	9570	12.30	1.07	0.15	14.17	441.00	96.96	1.83	13.48
	±5.19	±0.86	±0.86	±0.38	±5.77	±0.23	±0.04	±0.01	±0.05	±7.50	±0.02	±0.02	±0.27
F-value	69.01**	0.36^{NS}	77.23**	329.30**	0.390^{NS}	409.14**	26.08*	14.47**	230.10**	37.62**	1.07^{NS}	17.56**	47.60**

Index: * = p< 0.005, ** = p< 0.001, NS = Non-significant

Table 3: Mean values of the thirteen quantitative traits of six multivoltine races in monsoon season

Economic traits Races	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 By (no)	larvae brushed By wt (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (kg)
Pre	378.00	97.18	451.67	16.18	9698	7.18	0.79	0.098	12.38	358.00	95.00	1.68	15.70
	± 5.77	± 1.03	±3.46	±0.10	±28.86	±0.09	±0.06	±0.00	±0.10	±4.61	±0.57	±0.02	±0.45
npnd	404.00	97.69	493.44	16.26	9674	10.11	0.91	0.13	12.74	411.00	95.41	1.79	14.79
	± 2.88	± 0.23	±2.45	±0.28	±36.95	±0.34	±0.20	±1.01	±0.39	±6.35	±0.12	±0.02	±0.31
C.nichi	408.00	97.85	512.41	17.51	9666	10.76	1.02	0.14	13.30	425.00	95.81	1.82	13.94
	± 4.04	± 0.25	±5.19	±0.77	±30.32	±0.28	±0.02	±0.04	±0.11	±14.43	±0.86	±0.01	±0.14
Pure	448.00	97.91	622.67	18.98	9684	11.10	1.02	0.16	14.81	429.33	95.92	1.85	12.96
Mysore	± 11.54	± 0.17	±4.61	±0.86	±34.64	±0.23	±0.01	±0.02	±0.40	±11.25	±0.75	±0.02	±0.56
Nistari	463.00	97.96	563.56	21.41	9643	12.05	1.09	0.17	15.04	457.00	96.41	1.87	11.28
	± 7.50	± 0.11	±2.00	±0.80	±33.33	±0.28	±0.01	±0.01	±0.28	±5.77	± 0.63	± 0.02	± 0.43
Diazo	485.00	98.14	570.57	26.63	9650	13.18	1.19	0.18	16.65	460.00	97.10	1.89	10.81
	± 2.88	± 0.05	±5.20	± 0.96	± 28.86	± 0.14	± 0.03	± 0.02	± 0.34	±8.66	± 0.57	± 0.02	± 0.14
F-value	38.890**	0.530^{NS}	233.204**	33.802**	0.402^{NS}	67.991**	26.901**	4.009*	29.084**	16.481**	1.373^{NS}	22.232**	26.531**

Index: * = p< 0.005, ** = p< 0.001, NS= Non-significant

Table 4: Mean values of the thirteen quantitative traits of six multivoltine races in post – monsoon season

Economic traits Races	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 larvae By (no)	brushed By wt (lg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (kg)
Pre	368.00	96.19	433.34	14.72	9668	6.86	0.77	0.096	12.30	345.00	94.77	1.65	16.18
	±5.77	±0.68	±3.46	±0.34	±34.64	±0.11	±0.02	±0.01	±0.17	±5.77	±0.56	±0.01	±0.28
npnd	374.00	96.31	476.34	15.26	9652	9.84	0.88	0.10	12.32	396.00	95.38	1.76	15.15
	±2.88	±0.75	±3.63	±0.69	±17.32	±0.23	±0.04	±0.02	±0.28	±8.66	±0.21	±0.02	±0.23
C.nichi	395.00	96.51	476.67	17.32	9641	10.75	0.97	0.14	12.60	398.00	95.72	1.78	13.94
	±4.04	±0.57	±3.11	±0.69	±14.43	±0.17	±0.02	±0.02	±0.28	±10.39	±0.99	±0.01	±0.29
Pure	435.00	96.68	562.34	17.62	9633	10.92	0.98	0.15	13.78	420.00	95.86	1.79	14.27
Mysore	±4.61	±0.86	±4.21	±0.63	±23.09	±0.26	±0.01	±0.02	±0.51	±7.63	±0.57	±0.03	±0.52
Nistari	454.00	96.47	540.67	19.87	9628	11.75	1.08	0.16	13.80	428.00	96.42	1.81	11.77
	±4.04	±0.71	±4.27	±0.66	±43.30	±0.23	±0.04	±0.01	±0.51	±16.16	±0.80	±0.03	±0.46
Diazo	472.00	97.06	540.25	24.83	9610	12.50	1.14	0.17	15.54	456.00	97.03	1.86	11.10
	±5.19	±0.57	±3.51	±3.51	±28.86	±0.23	±0.023	±0.01	±0.43	±17.32	± 0.88	± 0.02	±0.52
F-value	92.439**	0.290^{NS}	180.980**	34.215**	0.488^{NS}	85.763**	31.482*	9.151**	10.292**	10.129**	1.198^{NS}	13.926**	23.135**

Index: * = p< 0.005, ** = p< 0.001, NS= Non-significant

Table 5: Mean values of the thirteen quantitative traits of four bivoltine breeds in pre-monsoon season

Economic traits Breeds	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 larvae brushed By (no)	By wt (kg)	Cocoon weight (g)	Shell wt (g)	Shell ratio(%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (kg)
C_{108}	4.733	94.14	562.00	37.92	9028.00	14.78	1.54	0.31	17.86	877.66	82.60	2.55	8.93
	±4.77	±1.27	±2.30	±0.80	±9.70	±0.23	±0.03	±0.01	±0.75	±6.66	±1.85	±0.04	±0.24
KA	478.66	94.82	568.00	40.16	9001.00	14.57	1.65	0.35	19.78	900.66	83.14	2.64	8.45
	±2.88	±1.78	±3.46	±0.75	±8.66	±0.17	±0.07	±0.01	±0.81	±7.13	±1.39	±0.03	±0.18
$NB4D_2$	492.66	95.59	574.00	40.63	8846.00	14.70	1.69	0.36	20.04	902.66	84.73	2.69	8.90
	±4.04	±1.21	±3.46	±0.75	±8.54	±0.28	±0.06	±0.01	±0.69	±8.89	±1.22	±0.06	±0.21
CSR_2	516.36	95.67	585.00	44.54	8778.00	16.84	1.80	0.42	21.17	987.33	86.73	2.71	7.30
	±2.34	±0.80	±3.92	±0.92	±5.78	±0.23	±0.04	±0.01	±0.80	±6.00	±1.41	±0.04	±0.17
F-value	23.272**	0.297^{NS}	3.978^{NS}	11.498**	144.525**	21.278**	13.559**	21.578**	3.21NS	36.329**	1.520^{NS}	3.433^{NS}	5.272**

Index: * = p< 0.005, ** = p< 0.001, NS= Non-significant

Table 6: Mean values of the thirteen quantitative traits of four bivoltine breeds in monsoon season

Economic traits Breeds	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 larvae brushed By (no)	By wt (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (kg)
C_{108}	506.33	95.76	601.00	38.95	9073	15.64	1.75	0.34	19.49	982.00	85.72	2.66	7.88
	±3.77	±0.98	±3.46	±0.57	±8.39	±0.86	±0.06	±0.006	±0.17	±5.77	±1.32	± 0.06	±0.21
KA	514.00	96.57	612.00	42.61	9044	16.69	1.84	0.36	20.67	1027.33	86.28	2.73	8.11
	±2.88	±0.57	±4.92	±1.15	±8.66	±0.80	±0.03	±0.006	± 0.21	±7.09	±1.38	± 0.05	±0.17
NB_4D_2	535.00	96.54	618.00	42.70	8898	16.72	1.89	0.38	20.91	1084.00	87.54	2.76	7.86
	±2.88	±0.86	±5.39	±0.86	±7.50	±0.69	±0.04	±0.007	± 0.23	±8.08	±1.32	± 0.06	±0.23
CSR_2	605.00	96.99	623.00	46.38	8882	18.57	1.97	0.44	23.12	1088.00	89.56	2.79	6.51
	±2.30	±0.19	±3.46	±1.03	±6.92	±0.63	±0.04	±0.002	± 0.12	±4.61	±1.21	±0.06	±0.17
F-value	146.020**	0.505^{NS}	1.993^{NS}	10.527**	134.296**	22.596**	4.195*	26.726**	78.433**	41.960**	1.677^{NS}	1.283^{NS}	14.676**

Index: * = p< 0.005, ** = p< 0.001, NS= Non-significant

Table 7: Mean values of the thirteen quantitative traits of four bivoltine breeds in post- monsoon season

Economic traits / Breeds	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Wt of 10 V age Larvae (g)	Yield/10,000 larvae brushed By (No)	By wt (kg)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta(kg)
C_{108}	491.33 ± 4.77	95.09 ±0.62	580.00 ±4.92	38.45 ±1.08	9054 ±6.00	14.85 ±0.20	1.64 ±0.06	0.33 ±0.01	18.56 ±0.69	938.66 ±9.93	85.10 ±1.15	2.58 ±0.05	8.32 ±0.12
KA	488.00 ±2.88	95.49 ±0.69	590.00 ±3.46	41.86 ±0.86	9023 ±9.27	15.86 ±0.057	1.72 ±0.02	0.36 ±0.01	20.55 ±0.57	992.22 ±6.88	84.18 ±0.10	2.69 ±0.03	8.26 ±0.15
NB_4D_2	512.00 ±4.92	95.71 ±0.33	598.00 ±5.92	41.89 ±0.75	8891 ±6.92	15.87 ±0.11	1.79 ±0.08	0.36 ±0.01	20.59 ±0.59	1001.66 ±7.22	85.89 ±0.92	2.74 ±0.03	8.28 ±0.11
CSR_2	596.00 ±4.92	96.82 ±0.19	604.00 ±3.46	45.75 ±0.85	8809 ±9.54	17.61 ±0.057	1.89 ±0.07	0.43 ±0.01	21.88 ±0.63	1030.58 ±8.89	87.87 ±1.19	2.76 ±0.04	6.83 ±0.19
F-value	74.310**	1.578^{NS}	3.600^{NS}	8.936**	133.820**	86.402**	3.018^{NS}	41.899**	4.772*	7.926**	2.714^{NS}	5.902*	26.357**

Index: * = p < 0.005, ** = p < 0.001, NS= Non-significant

of different genotypes under diverse environment (Knight, 1951; Finlay and Wilkinson, 1963; Perkins and Jinks, 1968; Freeman and Perkins 1971; Griffing and Zsioros, 1971 and Orozco, 1976). *Bombyx mori* one of the popular economic insect has an inherent genetic potential for the expression of various quantitative traits. It is clearly established through earlier studies that many of the quantitative traits in this organism respond differently to different environmental conditions because of the inherent polygenic system. Thus, differential response of the genotype of the *Bombyx mori* to the changing the environmental factors have been well documented.

The pioneering work of Kogure (1933) on the influence of light and temperature on certain characters of silkworm added a new dimension to the study of influence of environmental factors on the expression of commercial characters. In order to understand the degree of differential expression of various economic characters in different races for different seasons of the year, several attempts were made by various workers (Kumar, 1962; Sengupta, 1969; Kasiviswanathan *et al.,* 1970; Krishnaswami and Tikoo, 1971; Krishnaswami and Narasimhanna, 1974; Narasimhanna *et al.,* 1976; Subramanya, 1985, Rajanna and Sreeramareddy, 1990; Raju, 1990; Maribashetty, 1991; Kalpana, 1992 ; Datta 1994; Nirmal Kumar, 1995; Radhakrishna *et al*., 2001 and Doddaswamy, 2007). The studies by above authors has helped to understand the genetic potentialities of silkworm *Bomby mori* in relation to adaptability and productivity. The present studies involving the evaluation of the performance of multivoltine and bivoltine races in three season revealed that desirable traits vary significantly with regard to the expression of quantitative traits during different periods. Among multivoltines, Pure Mysore, Nistari and Diazo are very distinct with high pupation rate whereas, the bivoltine breed CSR_2 is known for higher metric cocoon characters. In view of the differential performance of each of the breeds it can be said that they are genetically distinct.

Considering the variable effects of the three seasons, it is important to note that the pre-monsoon season has considerable impact on the differential expression of economic traits, whereas monsoon season is most congenial for the expression of all the traits under study. Even though there is non uniform expression of the traits in three periods it is evident that post-monsoon season has significant effect on the larval period which is evident by prolongation in the growth and development of the larvae in both voltine groups. On the other hand, in the monsoon period the traits yield by number, yield by weight, filament length, cocoon weight, shell weight are found to be significantly influenced in relation to productivity in the both voltine groups.

From the results of the present investigation it can be inferred that the factor governing various productivity and viability characters in silkworm are found to be completely related and being influenced by internal and external factors as evidenced by the expression of various economic characters of the races in different seasons of the year.

ACKNOWLEDGEMENT

The authors wish to express sincere thanks to the University of Mysore, Mysore and the Chairman, Department of Studies in Sericulture Science, University of Mysore, Mysore for extending the necessary facilities to carry out the research work.

REFERENCES

Datta, R. K. 1994. Production and Demand of Silk in India. *Proc. Intl, Conf, Seric.* Oxford and IBH Pub. Co.Pvt. Ltd., New Delhi.

Datta, R. K. 2000. Silkworm breeding in India – Present status and new challenges. Lead paper. *Natl. Conf. Strat. Seric. Res. Dev.*, Nov.16-18 CSRandTI. Mysore.

Doddaswamy, M. S. 2007. Contribution towards the genetics of cross breeding strategies in the Silkworm, *Bombyx mori.*L Ph.D thesis, University of Mysore, Mysore.

Finlay, K. W. and Wilkinson, G. N. 1963. The analysis of adaptation in plant breeding Programme. *Aust. J. Agric. Res.* **14:** 742-754.

Freeman, G. H. and Perkins J. M. 1971. Environmental and genotype – environmental components of variability. VIII. Relations between genotypes grown in different environments and measures of these environments. *Heredity.* **27**: 15-23.

Griffing, B. and Zsioros, E. 1971. Heterosis associated with genotype – Environment interactions. *Genetics.* **68:** 443-445.

Kalpana, G. V. 1992. Breeding of superior races of silkworm *Bombyx mori L.,* for tropical climates. Ph.D. thesis, University

of Mysore, Mysore.

Kasivishwanathan, K., Iyengar M. N. S. and Krishnaswami, S. 1970. Effect of feeding leaves grown under different systems of mulberry cultivation on the silkworm cocoon crops. *Ind. J. Seric.* **9(1):** 53-58.

Knight, R. 1951. A multiple regression analysis of hybrid vigour in single crosses of *Doctylis glomerata L. Theo. App. Genet.* **41:** 306-311.

Kogure, M. 1933. The influence of light and temperature on certain characters of silkworm. *Bombyx mori. J. Dept. Agri. Kyushu Imperial Univ*. **4:** 1-93.

Krishnaswami, S. and Narasimhanna, M. N. 1974. Large scale trails on bivoltine hybrids in Mysore state Ind. *J. Genet. and Pl. Breed.* **34A:** 229-236.

Krishnaswami, S. and Tikoo, B. L. 1971. A comparative study of performance of pure races currently under rearing in Mysore state. *Ind. J. Seric.* **10(1):** 66-71.

Kumar, G. A. R. 1962. Seasonal variation in fertility and hatchability of duck eggs. *Poultry Sci* **4:** 1029-1035.

Maribashetty, V. G. 1991. Evolution of superior bivoltine races of silkworm *Bombyx mori L. for tropics. Ph.D. Thesis*, University of Mysore, Mysore.

Narasimhanna, M. N., 1976. Contribution to the Genetics of silkworm. *Ph.D. Thesis,* University of Mysore, Mysore.

Narasimhanna, M. N., Chandrashekaraiah, Geethadevi, R. G. and Prabha, G. 1976. Ecogenetic attributes of the newly evolved bivoltine hybrid "Nandi" in *Bombyx mori* L. *Proc. Dunn. Dohzhansky Symp Genet*. pp. 379-386.

Narayanan, E. S., Prahalada Rao, L. S. and Nagaraja Rao, H. A. 1964. Studies on correlation between the duration of mating and number of viable eggs laid by the silk moth. *Bombyx mori* L. I-Effect of duration of copulation on the resulting number of viable eggs. *Ind. J. Seric.* **3(2):** 1-9.

Nirmal Kumar, S. 1995. Studies on the synthesis of appropriate silkworm breeds (*Bombyx mori* L.) for tropics. *Ph.D. Thesis***,** University of Mysore, Mysore**.**

Orozco, F. 1976. Heterosis and genotype environment interaction: theoretical and experimental aspects. *Poultry Sci.* **4:** 1029-1035.

Perkins, J. M. and Jinks, J. L. 1968. Environmental and genotype environmental components of variability III. Multiple lines and crosses. *Heredity. **23***: 339-356.

Radhakrishna, P. G., Sekharappa, B. M. and Gururaj, C. S. 2001. Seasonal response of the new multi-bivoltine hybrids of the silkworm *Bombyx mori.L. Ind. J. Seric.* **40(2):** 174-176.

Rajanna, G. S. and Sreerama Reddy, G. 1990. Studies on the variability and inter relationship between some quantitative characters in different breeds of silkworm, *Bombyx mori. L. Sericologia*. **30(1):** 67-73.

Raju, P. J. 1990. Studies on the hybridization and synthesis of new breeds of silkworm *Bombyx mori*. L. *Ph.D. Thesis,* University of Mysore, Mysore.

Sengupta, K. 1969. An analysis of genotype environment interaction in some races of silkworm *Bombyx mori L. Ind. J. Seric.* **8(1):** 4-6.

Subramanya, G. 1985. Ecogenetic approach for determination of high yielding breeds of silkworm *Bombyx more L. Ph.D Thesis,* University of Mysore, Mysore.

Subramanaya, G. and Murakami, A. 1995. Climatic differential phenotypic expression of voltine genes in *Bombyx mori. Ind. J. Seric.* **33(2):** 103-109.