Environment & Ecology 27 (4) : 1570—1575, 2009
ISSN 0970-0420

Latitudinal Variation in the Population of Ecoraces Bhandara of Tropical Tasar Silk Insect *Antheraea paphia* L. (Lepidoptera : Saturniidae)

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Abstract

The ecorace Bhandara of tropical tasar silk insect *Antheraea paphia* L (Lepidopera : Saturniidae) is a unique sericigenous insect, eurythermic, trivoltine, polyphagous in its habitat and differs in its adaptation in different eco-pockets at different latitudes in the distinct belt of southern, tropical, dry, deciduous, mixed forests of Armori, Bhandara and Seoni. The present study adduces the morphogenetic variation in the quantitative traits of cocoons of the natural population obtained from the different parallels of latitudes. The quantitative traits of cocoons conferred significant variation at the level of different eco-pockets having different latitudes. The male population of ecorace Bhandara of tasar silkworm from eco-pocket Seoni (22.28°N) was significantly of higher value over the male population from eco-pocket Bhandara (21.09°N) in more than 75% traits and male population of ecorace Armori (20.28°N) in 84.61% traits under study. All the traits except peduncle length, cocoon breadth and denier in male cocoons evinced positive association with increase in the parallels of latitudes. Similarly, all the traits except peduncle thickness, cocoon length in female cocoons adduced significant positive relation with increase in parallels of latitudes in different eco-pockets. By the use of regression coefficient as base, the different populations at different parallels of latitudes conferred different degree of stability in both the sexes. These genotypic differences for adaptation arose mainly from the nature having different parallels of latitudes. The genotypes of different latitudes tend to show a definite response to rise and fall in the quantitative traits with a different level of regression function. The intercept of regression function altered accordingly in the positive or negative direction. Such response to latitudes adjudicated linear sensitivity and it can be predicted on the bases of coefficient of determination. The performance of the different genotypes at different latitudes improves with increase in latitudes under Armori, Bhandara and Seoni conditions of India.

Key words : Tasar silk insect, *Antheraea paphia*, Latitudinal variation, Ecorace Bhandara, Morpho-genetic variation.

The ecorace Bhandara of Indian wild tasar silk insect is a unique, sericigenous insect, eurythermic in the torrid zone, bivoltine in some places and trivoltine in some places, confers plasticity in the voltenism, polyphagous, bimodal indistribution depending upon the availability of tasar flora especially on *Lagerstroemia parviflora* (26.46%) and *Anogeissus latifolia* Wall (26.16%). The highest frequency of occurrence is on *Terminalia tomentosa* W & A (46.0%) and the population remains at antimode on *Terminalia arjuna* Bedd as its primary center of diversity is river and rivulate in the natural mixed forests (Yadav et al. 1996). Variation within population provides a basis on which natural selection can act. There are some other conditions which influence the genotypes within the population. One pertinent factor is the genetic nature of the individuals that founded the population and any subsequent changes due to migration, mortality or an effect of edge zone where two or more than two populations meet. The ecorace Bhandara is known by different lineal names i.e. Bhandara in Bhandara ; Mulki in Bhandara, Gadchiroli and Chandrapur and Ranat in Gondia of Maharashtra province, Bara Seoni of Madhya Pradesh provinces of India. The present study adjudicates the morphogenetic variation in the quantitative traits of cocoons of the natural population collected from the different parallels of latitudes

Table 1. Latitudinal variation in the morphometric traits of cocoons of ecorace Bhandara of different eco-pockets. Armori (20°28′ N. latitude, 80°02′ E. Longitude), Bhandara (21°09′ N. latitude, 79°42′ E. Longitude) Seoni (22°28′ N. latitude, 77°29′ E. Longitude). Any two means having a common letter are not significantly different at 5 P. c. level of significance (df=14).

Eco-pocket sex		(A) Armori (male)	(B) Bhandara (male)	(C) Seoni (male)	(A) Armory (female)	(B) Bhandara (female)	(C) Seoni (female)
		a	a	a	a	a	a
Peduncle length (cm)	Mean	3.08	4.43	3.66	3.40	3.66	3.78
	±S.E.	± 0.09	± 0.68	±0.39	± 0.20	± 0.46	± 0.30
	C.V.%	7.14	34.53	24.31	13.52	28.68	17.98
		a	ab	bc	a	b	b
Peduncle thickness (cm)	Mean	0.17	0.20	0.20	0.23	0.20	0.23
	±S.E.	± 0.008	± 0.01	± 0.00	± 0.01	± 0.003	± 0.01
	C.V.%	11.76	8.89	0.00	17.39	3.35	17.39
		a	b	ab	a	a	b
Peduncle ring circumference (cm)	Mean	2.39	3.71	3.49	3.25	2.70	4.24
	±S.E.	± 0.39	± 0.14	± 0.25	± 0.03	± 0.25	± 0.27
	C.V.%	37.23	8.89	16.04	2.46	20.74	14.62
		a	b	a	a	a	b
Peduncle ring diameter (cm)	Mean	0.52	0.88	0.99	0.70	0.64	1.00
	±S.E.	± 0.10	± 0.04	± 0.08	± 0.003	± 0.06	± 0.07
	C.V.%	46.15	2.22	18.18	1.14	21.87	17.00
		a	a	a	a	a	a
Cocoon length (cm)	Mean	3.98	4.04	4.06	4.23	4.11	4.23
	±S.E.	± 0.08	± 0.11	± 0.05	± 0.13	± 0.13	± 0.13
	C.V.%	4.52	6.18	3.20	6.85	7.54	7.32
		a	a	a	a	ab	bc
Cocoon breadth (cm)	Mean	2.48	2.40	2.52	2.49	2.52	2.65
	±S.E.	± 0.08	± 0.06	± 0.02	± 0.02	± 0.07	± 0.04
	C.V.%	7.66	5.83	2.18	2.00	6.34	3.77
		a	a	a	a	a	a
Longitudinal circumference (cm)	Mean	8.16	10.59	10.55	10.75	10.62	11.12
	±S.E.	± 1.87	± 0.18	± 0.10	± 0.20	± 0.24	± 0.22
	C.V.%	51.34	3.87	2.05	4.27	5.17	4.58
		a	ab	bc	a	ab	bc
Horizontal circumference (cm)	Mean	7.66	8.02	8.26	8.03	8.06	8.53
	±S.E.	± 0.14	± 0.15	± 0.07	± 0.32	± 0.14	± 0.13
	C.V.%	4.17	4.24	6.65	2.98	4.09	3.60
		a	ab	bc	a	a	b
Cocoon weight (g)	Mean	7.11	7.89	8.42	9.15	8.86	11.65
	±S.E.	± 0.33	± 0.17	± 0.25	± 0.05	± 0.29	± 0.72
	C.V.%	10.54	4.94	14.51	7.97	7.45	13.99
		a	b	b	a	a	b
Shell weight (g)	Mean	1.36	1.70	1.86	1.51	1.41	2.31
	±S.E.	± 0.10	± 0.04	± 0.12	± 0.05	± 0.07	± 0.16
	C.V.%	17.64	5.29	9.87	8.56	11.34	15.58
		a	a	a	a	a	b
Shell %	Mean	19.40	21.55	21.88	16.56	16.00	19.92
	±S.E.	± 0.82	± 0.47	± 0.96	± 0.07	± 0.51	± 0.87
	C.V.%	9.71	4.96	9.87	0.96	7.25	9.83
		a	ab	bc	a	ab	bc
Filament length (m)	Mean	804.0	854.6	927.6	780	825.2	906.4
	±S.E.	± 30.87	± 42.92	± 28.22	± 32.59	± 36.53	± 27.47
	C.V.%	8.58	11.23	6.80	9.34	9.90	6.77
		a	a	a	ab	bc	bd
Denier (d)	Mean	10.20	9.00	10.60	8.60	8.20	10.60
	±S.E.	± 0.37	± 0.44	± 0.50	± 0.39	± 0.50	± 1.02
	C.V.%	8.13	11.11	10.75	10.34	13.29	21.69

Table 2. Relation between the latitudes (X) and different quantitative traits (Y_1—Y_{13})in the natural cocoons of ecorace Bhandara of *Antheraea paphia* L. (Male cocoons). X =Latitude, Y_1—Y_{13} = Cocoon traits, *r* = Coefficient of correlation, r^2= Coefficient of determination, P.E. (*r*) = Probable error of correlation coefficient, t (*r)* = *t* test for existence of correlation coefficient, NS = Not Significant, ** = $P < 0.01$ (df = 13), Y = a + bx (regression function).

		STATISTICS						
	Cocoons traits	*r*	P.E. (*r*)	*r*/P.E. (*r*)	*t* (*r*)	r^2	Latitudinal control on the trait (%)	Y=a+bx
1	Peduncle length (cm) Y_1	$+0.3271^{NS}$	±0.1554	2.1049^{NS}	1.3207^{NS}	0.1069	10.69	$Y_1 = -0.9504 + 0.2202\ X$
2	Peduncle thickness (cm) Y_2	+0.8159**	±0.0582	14.0189**	5.087**	0.6657	66.57	$Y_2 = -0.1054 + 0.0139\ X$
3	Peduncle ring circumference (cm) Y_3	+0.7149**	±0.0851	8.4007**	3.686**	0.5110	51.10	$Y_3 = -1.6362 + 0.0732\ X$
4	Peduncle ring diameter (cm) Y_4	+0.9184**	±0.0404	22.7326**	8.370**	0.8434	84.34	$Y_4 = 3.9628 + 0.2244\ X$
5	Cocoon length (cm) Y_5	+ 0.9273**	±0.0244	38.0040**	8.932**	0.8593	85.93	$Y_5 = 3.2147 + 0.03827\ X$
6	Cocoon breadth (cm) Y_6	$+ 0.4276^{NS}$	±0.1423	3.0049^{NS}	1.705^{NS}	0.1828	18.26	$Y_6 = -1.915 + 0.0260\ X$
7	Longitudinal circumference of cocoons (cm) Y_7	+0.8022**	±0.0620	12.9387**	4.844**	0.6435	64.35	$Y_7 = -13.6394 + 1.1037\ X$
8	Horizontal circumference of cocoons (cm) Y_8	+0.9754**	±0.0084	116.1190^{**}	15.95**	0.9514	95.14	$Y_8 = 1.7720 + 0.2927\ X$
9	Cocoon weight (g) Y_9	+ 0.9763**	±0.0081	120.5308^{**}	16.26**	0.9531	95.31	$Y_9 = -5.7637 + 0.6395\ X$
10	Shell weight (g) Y_{10}	+0.9915**	±0.0029	341.8965^{**}	27.47**	0.9830	98.30	$Y_{10} = -1.8129 + 0.1628\ X$
11	Shell % Y_{11}	+0.8727**	±0.0415	21.0289**	6.445**	0.7616	76.16	$Y_{11} = -3.8398 + 1.1681\ X$
12	Filament length (m) Y_{12}	+ 0.9999**	±0.00003	33.330**	255.68	0.9998	99.98	$Y_{12} = -447.9056 + 61.7617\ X$
13	Denier (d) Y_{13}	-0.4153^{NS}	±0.1441	2.8820^{NS}	1.646^{NS}	0.1724	17.24	$Y_{13} = -17.2241 + 0.3437\ X$

from its primary food plant *Terminalia tomentosa.*

Methods

The experiment was initiated with the nature grown cocoons of ecorace Bhandara collected from the Asan (*Terminalia tomentosa*) from the forests of district Bhandara, Maharashtra, India (21.09° N latitude, 79.42°E longitude), Armori, district Gadchiroli, Maharashtra, India (20.28°N latitude 80.02°E longitude) and Seoni, MP, India (22.28°N latitude, 77.29°E longitude). The male and female cocoons were separated sex wise for analysis of different economic traits associated with the cocoons. There were (3 eco-pockets having different parallels of latitudes × 2 sexes × replications) 30 combinations associed with sex and parallels of latitudes and 50 cocoons were used per adduced combination to analyze the different cocoon traits. The shell percent was calculated following the equation :

$$\text{Shell per cent} = \frac{\text{Shell weight of green cocoons (g)}}{\text{Cocoon weight of green cocoons (g)}} \times 100$$

The data were analyzed statistically and are presented. Latitudinal variation in the morpho-metric

Table 3. Relation between the latitudes and different quantitative traits (Y_1—Y_{13}) in the natural cocoons of ecorace Bhandara of *Antheraea paphia* L. (Female cocoons). X =Latitude, Y_1—Y_{13} = Cocoon traits, r = Coefficient of correlation, r^2 = Coefficient of determination, P. E. (r) = Probable error of correlation coefficient. t (r) = 't' test for existence of correlation coefficient, NS = Not Significant, ** = $P < 0.01$ (df = 13), Y = a + bx (regression function).

		STATISTICS						
	Cocoons traits	r	P.E. (r)	r/P.E. (r)	t (r)	r^2	Latitudinal control on the trait (%)	Y=a+bx
1	Peduncle length (cm) Y_1	+ 0.9497**	± 0.0170	55.8647**	17.0863**	0.9019	90.19	Y_1 = –0.2766 + 0.1834 X
2	Peduncle thicknes (cm) Y_2	+ 0.1094^{NS}	± 0.2551	0.4288^{NS}	0.3969^{NS}	0.0119	01.19	Y_2 = 0.1818 + 0.0018 X
3	Peduncle ring circumference (cm) Y_3	+ 0.7150**	± 0.1262	5.6656^{NS}	3.6875**	0.5112	51.12	Y_3 = –8.3730 + 0.5547 X
4	Peduncle ring diameter (cm) Y_4	+ 0.8421**	± 0.0751	11.2130**	5.6298**	0.7091	70.91	Y_4 = –2.6411 + 0.1613 X
5	Cocoon length (cm) Y_5	+0.1101^{NS}	± 0.2550	0.4317^{NS}	0.3993	0.0121	01.21	Y_5 = 4.0309 + 0.0075 X
6	Cocoon breadth (cm) Y_6	+ 0.9727**	± 0.0139	69.9784**	15.1163**	0.9461	94.61	Y_6 = 5.9166 + 0.0822 X
7	Longitudinal circumference of cocoons (cm) Y_7	+ 0.7922**	± 0.0961	8.2435**	4.6804**	0.6275	62.75	Y_7 =–4.0850 + 0.2025 X
8	Horizontal circumference of cocoons (cm) Y_8	+ 0.9738**	± 0.0133	73.2180**	15.4399**	0.9482	94.82	Y_8 = –5.3115 + 0.2608 X
9	Cocoon weight (g) Y_9	+ 0.8750**	± 0.0605	14.4628**	6.5168**	0.7656	76.56	Y_9 = –18.3653 + 1.3317 X
10	Shell weight (g) Y_{10}	+ 0.8759**	± 0.0601	14.5740**	6.5450**	0.7672	76.72	Y_{10} = –7.3067 + 0.4265 X
11	Shell % Y_{11}	+ 0.8561**	± 0.0689	12.4252**	5.9725**	0.7329	73.29	Y_{11}= –20.8140 + 1.8061 X
12	Filament length (m) Y_{12}	+ 0.9987	± 0.0007	1426.71**	70.6454**	0.9970	99.70	Y_{12}= –511.8065 + 63.5826 X
13	Denier (d) Y_{13}	– 0.8416	± 0.0756	11.1766**	5.6181**	0.7082	70.82	Y_{13}= 1.4465 + 0.3623 X

traits of cocoons with their standard errors and coefficient of variations were analyzed following the methods Gomez and Gomez (1984) to determine the level of significance by t test and was super scribed by a common or different letter to predict the vested significance level. The relation between the parallels of latitudes as variable (x) and different quantitative traits (Y_1 to Y_{13}) were computed following the methods of Elhance et al. 1997 for male and female cocoons. The significance of coefficient of correlation was tested from Fisher and Yates (1963) table for r value to adjudicate the probability of significance, r value was tested by the ratio of correlation coefficient (r) and probable error of correlation $PE_{(r)}$. The traits which presented the ratio more than 6 were adjudicated as significant at 1% level ; r value was further tested by t test for correlation coefficient t (r) and significance of traits were confirmed with the table values of Fisher and Yates (1963). The regression function between the X and Y_1 to Y_{13} associates was calculated by the methods of (Gomez and Gomez 1984) following the equation Y=a+bX. The latitudinal control on dependent variables (Y_1 to Y_{13}) was calculated following the equation $r^2 \times 100$.

Results and Discussion

The relevant results of the analysis for the t

test, correlation coefficient (*r*), coefficient of determination, latitudinal control on each predicted variable (Y_1 to Y_{13}) and regression function are presented in Tables 1 to 3. There was no difference in the population of *A. paphia* for peduncle length, occurring at three different latitudes of Armori (20°28′ N). Bhandara (21°0 ′ N) and Seoni (22°22′ N) conditions of India within the same sex (Table 1). The regression function between the latitudes and peduncle length of the population of ecorace Bhandara of *A. paphia* has conferred a negative intercept of the regression of less than unity in both the sexes. The different latitudes adduced 10.69% control on peduncle length in the male cocoons. Contrary to this, the latitudinal control on peduncle length in female cocoons was to an extent of 90.19% and the relation between the independent variable and dependent variable was significant ($r = +0.9497^{**}$, df 13, $P < 0.01$).

Peduncle thickness has evinced latitudinal variations with a positive association ($r=+0.8159$, df 13, $P<0.01$) of this trait with the increasing latitudes in male cocoons, having a latitudinal control of 66.67%. This trait failed to show any significant difference with the increasing latitudes in its female population ($r = +0.1094^{NS}$, df = 13, $P > 0.05$).

The peduncle ring circumference, peduncle ring diameter, longitudinal circumference of cocoons, horizontal circumference of cocoons, cocoon weight, shell weight, shell percent and filament length in the difference population of ecorace Bhandara of *A. paphia* presented positive association with increasing latitudes ($P < 0.01$, df 13). However, the denier of the silk filament conferred negative association ($r = -0.4153$, df 13, $P > 0.05$) in males and females ($r = -0.8416$, df 13, $P < 0.01$). The trait filament length in males and females presented maximum control of latitudes. Thus, the latitudinal stability of the trait was highest for filament length in both the sexes followed by shell weight, cocoon weight in males and horizontal circumference of cocoons followed by cocoon breadth in females (Tables 2 and 3). Contrary to this, there was no control of latitudes in peduncle length and cocoon breadth in males and peduncle thickness and cocoon length in females.

The prediction equation of Y (Y_1 to Y_{13}) on the X axis (different latitudes) drawn separately for all types of ecorace Bhandara of *A. paphia* provides an exact differentiation of the population involved in both the sexes (Tables 2 and 3). The Y intercept which is found from the point at which the regression line cuts the Y axis differs in all the 3 populations of different altitudes in both the sexes. The slope of the regression line which is the ratio of the rise to run, for any run and steeper the line greater the slops (Paul 1983). The Y intercept has negative or positive values for the different traits of both the sexes.

The performance of a genotype mainly depends on the environmental interaction. However, in many cases a linear relationship is found between the performance of genotypes and environmental conditions as observed in the present study with increasing latitudes. Estimation of the phenotypic stability, which involves the regression analysis, can also be analyzed for the populations at different latitudes as regression analysis proved to be valuable technique in the assessment of this linear relationship between the responses of genotypes and environmental changes (Singh 1993). Regression coefficient of the unity indicates average stability, greater than one means below average stability and less than one means the genotypes has a greater resistance to the environmental changes and possess average stability (Singh 1993). However, in deciding about the worth of a genotypes its mean performance must be considered along with its phenotypic stability. Otherwise, a variety which is the lowest yielding in all the environment will necessary show a b value (regression coefficient) less than one. Generally a trait at its latitude having b = 1 and high mean (Tables 2 and 3) would be considered as most widely adapted. A b value of one and low mean value of the trait would indicate a poorly adopted trait and hence a poorly adapted population.

Eberhart and Russel (1996) defined the stability of a variety based on the slope of the regression line and deviation from the regression line. They defined a stable variety as one with a regression coefficient of unity (b = 1) and minimum deviation from the regression line ($sd^2 = 0$). Using this definition a breeder would usually desire to develop a variety that has mean yield and meets the above requirements for stability. Natural selection confers adaptive capacity on the individuals selected. Therefore, it selects for fitness in a term of high productivity of the traits under selection (Sharma 1994). Adaptation to different environments or different ways of adaptation in the same environment is consummated by the natural selection. The best adapted form is close to the average in all the metric traits (Fisher 1930, Wright 1951). These three populations of Armori, Bhandara and Seoni present different voltenism. The population of ecorace Armori is trivoltine as it is closer to the equator than Bhandara and Seoni populations. The population of *A. paphia* at Bhandara confers 20% bivoltenism and 80% trivoltenism whereas the population of *A. paphia* at Seoni adduces 80% bivoltenism and 20% trivoltenism just opposite to the population at Bhandara. Thus, voltenism of *A. paphia* changes with increasing latitude from trivoltine to bivoltine. Variant adaptation consists of the thermic diversity conferring an additional ability of an organism to control the metric traits in the three different populations occurring at different latitudes Sharma 1994, presented the reason that diversity in a population is an ability of organism to control and regulate the synthesis of an array of characteristic proteins and other substances responsible for bringing about modification in the phenotype.

The phenotypic flexibility is however complementary to genetic flexibility because a phenotypically flexible group of genotypes may be able to meet the challenges of the environment only when they are endowed with requisite genetic flexibility i.e. capacity of the genotypes to vary on changes in conditions (Thoday 1955).

Therefore, it must be realized that lot of differences are noticed in the characteristics of the different population of ecorace Bhandara. When the morphology of the cocoons are compared for various traits, it shows significant differences either in the cocoon length or in the cocoon breadth and all other associated traits for both the sexes (Tables 2 and 3). This study rendered a useful comparative analysis to distinguish between different morpho-variants or biotypes having variations in the volenism from trivoltine to bivoltine with the increasing parallels of latitudes,adjudicating different stability level of the traits on the basis of the values of different levels of regression coefficient.

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