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RESEARCH ARTICLE

Biology of *Bombyx mori* L. (Lepidoptera: Bombycidae)

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ABSTRACT

Studies on biology of *Bombyx mori* L. (Lepidoptera: Bombycidae) on mulberry plant showed that the silkworm moth laid the eggs which were singly coated with gummy substance, ellipsoidal in shape and dull white in colour under the laboratory condition. The average incubation period and hatching percentage were 8.32 ± 1.179 days and 91.60 ± 5.317 per cents, respectively. The larvae passed through five instars. The average larval period was 24.44 ± 1.509 days while pupal weight and duration varied from 0.622 ± 0.052 g and 12.54 ± 1.22 days, respectively. Shell weight varied from 0.105 ± 0.022 g. The average pre-oviposition, oviposition and post-oviposition periods were, 0.43 ± 0.028, 2.30 ± 0.483 and 3.50 ± 0.527 days, respectively. The average fecundity of the female was 269 ± 30.21 eggs during entire life span. The average longevity of male and female moth was, 5.60 ± 0.699 and 6.23 ± 0.431 days, respectively. The life span of female was found to be relatively more than male moth.

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INTRODUCTION

Sericulture is an agro-based labour intensive rural cottage industry. It plays an important role in the economic life of rural people by providing employment on large scale. It is a home industry. Hence, women could very well be involved in sericulture development. By providing self-employment in rural areas, not only the rural migration is arrested but also the cottage and small industries get established in rural areas. Silk contributes foreign exchange to the national economy and it is probable the most expensive staple cargo that enters the commerce of our nation.

India produced 20,410 MT of raw silk during 2010-11, out of which 16,360 MT is being contributed by mulberry silkworm, which makes it the second largest producer in the world next only to China. Tasar, Eri and Muga contribute 1166, 2760 and 124 MT respectively. (Anonymous, 2011).

Mulberry (*Morus alba* L.) is the only food plant of silkworm (*Bombyx mori* L.) on commercial scale with great economic importance to sericulture industry. Silkworm requires maximum quantity of good quality mulberry leaf for successful cocoon production. Chemical composition of mulberry leaf is influenced by variety, spacing, irrigation levels, nitrogen levels and seasons (Basanna *et al.*, 1979). Different factors responsible for a successful cocoon crop are mulberry leaf (38.2%), climate (37%), rearing technique (9.3%), silkworm race (4.2%), silkworm eggs (3.0%) and other factors (8.2%) (Miyashita, 1986).The crop responses are known to vary with levels of nitrogen, since the mulberry is being grown on variety of soils under different agro-climatic conditions.

Moriculture is extensively practiced in the states of Karnataka, West Bengal, Jammu and Kashmir, Tamil Nadu and Andhra Pradesh. Among them, Karnataka is leading state in the production of mulberry silk in the country. Rearing of mulberry silkworm is also practiced to the lesser extent in the states like Maharashtra, Gujarat, Madhya Pradesh, Bihar, Orissa, Punjab, Haryana, Tripura, Nagaland and Meghalaya. In Gujarat, Jari industry has drawn attention both by farmers as well as scientists. In Surat city alone, where Jari industries are working, needs 400 to 500 tons of raw silk every year. Considering the requirements of silk, State Government took interest in sericulture and introduced mulberry plantation in 1984. Over and above, the land of South Gujarat is most suitable for mulberry cultivation. Thus, the requirements of silk for

industries coupled with suitability of mulberry cultivation played significant role in development of sericulture in Gujarat. It is well developed in districts like Navsari, Surat, Valsad, Bharuch, Vadodara, Kheda, Ahmedabad and Mehsana (Vakil, 1990). Farmers of the state realized the scope of sericulture and started shifting to sericulture from traditional cultivation of crops like sugarcane, cotton, tobacco and others.

MATERIAL AND METHODS

Studies were conducted at Sericulture Laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat.

***Culturing* B. mori :**

The disease free layings of *B. mori* was procured from Central Silk Board, Bangalore and reared in Sericulture laboratory, Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari. Eggs were kept for hatching in the laboratory at room temperature and care was taken to protect the eggs from ants. After hatching of the eggs, tender mulberry leaves as per the treatments was chopped into small pieces and sprinkled over the newly hatched young larvae, which crawled on the leaves and started feeding from cut edges. Subsequently after 30 minutes the newly hatched larvae together with mulberry food was transferred into the rearing trays with the help of brush. The bed was made in a uniform size as per space required to the larvae. The mass rearing was followed during first instars. The food, spacing and cleaning was done as per the stages of the larvae and requirements. The equal quantity of food was given every time, which was thoroughly chopped as per the requirement before feeding. Four feedings of chopped mulberry leaves was given in a day. The timing of feedings was fixed at 6.00 a.m., 11.00 a.m., 16.00 p.m. and 21.00 p.m. in a day. The size of the chopped leaves was regulated according to conditions and size of the larvae. During moulting the larvae were not provided any food and not disturbed. The quantity of food was increased as per the growth of the silkworm. After the full development, the matured larvae was identified as they ceased to eat and looked translucent with creamy colour. Such type of larvae was handpicked and kept on the mountage for spinning the cocoon. Larvae were allowed to spin the cocoon for 48-72 hours. Freshly laid eggs of *B. mori* were used throughout the study of biology.

***Biology of* B. mori *on* Morus alba :**

The study on biology of *B. mori* on *Morus alba* was carried out in the Sericulture Laboratory during March 2011, at 25 ^{0}C and 70 per cent relative humidity. A set of 50 eggs was used to study the biology of *B. mori*. Egg period was assessed as a time between date of egg laying and date of egg hatching. The colour and shape of eggs were also observed. With a view to determine the number and duration of larval instars, the newly hatched larvae were transferred and kept individually in the plastic Petridishes (110 mm) and fed with mulberry leaves. The size of eggs and each instar larva were measured under microscope with the help of ocular and stage micrometers. The total larval period was calculated from the date of egg hatching to the date of formation of pre-pupa. For the pre-pupal period, the larva was observed from the time when it stopped feeding and became sluggish when it turned to pupa. The duration between formations of pupa to the emergence of adult was considered as pupal period. After formation of cocoon, it was cut and a pupa was taken out from it. Measurement regarding weight of pupae was also recorded. The length, breadth and weight of cocoon were measured with the help of scale. Adult emergence from pupae was observed for their colour and longevity. Male and female were differentiated on the basis of shape and their abdomen. In order to determine the pre-oviposition period, the newly emerged 10 pairs adult moths of *B. mori* were kept separately on starch paper sheet covered with cellules individually. The period between the emergence of adult female and commencement of egg laying was recorded as the pre-oviposition period. Period between commencement the egg laying and ceasing of the egg laying by individual female was recorded as oviposition period and period between ceasing of egg laying to death of female was considered as post-oviposition period. Eggs laid by female were collected and counted daily in the morning (8:00 to 10:00 am). The total number of eggs laid during the life span of the adult female was considered as its fecundity. Longevity of male and female moths was calculated separately from the date of emergence to death of adults. Total life cycle was considered as the period between the date of egg laying to the death of adults.

RESULTS AND DISCUSSION

The results of the present study along with relevant discussion have been presented as below :

Biology of mulberry silkworm *(Bombyx mori)* on mulberry *(Morus alba)* :

Observations recorded on various aspects of the biology of bivoltine race PM × CSR2 of mulberry silkworm, *B. mori* is presented as detailed below. The paring and mating of sexes were observed immediately after emergence of moths, usually during morning hours. Tail to tail mating was observed in adult of *B. mori* which was confined for 6 to 12 hours. The observations made during present study are similar to those reported by Rahman *et al.* (1978) who reported the mating took place immediately after adult emergence in Nistari race of *B. mori.* Tail to tail type of mating was observed during present study which lasted for 6 to 12 hours.

Observations were recorded on pre-oviposition,

oviposition and post-oviposition periods are given in Table 1. It clearly indicated that the pre-oviposition, oviposition and post-oviposition periods in PM × CSR2 strain of *B. mori* were 0.43 ± 0.028, 2.30 ± 0.483 and 3.50 ± 0.527 days, respectively.

The results obtained during the present study are in confirmatory with those reported by Rahman *et al.* (1978) who reported 3 days oviposition period in *B. mori* race Nistari.

The eggs of *B. mori* under study were laid singly coated with gummy substance. The eggs of PM × CSR2 were ellipsoidal in shape and dull white in colour. The morphometric of eggs indicated that the eggs of PM × CSR2 were 1.18 ± 0.030 mm in length and 0.99 ± 0.042 mm in width (Table 2). The observations made during the present study are more or less similar to those as reported by Singh and Mavi (1987). They reported that the colour and shape of egg was whitish or yellowish and semi round, respectively.

Data recorded on fecundity of PM × CSR2 race of *B. mori* are presented in Table 3 and it indicated that the female of PM × CSR2 laid 269 ± 30.21 eggs during entire ovipositional period. The result is more or less similar with those reported by Rahman *et al.* (1978) who reported maximum 544 eggs and minimum 230 eggs in *B. mori* race Nistari.

Data recorded on incubation period and hatching percentage of *B. mori* are presented in Table 4 and 5. The average incubation period was 8.32 ± 1.179 days whereas the hatching percentage was 91.60 ± 5.317.

The body colour of newly hatched larva (neonate) was yellowish brown in PM × CSR2 race. No any marking was observed on larval body. However, the body wall of fifth instar larva was creamy white, cylindrical and slender. They were found to moult four times and passed through five larval instars.

Table 1 : Pre-oviposition, oviposition and post-oviposition period of *B. mori*

Sr. No.	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Female adult longevity (days)	Male adult longevity (days)
1.	0.44	2	4	6.44	5
2.	0.42	2	4	6.42	5
3	0.46	3	3	6.46	5
4.	0.43	2	4	6.43	6
5.	0.45	3	3	6.45	5
6.	0.38	2	4	6.38	6
7.	0.47	2	4	6.47	6
8.	0.46	3	3	6.46	5
9.	0.42	2	3	5.42	7
10.	0.42	2	3	5.42	6
Min.	0.38	2	3	5	5
Max.	0.47	3	4	6	7
Av. ± S.D.	0.43 ± 0.028	2.30 ± 0.483	3.50 ± 0.527	6.23 ± 0.431	5.60 ± 0.699

Table 2 : Morphometric of eggs of *B. mori*

Sr. No.	Egg length (mm)	Egg width (mm)
1.	1.13	0.96
2.	1.20	1.01
3.	1.22	0.97
4..	1.16	0.91
5.	1.19	0.95
6.	1.21	1.05
7.	1.20	1.03
8.	1.14	0.98
9.	1.16	0.99
10.	1.17	1.01
Min.	1.13	0.91
Max.	1.22	1.05
Av. ± S.D.	1.18 ± 0.030	0.99 ± 0.042

Table 3 : Fecundity of *B. mori*

Sr. No.	Fecundity in number
1.	292
2.	220
3.	288
4.	258
5.	280
6.	303
7.	269
8.	300
9.	219
10.	261
Min.	219
Max.	303
Av. ± S.D.	269 ± 30.21

Table 4 : Incubation periods of eggs of *B. mori*

Sr. No.	Incubation period (Days)	Sr. No.	Incubation period (Days)	Sr. No.	Incubation period (Days)	Sr. No.	Incubation period (Days)
1.	8	14.	10	27.	10	40.	8
2.	8	15.	7	28.	10	41.	7
3.	10	16.	7	29.	7	42.	7
4.	7	17.	8	30.	8	43.	9
5.	10	18.	9	31.	7	44.	9
6.	7	19.	8	32.	8	45.	9
7.	8	20.	8	33.	7	46.	9
8.	9	21.	9	34.	8	47.	7
9.	7	22.	9	35.	8	48.	8
10.	8	23.	11	36.	10	49.	10
11.	8	24.	8	37.	7	50.	10
12.	10	25.	7	38.	7		
13.	8	26.	7	39.	10		
		Min.				7	
		Max.				11	
		Av. ± S.D.				8.32 ± 1.179	

Table 5 : Hatching percentage of eggs of *B. mori*

Sr. No.	Number of eggs observed	Number of eggs hatched	Hatching percentage
1.	50	42	84.00
2.	50	45	90.00
3.	50	47	94.00
4.	50	50	100.00
5.	50	46	92.00
6.	50	45	90.00
7.	50	44	88.00
8.	50	50	100.00
9.	50	46	92.00
10.	50	43	86.00
Min.			84
Max.			100
Av. ± S.D.			91.60 ± 5.317

Table 6 : Duration of larval instar of *B. mori* (days)

Sr. No.	I Instar	II Instar	III Instar	IV instar	V instar	Total
1.	4	3	5	5	7	24
2.	3	4	5	5	8	25
3.	4	4	6	5	8	27
4.	3	4	4	6	7	24
5.	3	4	4	6	8	25
6.	3	3	6	6	8	26
7.	3	3	5	5	8	24
8.	4	3	3	6	7	23
9.	4	3	5	5	7	24
10.	4	3	4	5	7	23
11.	3	3	3	5	8	22
12.	4	4	3	5	8	24
13.	3	4	5	6	7	25
14.	4	3	5	6	8	26
15.	4	4	3	6	8	25
16.	4	3	5	5	7	24
17.	4	4	5	5	8	26
18.	3	4	5	5	7	24
19.	3	3	3	6	8	23
20.	3	3	3	6	8	23
21.	4	3	5	5	8	25
22.	4	3	6	6	8	27
23.	3	3	4	6	8	24
24.	4	4	4	6	8	26
25.	3	4	3	5	8	23
26.	3	4	3	5	8	23
27.	3	3	5	5	8	24
28.	3	4	3	5	8	23
29.	4	3	5	6	8	26
30.	3	3	5	6	7	24
31.	3	3	6	5	7	24
32.	3	3	6	6	8	26
33.	4	3	4	5	8	24
34.	3	3	5	5	7	23
35.	4	3	4	6	8	25
36.	4	4	6	5	8	27
37.	3	3	3	6	7	22
38.	4	3	5	6	7	25
39.	3	4	5	6	7	25
40.	3	4	4	6	7	24
41.	4	4	4	5	7	24
42.	4	4	6	5	8	27
43.	4	4	4	6	7	25
44.	4	3	3	5	8	23
45.	4	4	4	6	7	25
46.	3	4	5	6	8	26
47.	3	4	5	6	7	25
48.	3	4	6	5	7	25
49.	4	4	3	5	7	23
50.	4	3	3	5	7	22
Min.	3	3	3	5	7	22
Max.	4	4	6	6	8	27
Av. ± S.D.	3.50 ± 0.483	3.48 ± 0.422	4.42 ± 1.160	5.48 ± 0.516	7.56 ± 0.483	24.44 ± 1.509

Observations recorded on duration of first, second, third, fourth and fifth larval instar are presented in Table 6. An average larval duration in each instar was 3.50 ± 0.483, 3.48 ± 0.422, 4.42 ± 1.160, 5.48 ± 0.516 and 7.56 ± 0.483 days, respectively. Data recorded on total larval durations revealed that the average period required for completion of larval development was 24.44 ± 1.509 days (Table 6).

The result obtained during present study in accordance with those reported by Tembhare (1997), Alvarez (1993) and Singh and Mavi (1987). Tembhare (1997) reported 3-4, 2-3, 3-4, 5-6 and 7-8 days of each instar larval duration and 25-30 days total larval period. Alvarez (1993) recorded five larval instar with 4.6, 6.0, 6.06, 6.47 and 9.87 days mean duration of each instar. Singh and Mavi (1987) reported that the larval development was fast in the autumn.

Data recorded on duration of pre-pupal stage of PM × CSR2 race revealed that there was average pre-pupal period of 2.98 ± 0.89 days (Table 7).

The cocoon of the PM × CSR2 race was observed to be tough, light yellow in colour and spindle shaped with one or two layers of tough elastic protein. The morphometric of cocoon revealed that the mean weight of cocoon was 0.72 ± 0.06 g. and the length and width of cocoon was 2.702 ± 0.335 and 1.241 ± 0.040 cm, respectively (Table 8).

The results obtained during the present study are in confirmatory with those reported by Singh and Mavi (1987) who reported highest cocoon weight in February and April.

Pupation took place in silken cocoon. On cutting the outer shell of cocoon, shrinkage in pupal length and expansion of pupal width, particularly at middle of the body was noticed. The pro-legs were shriveled up and inwardly curved. The true thoracic legs as well as wing pads were developed. The pupa of PM × CSR2 race was yellowish brown in colour. Observations of weight and duration of pupa were 0.622 ± 0.052 g (Table 8) and 12.54 ± 1.22 days (Table 7).

The observations made during present study on pupal duration are more or less similar to those reported by Singh and Mavi (1987) who reported 14 days pupal period in autumn, 8 days in spring season and 10 to 12 days in general.

Observation recorded on PM × CSR2 race revealed that shell weight was 0.105 ± 0.022 g and shell ratio was 14.44 per cent (Table 9).

The male was dirty white coloured moth. Antennae were bi-pectinate. Ocelli were absent and black compound eyes were present. The female moth was dull white in colour with bi-pectinate antennae. The forewings and hind wings of both the sexes were dirty and dull white coloured, respectively. Adults were sluggish and weak fliers. The entire body and wings were covered with scales. Head was small and hypognathous. Proboscis was well developed and coiled.

Table 7 : Pre-pupal and pupal period of *B. mori*

Sr. No.	Pre-pupal period (Days)	Pupal period (Days)	Sr. No.	Pre-pupal period (Days)	Pupal period (Days)	Sr. No.	Pre-pupal period (Days)	Pupal period (Days)
1.	4	11	18.	4	13	35.	4	11
2.	2	12	19.	4	12	36.	4	11
3.	2	11	20.	4	11	37.	2	11
4.	2	11	21.	2	12	38.	2	14
5.	3	14	22.	4	14	39.	4	12
6.	2	12	23.	4	11	40.	4	14
7.	3	14	24.	3	14	41.	3	12
8.	2	13	25.	2	14	42.	4	12
9.	3	13	26.	4	14	43.	2	14
10.	2	14	27.	2	11	44.	2	14
11.	2	13	28.	4	14	45.	3	11
12.	2	12	29.	2	13	46.	3	13
13.	4	14	30.	2	13	47.	4	14
14.	4	11	31.	2	12	48.	2	13
15.	4	11	32.	2	14	49.	4	14
16.	3	13	33.	3	12	50.	4	12
17.	3	11	34.	3	11			
Min.							2	11
Max.							4	14
Av. ± S.D.							2.98 ± 0.89	12.54 ± 1.22

Table 8 : Morphometrics of cocoons of *B. mori*

Sr. No.	Cocoon			Shell weight (g)	Pupal Weight (g)
	Weight (gm)	Length (cm)	Width (cm)		
1.	0.63	2.74	1.20	0.06	0.57
2.	0.80	3.06	1.28	0.11	0.69
3.	0.65	2.46	1.21	0.08	0.57
4.	0.69	2.24	1.25	0.11	0.58
5.	0.81	2.52	1.29	0.12	0.69
6.	0.72	3.27	1.23	0.09	0.63
7.	0.76	2.33	1.25	0.13	0.63
8.	0.75	2.60	1.18	0.11	0.64
9.	0.79	2.81	1.22	0.12	0.67
10.	0.67	3.00	1.30	0.12	0.55
Min.	0.63	2.24	1.18	0.06	0.55
Max.	0.81	3.27	1.30	0.13	0.69
Av. ± S.D.	0.727 ± 0.065	2.702 ± 0.335	1.241 ± 0.040	0.105 ± 0.022	0.622 ± 0.052

Table 9 : Shell ratio percentage of *B. mori*

Sr. No.	Cocoon weight (g)	Shell weight (g)
1.	0.63	0.06
2.	0.80	0.11
3.	0.65	0.08
4.	0.69	0.11
5.	0.81	0.12
6.	0.72	0.09
7.	0.76	0.13
8.	0.75	0.11
9.	0.79	0.12
10.	0.67	0.12
Total	7.27	1.05
Mean	0.727	0.105
SR %	14.44	

Prothorax was prominent. Abdomen in female was with seven visible segments and eight visible segments were observed in male. Females were slightly bigger than males.

The life span of female was found to be relatively more than male moth. The results obtained during the present study are more or less in confirmatory with those reported by Silayach and Khokhar (1995). They reported male longevity of 5.48 to 6.98 days and female longevity of 6.50 to 7.30 days in bivoltine race of *B. mori*.

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