



The impact of environmental factors on the post-embryonic development of the tropical tasar silkworm *Antheraea mylitta* eco-race Bhandara (Lepidoptera: Saturniidae)

Deepak D Barsagade¹, Ravindra S Bahekar², Hemraj M Meshram³

¹Department of Zoology, MJF Educational Campus, RTM Nagpur University, Nagpur, Maharashtra, India

²Department of Zoology, Taywade College, Mahadula, Kamptee Rd, Koradi, Maharashtra, India

³Department of Zoology, Shri Govindrao Munghate Arts and Science College, Kurkheda, Gondwana University, Gadchiroli, Maharashtra, India

Abstract

Temperatures play a vital role in the growth and productivity of the silk worm. Increasing the temperature during late instars will accelerate larval growth and shorten the larval period. The rate of development and physiology of larvae may be influenced by high temperature. In the present study, it is found that Vidarbha forest comes under tropical conditions, and the first cycle (June to August) of Tasar silkworm is more affected. The average mortality of *Antheraea mylitta* larvae due to fluctuation in temperature and humidity was higher, i.e., 30%, in the first cycle than in the second and third cycles. The environmental role can be explained by cocoons with high shell and silk yield observed during seed crop (July/August) and thick shell and high silk during commercial crop (September/December) seasons.

Keywords: *Antheraea mylitta* (D), temperatures, humidity, silk

Introduction

The impact of environmental factors such as biotic and abiotic factors is vital to the success of the sericulture industry. Among the abiotic factors, temperature, humidity, and rainfall play a major role in the growth and productivity of the silkworm, as it is a poikilothermic (cold-blooded) insect (Ullal *et al.*, 1978) [37]. Temperature has a direct influence on many life history parameters and profound effects on insect life history processes such as changes in life-cycle duration (rate of development), voltinism, population density, size, and genetic composition (Bale *et al.*, 2002; Battisti *et al.*, 2005; Tobin *et al.*, 2008; Faccoli, 2009) [1, 2, 8, 34].

The climatic conditions in Maharashtra are semi-dry and temperature range from 10°C to 47°C, along with annual rainfall is from 700 mm to 1000 mm (Patil *et al.*, 2009) [24]. The Vidarbha region is the most prominent area of tropical tasar silk production (Jolly *et al.*, 1979) [12].

Temperature and humidity are key environmental factors that influence the physiology of insects. The Tasar silkworm, *Antheraea mylitta* (D), is polyphagous and trivoltine in nature, depending on the availability of food plants and environmental conditions (Mathur *et al.*, 2000). During the rearing and spinning, the quality and quantity of the cocoons depend on the ideal environmental conditions, ranging from 25°C - 30°C and a humidity of 65 to 85%. Temperature, humidity, and rainfall factors greatly influence the growth and development of silkworms and, consequently, cocoon weight, pupal weight, shell weight, silk percentage, potential fecundity, and reliability of the silk (Thangavelu *et al.*, 1986; Ullal *et al.*, 1978; and Yadav *et al.*, 1991) [33, 37, 39]. In the Saturniidae, the effect of photoperiod and temperature on the development of pupae has been extensively studied. *Bombyx mori* silkworms provided with better rearing conditions, environment, and nutrition during the larval period may have higher fecundity

(Miller, 2005; Malik and Reddy, 2008; Bhatia & Mohammad, 2014) [18, 19, 23, 29].

For the present study, the effect of environmental factors such as temperatures, humidity, and rainfall on the post-embryonic developmental stages from the first to the last instar larvae of *A. mylitta* was examined using the statistical method. The length, width, weight, instar duration, and mortality after the effect of environmental factors on the life stages of *A. mylitta* were examined. After cocoon formation, the length, width, and weight of the cocoon and pupa were calculated. Adults emerged from cocoons, and the percentage of emergences, mating, egg laying, and hatching was calculated with the help of statistical methods.

Materials and Methods

The naturally grown cocoons of *A. mylitta* eco-race Bhandara were collected from the forest of Chandrapur district and brought to the insectaria of the Department of Zoology, RTM Nagpur University, Nagpur. The cocoons were stored, which were used for the first grainage in 2018, and temperature and humidity were controlled. After hatching, the adult moths were allowed to mate. The mother moths were sent for pathogen detection, and selected DFLs were kept for hatching. With proper care, DFLs were produced.

The newly hatched, tiny larvae from 15 DFLs 240 healthy larvae were selected and reared on tender leaves of the primary food plants for experimental study in the natural rearing field of Gadchiroli district with the help of tribal rearers. The rearing was conducted for three successive generations (crop) in the years 2019–2021. The study recorded daily environmental parameters such as air temperature, which was measured with a maximum and minimum thermometer, humidity with a hygrometer, and rainfall with a rain gauge. The study was made during all three generations

To study the primary effects of temperature, relative humidity, and rainfall on the post-embryonic development of the tasar silkworm, the numbers of dead larvae without diseases were noted down and larval mortality correlated accordingly. The average weight, length, and width of 50 naturally reared larvae were measured. Similarly, cocoon formation, weight, length of pupa, and cocoon shell weight of 50 cocoons were taken after completion of pupation, as well as the percentage of adult emergence, matting, egg laying, and hatching, using statistical methods. The meteorological data were

Regularly collected data from experimental rearing fields in all three generations were analysed statistically.

Observation

During the present study, the effects of temperature, relative humidity, and rainfall on the post-embryonic development of *Antheraea mylitta* were studied during three successive generations within the same year, from 2019 to 2021. The mean value of the rate of development, i.e., length, width, weight, and duration of larvae, the rate of mortality at different instars, and the percentage of total emergences of adults, matting, fecundity (no.), and hatching of eggs were recorded in three successive generations of the year.

The mean values of the data obtained from rearing crop I (June to August), crop II (September to October), and crop III (November to January) during the years 2019, 2020, and 2021 recorded and observed are presented in Tables 1 to 5.

Table 1: The effect of environmental factors on morphometry and mortality of I instar larvae

Crops	Year	Temp. (°C)	Humidity (%)	Rain fall (mm)	Length (cm)	Weight (gm)	Instar duration (days)	Mortality (%) due to temp.	Mortality (%) due to rain fall
Crop I	2019	35.5±0.3	87.2±0.2	296±0.8	0.69±0.2	0.051±0.07	3.8±0.2	12.7±0.6	6.32±0.4
	2020	37.7±0.3	87±0.3	318±0.7	0.67±0.2	0.05±0.03	3.66±0.2	17.26±0.7	7.28±0.4
	2021	38.4±0.2	85.6±0.2	361±0.9	0.66±0.2	0.049±0.03	3.1±0.3	21.78±0.8	9.2±0.7
Crop II	2019	31.8±0.2	79±0.5	189±0.7	0.81±0.4	0.054±0.09	4.01±0.3	8.9±0.4	7.2±0.4
	2020	33.9±0.1	85±0.4	193±0.8	0.74±0.2	0.052±0.08	4.1±0.5	10.5±0.4	3.5±0.2
	2021	33.4±0.3	90.8±0.6	195±0.6	0.72±0.2	0.051±0.07	4.2±0.4	14.6±0.4	4.02±0.2
Crop III	2019	21.2±0.3	77.2±0.6	39±0.5	0.83±0.2	0.057±0.03	4.4±0.6	3.1±0.4	0.9±0.2
	2020	19.6±0.1	77.8±0.5	49.6±0.6	0.82±0.02	0.056±0.06	4.6±0.6	4.9±0.4	1.41±0.1
	2021	17.4±0.4	80.6±0.4	46.8±0.8	0.76±0.07	0.055±0.06	4.8±0.7	6.7±0.3	2.18±0.1

Table 2: The effect of environmental factors on morphometry and mortality of III instar larvae

Crops	Year	Temp. (°C)	Humidity (%)	Rain fall (mm)	Length (cm)	Weight (gm)	Instar duration (days)	Mortality (%) due to temp.	Mortality (%) due to rain fall
Crop I	2019	35.5±0.3	87.2±0.2	296±0.8	4.0±0.3	1.41±0.2	3.7±0.2	2.3±0.1	4.5±0.7
	2020	37.7±0.3	87±0.3	318±0.7	3.92±0.5	1.29±0.1	3.6±0.2	2.7±0.4	4.9±0.3
	2021	38.4±0.2	85.6±0.2	361.6±0.9	3.88±0.5	1.20±0.1	3.5±0.2	3.62±0.3	5.86±0.4
Crop II	2019	31.8±0.2	79±0.5	189±0.7	4.1±0.5	1.5±0.3	3.9±0.5	2.18±0.1	4.9±0.3
	2020	33.9±0.1	85±0.4	193±0.8	3.96±0.6	1.34±0.2	3.8±0.6	2.72±0.1	2.8±0.1
	2021	33.4±0.3	90.8±0.6	195.8±0.6	3.90±0.5	1.28±0.3	3.7±0.4	2.88±0.2	4.7±0.1
Crop III	2019	21.2±0.3	77.2±0.6	39±0.5	4.4±0.6	1.36±0.6	4.08±0.6	1.94±0.1	0.86±0.1
	2020	19.6±0.1	77.8±0.5	49.60±0.6	4.2±0.1	1.35±0.5	4.2±0.4	2.18±0.1	1.38±0.1
	2021	17.4±0.4	80.6±0.4	46.80±0.8	4.04±0.08	1.28±0.4	4.3±0.6	2.2±0.1	1.8±0.18

Table 3: The effect of environmental factors on morphometry and mortality of V instar larvae

Crops	Year	Temp. (°C)	Humidity (%)	Rain fall (mm)	Length (cm)	Weight (gm)	Instar duration (days)	Mortality (%) due to temp.	Mortality (%) due to rain fall
Crop I	2019	35.5±0.3	87.2±0.2	296±0.8	11.5±0.6	25.01±0.8	12.69±0.6	1.9±0.09	3.1±0.2
	2020	37.7±0.3	87±0.3	318±0.7	11±0.5	24.28±0.6	11.98±0.5	2.5±0.2	3.14±0.3
	2021	38.4±0.2	85.6±0.2	361.6±0.9	10.9±0.7	23.01±0.7	11.48±0.5	2.9±0.1	4.1±0.3
Crop II	2019	31.8±0.2	79±0.5	189±0.7	12.5±0.7	27.2±0.5	14.1±0.6	1.7±0.1	3.1±0.2
	2020	33.9±0.1	85±0.4	193±0.8	11.9±0.6	26.8±0.8	13.4±0.4	2.01±0.1	2.30±0.1
	2021	33.4±0.3	90.8±0.6	195.8±0.6	11.1±0.5	25.04±0.6	12.86±0.6	2.08±0.1	2.6±0.1
Crop III	2019	21.2±0.3	77.2±0.6	39±0.5	13.1±0.3	28.13±0.7	14.8±0.5	1.28±0.1	1.38±0.1
	2020	19.6±0.1	77.8±0.5	49.60±0.6	12.9±0.4	27.88±0.7	15.96±0.7	1.6±0.09	1.86±0.1
	2021	17.4±0.4	80.6±0.4	46.80±0.8	12.1±0.4	26.36±0.5	16.5±0.6	1.92±0.1	1.9±0.1

Table 4: The effect of environmental factors on cocoon characters and percentage of shell ratio

Crops	Year	Temperature (°C)	Humidity (%)	Rain fall (mm)	Cocoons		Shell weight (gm)	Shell ratio (%)	Duration of pupa (days)
					Length (cm)	Weight (gm)			
Crop I	2019	35.5±0.3	87.2±0.2	296±0.8	4.2±0.2	8.5±0.2	1.5±0.2	17.64±0.2	28±0.3
	2020	37.7±0.3	87±0.3	318±0.7	4.19±0.3	7.3±0.3	1.5±0.3	20.54±0.3	29.5±0.4
	2021	38.4±0.2	85.6±0.2	361.6±0.9	4.1±0.4	7.05±0.4	1.3±0.2	18.43±0.6	32±0.6
Crop II	2019	31.8±0.2	79±0.5	189±0.7	4.3±0.4	8.83±0.3	1.7±0.1	19.25±0.3	32±0.5
	2020	33.9±0.1	85±0.4	193±0.8	4.2±0.3	8.78±0.3	1.68±0.2	19.13±0.4	34±0.6
	2021	33.4±0.3	90.8±0.6	195.8±0.6	4.2±0.4	8.5±0.2	1.65±0.1	19.41±0.2	37±0.7
Crop III	2019	21.2±0.3	77.2±0.6	39±0.5	4.4±0.5	9.2±0.4	1.82±0.3	19.78±0.4	151±0.8
	2020	19.6±0.1	77.8±0.5	49.60±0.6	4.4±0.3	9.09±0.4	1.73±0.3	19.03±0.4	157±0.8
	2021	17.4±0.4	80.6±0.4	46.80±0.8	4.3±0.4	8.9±0.6	1.7±0.4	19.1±0.3	159±0.7

Table 5: The effect of environmental factors on matting of adult moth, egg laying and hatching percentage

Crops	Year	Temp. (°C)	Humidity (%)	Rain fall (mm)	Emergence (%)	Matting (%)	Fecundity (no.)	Hatching (%)
Crop I	2019	35.5±0.3	87.2±0.2	296±0.8	61.6±0.3	37.6±0.4	158±0.3	49.5±0.5
	2020	37.7±0.3	87±0.3	318±0.7	57.7±0.5	32.1±0.3	147±0.4	41.7±0.5
	2021	38.4±0.2	85.6±0.2	361.6±0.9	55.75±0.7	29.0±0.3	141±0.6	34.2±0.6
Crop II	2019	31.8±0.2	79±0.5	189±0.7	69.1±0.5	43.6±0.5	180±0.6	62.9±0.6
	2020	33.9±0.1	85±0.4	193±0.8	67.9±0.4	40.8±0.6	167±0.5	55.0±0.4
	2021	33.4±0.3	90.8±0.6	195.8±0.6	62.03±0.5	38.06±0.2	154±0.3	50.03±0.3
Crop III	2019	21.2±0.3	77.2±0.6	39±0.5	53.2±0.4	34.2±0.4	142±0.6	32.6±0.5
	2020	19.6±0.1	77.8±0.5	49.60±0.6	49±0.6	30.1±0.5	137±0.5	29.6±0.8
	2021	17.4±0.4	80.6±0.4	46.80±0.8	46.8±0.6	24.5±0.2	125±0.6	26.9±0.6

Discussion

Temperatures play a significant role in the development and productivity of the silk worm (Ueda *et al.*, 1975; Benchamin and Jolly, 1986) [3, 36]. At high temperatures, early instar larvae are resistant, which helps improve survival and cocoon production. (Ullal *et al.*, 1978; Rahmathulla, 2012) [25]. Temperature has a direct impact on the growth of silkworms, with an increase in temperature during the late instar accelerating larval growth and shortening the larval period, while at low temperatures the larval period is prolonged. (Willmer *et al.*, 2004; Reddy *et al.*, 2002; Mishra *et al.*, 2002; Morohoshi, 1969; Kamili and Masoodi, 2004; Rahmathulla, 2012) [13, 20, 21, 27, 38]. High temperatures can affect the rate of development and physiology of larvae, leading to reduced egg yield, increased mortality, and increased disease incidence due to the production of apyrene sperm. (Kovalve, 1970; Hussain *et al.*, 2011; Das *et al.*, 1996; Biram *et al.*, 2009) [4, 6, 10, 14].

In the present study, it has been observed that *A. mylitta* (Drury) is a polyphagous tasar silkworm that mainly feeds on the primary host plants *Terminalia tomentosa* and *Terminalia arjuna* in Vidarbha forest and successfully completes three life cycles, starting from June to the end of January. The first life cycle is completed during June to the middle of August, the second generation during late August to mid-October, and the third generation during early November to the end of January.

During three life cycles, due to change in temperature, relative humidity and rainfall, the variation in the mortality from I to V instar larvae has been noted indicating the impact of physical factors *viz.*, temperature, humidity, and rainfall, on the biology and voltinism of silkworm *A. mylitta* and supporting earlier workers (Nitu Kumari and Roy, 2011) [22]. According to Nitu Kumari and Roy (2011) [22] voltinism manipulations can increase silk productivity due to physical factors, such as high temperatures and low humidity, which are characteristics of tropical climatic conditions. (Ueda and Lizuka, 1962; Shirota, 1992; and Tazima and Ohuma, 1995) [30, 32, 35].

In the present study, it is found that Vidarbha forest comes under tropical conditions, and the first cycle (June to August) of the tasar silkworm is affected more. The mortality percentage of larvae increases due to physical factors and affects commercial characters like cocoon weight, larval period, and silk ratio, as found in earlier observations (Nitu Kumari and Roy, 2011; Srivastava *et al.*, 2004; Shirota, 1992; Kumar *et al.*, 1999, 2000, 2001) [15, 16, 17, 22, 30, 31].

It should also be noted that the high rainfall during the first two crops and the low rainfall during the third crop contributed to evident changes in the dietary content of the leaves and resulted in differences in morphometric and behavioural characters.

Gowada and Reddy (2007) [9] found that high temperature and high relative humidity were more detrimental to the rearing and spinning of silkworm larvae of *Bombyx mori* than other temperature and relative humidity treatments. This study found that the average mortality of larvae due to fluctuations in temperature and humidity was higher in the first cycle than in the second and third cycles, indicating the influence of temperature on the post-embryonic developmental stages of *A. mylitta*.

Similarly, rainfall also increased the average mortality of larvae in the first cycle up to 24%, which is higher than the second cycle (13%), and the third cycle (6.3%), respectively. This is because high rainfall up to 300 mm in the Vidarbha region causes adverse effects on the survival of larval stages of *A. mylitta*.

The variation in climate, nutrient status, feeding duration, and larval crowd can affect the body size of an insect as well as the expression of parental combinations (Davidowitz *et al.*, 2004; Miller, 2005; Reddy *et al.*, 2009; Chandrasekhar and Basavaraja, 2008) [5, 7, 28].

In the present study, it has been noted that the third cycle was a commercial crop carried out from November to January. When the temperature was at its minimum with 80% relative humidity and negligible rainfall, the pupal weight, shell weight, and silk ratio were higher in the third cycle as compared to the first and second cycles, showing the influence of temperature on silk quality.

According to Rathod *et al.* (2010) [26], the fluctuation in environmental conditions like temperature, humidity, and rainfall caused larval mortality due to outbreaks of diseases and affected the rearing of *A. mylitta*.

Hussain *et al.* (2011) [11] Temperature and humidity have a significant effect on the fertility and fecundity of silk moths, with decreased eggs laid when exposed to increased temperatures and low humidity.

In the present study, it is noted that when the temperature was 17-21 °C with 77-80% relative humidity and minimum rainfall, the pupal duration was high, and as the temperature increased gradually, the pupa underwent diapause over the summer season. During the first two crops, when the temperature ranged from 31-38 °C with 80-90% relative humidity and rainfall of about 190-360 mm, the pupal duration was about 24-30 days, with higher emergences and maximum hatching in these two cycles. The fecundity also ranges from 140 to 180, with 50-60% hatching. Therefore, the second and third cycles, which are completed between mid-August and the end of January, give the best results in correlation with cocoon weight and a high silk ratio. The temperature, humidity, and rainfall are favourable during the second and third crops for the tasar silkworm rearing in the Vidarbha region.

Conclusion

The present study concludes that the rate of larval growth and other physical developmental parameters associated with cocoon crop performance of the first crop are quite low as compared to the second and third crops, but as compared to the first and second crops, the third crop shows the highest intensification; therefore, environmental abiotic factors such as temperature, humidity, and rainfall play a major role in the growth and productivity of silk.

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