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REPRODUCTIVE CHARACTERISTICS OF MODAL ECORACE OF WILD TASAR SILKMOTH, *ANTHERAEA PAPHIA* LINN. IN DIFFERENT ALTITUDES OF SIMILIPAL BIOSPHERE RESERVE, ORISSA, INDIA

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ABSTRACT
The life cycle of Modal ecorace of wild tasar silkmoth, *Antheraea paphia* Linn. is trivoltine (TV), bivoltine (BV) and univoltine (UV) in lower, middle and higher altitude respectively in Similipal Biosphere Reserve. The life span in each stage (egg, larva, pupa, moth and diapause period) of life history of Modal ecorace increases irrespective of rearing season from lower altitude to higher altitude (i.e., from TV to UV form). The factors of reproductive efficiency (multiplication efficiency) such as percentage of pupal survivability, coupling, fecundity and hatching of eggs of this ecorace increase with an increase in altitude and from TV to UV form whereas the reverse trend is observed in the pupal mortality and juvenile mortality. The productive efficiency and commercial traits such as effective rate of rearing, cocoon weight, pupal weight, shell weight, shell ratio and total shell production of Modal ecorace are noticeably increased with increase in altitude in each crop season and from TV to UV type. The wide geographical condition with varying climatological parameters of Similipal Biosphere Reserve regulates the voltinism, the reproductive biology and economic traits and finally influences the population structure of the Modal ecorace of *Antheraea paphia*.

INTRODUCTION

Orissa is the third largest tasar producing State of India. India has about fortyfour ecoraces of *Antheraea* species out of which the State of Orissa has five ecoraces, viz. Modal and Nalia under *Antheraea paphia* Linn. (wild varieties) whereas Daba and Sukinda under *Antheraea mylitta* Drury (semi-domesticated varieties). Depending upon brood frequency (number of generations produced in a year) the silkmoth may be univoltine (UV), bivoltine (BV), trivoltine (TV) or multivoltine (Morohoshi, 1957). Generally Daba and Nalia ecoraces are bivoltine whereas Sukinda ecorace is trivoltine in nature. Though Modal ecorace is univoltine but depending upon the altitude of occurrence the life cycle are UV, BV and TV with respect to higher, middle and lower attitude (Nayak *et al*., 1993).

A lot of work has been worked out on different aspects of reproductive characters of *A. mylitta* (Dash and Nayak, 1990; Mishra *et al.,* 1993; Ojha *et al.,* 1994, 1999; Khan *et al*., 2000 and Narain *et al.,* 2003) as ecoraces of above species are semi-domesticated and mostly used in commercial rearing. But very few works on reproduction of wild tasar silkmoth, *A. paphia* are studied (Nayak *et al.,* 1993 and Dash *et al.,* 1994). Usually, the study of reproductive characters on any commercial rearing animal is important from management point of view, because the climatic factors of the environment influence the chance of survival and multiplying of the tasar silkmoth. The life history, reproductive efficiency (multiplication efficiency) and the productive efficiency (commercial traits) of wild tasar silkmoth, *A. paphia* specially on Modal ecorace are not studied those are used as seed cocoons in tasar rearing.

Further, the tribal tasar rearers in and around Similipal Biosphere Reserve, Mayurbhanj, Orissa mainly depend on the wild Modal cocoons for tasar cultivation. So, the objective of this work is to suggest the tribal rearers that which seasons are the best for better yield of crop in different attitudes. Also, it is important to abstain the rearers from rearing practice in natural rearing fields of SBR in those seasons which will damage the host plants in comparison to crop yield. Therefore, attempt has been made to study the reproductive performance of Modal ecorace of *A. paphia* in different crop seasons and at different altitudes in Similipal Biosphere Reserve (SBR).

MATERIALS AND METHODS

The study was conducted in Similipal Biosphere Reserve, Mayurbhanj, Orissa. The land is undulating and filled with valley forest, plain forest and hilly forest. The altitude varies from 50 to 1,150 m ASL (Above Sea Level). The ecosystem and the climatological parameters vary in an altitudinal gradient. As the Modal ecorace shows trivoltine (TV) in lower altitude (100 - 200 m ASL), bivoltine (BV) in middle altitude (500 - 600 m ASL) and univoltine (UV) in higher altitude (700 - 800 m ASL) our study was taken at these three altitudinal ranges. *A. paphia* was reared at different altitudes and in

different rearing seasons on Asan plant (*Terminalia alata*). Package of practices for tasar rearing were followed as per Jolly *et al*. (1979) and Nayak (1988). The performance of Modal ecorace of *A. paphia* in terms of reproductive efficiency such as percentage of pupal survivability, coupling, fecundity, hatching of eggs etc. and the productive efficiency such as effective rate of rearing (ERR), cocoon weight, pupal weight, shell weight, shell ratio, total shell production etc. were assessed following standard procedures. Temperature, humidity, rainfall, duration of sunshine hours per month (photoperiod) was observed daily at the different locations. From five years (1998-2002) of observation season-wise values of the above parameters were calculated.

RESULTS

Reproductive efficiency of Modal ecorace of *Antheraea paphia* at different altitudes

The reproductive or multiplication efficiency such as percentage of diapause recovery (pupal survivability), pupal mortality (diapause loss), coupling, fecundity, hatching of eggs and juvenile mortality of Modal ecorace of wild tasar silkmoth, *Antheraea paphia* with respect to voltinism and season are presented in Table 1.

The percentage of pupal survivability of Modal ecorace is increased from lower altitude to higher altitude, *i.e.,* from TV to UV. Moreover, it is the highest in autumn season in comparison to rainy both in TV and BV forms. The reverse trend is observed in pupal mortality of this ecorace of *A. paphia*. With respect to altitude the percentage of coupling of moths increased from lower to higher altitude in all crop seasons. The coupling percentage is the highest in autumn season both in TV and BV forms in comparison to other crops in the same altitude.

In rainy season the fecundity is increased from lower altitude to higher altitude and is highest in higher altitude. It is also increased in a seasonal gradient from rainy through winter both in TV and BV types. The percentage of hatching of eggs and net reproductive rate show same pattern as that of fecundity with respect to altitudes and seasons. The reverse trend of the result is observed in case of juvenile mortality. Generally the juvenile mortality is decreased from lower altitude to higher attitude (*i.e.,* from TV to UV form).

Life history of Modal ecorace of *Antheraea paphia* at different altitudes

The life history of Modal ecorace of wild tasar silkmoth such as life span of egg, larva, pupa and moth, and diapause period with respect to voltinism and rearing seasons are presented in Table 2. With regard to different altitudes the life span of egg increased in a rearing season from lower altitude to higher altitude. Moreover, the life span of egg is increased from TV to UV forms and also within seasons in the particular altitude. The larval life span, pupal life span, moth life span and diapause period show almost same pattern as that of life span of egg both in altitudinal and seasonal gradients.

Productive efficiency of Modal ecorace of *Antheraea paphia* at different altitudes

The tasar silkmoth of *Antheraea paphia* belonging to Modal ecorace produced three crops in lower altitude, *i.e.*, in rainy, autumn and winter seasons where the species shows trivoltinism. This ecorace produces two crops in middle altitude, *i.e.,* in rainy and autumn where it shows bivoltinism and produces one crop in higher altitude in rainy season due to its univoltine nature. Regardless to any season it has been observed that the overall productive efficiency of wild tasar silkmoth increased from lower altitude to higher altitude (Table 3).

The weight of the cocoon, shell ratio and total shell production increased from lower altitude to higher altitude and from TV

Table 1: Reproductive efficiency of Modal ecorace of wild tasar silk moth, *Antheraea paphia* reared during different seasons at different altitudes in SBR

Sl. No.	Study sites (Altitude)	Rearing season	Emergence (%)	Pupalmortality(%)	Coupling(%)	Fecundity (No. of eggs/ female)	Hatching (%)	Juvenile mortality (%)	Net reproduc -tive rate
1	100 - 200 m ASL	Rainy	65.45(0.91)	34.55(1.25)	64.70(2.85)	209.36(3.19)	74.65(2.32)	25.35(2.35)	52.08
		Autumn	91.54(1.94)	8.46(0.92)	74.35(2.32)	225.54(4.62)	82.40(1.95)	17.60(1.90)	52.44
		Winter	72.50(3.25)	27.50(2.05)	71.31(2.32)	240.30(6.00)	84.80(2.40)	15.20(1.72)	84.41
2	500 - 600 m ASL	Rainy	80.28(2.25)	19.72(1.92)	82.80(1.72)	290.70(2.85)	88.10(2.20)	11.90(0.85)	100.33
		Autumn	90.70(2.38)	9.30(0.95)	91.30(1.75)	322.20(4.15)	90.25(1.63)	9.75(0.80)	108.60
3	700 - 800 m ASL	Rainy	85.25(3.56)	14.75(1.35)	88.00(3.27)	346.60(6.25)	89.80(1.52)	10.20(1.22)	142.27

Figures in parentheses are ± SD values

Table 2: Life history of Modal ecorace of wild tasar silk moth, *Antheraea paphia* at different altitudes in SBR with respect to rearing seasons

Sl. No.	Study sites (Altitude)	Type of voltinism	Rearing season	Life span of egg(day)	Life span of larva(day)	Life span of pupa(day)	Life span of moth(day)	Diapause period(day)
1	100 - 200 m ASL	Trivoltine	Rainy	8.05(0.96)	24.60(1.86)	16.30(4.22)	12.30(2.10)	24.73(5.00)
			Autumn	8.75(1.00)	26.00(2.00)	18.60(4.11)	13.44(3.15)	28.19(8.00)
			Winter	10.80(1.05)	44.00(3.00)	160.40(7.89)	16.20(3.86)	172.43(10.00)
2	500 – 600 m ASL	Bivoltine	Rainy	8.65(0.98)	32.74(1.96)	20.46(4.25)	13.18(3.00)	39.34(5.30)
			Autumn	10.68(1.12)	50.68(3.26)	210.61(8.30)	15.12(3.50)	235.47(7.50)
3	700 – 800 m ASL	Univoltine	Rainy	10.72(1.25)	52.23(3.45)	267.38(8.75)	15.92(3.52)	291.49(8.85)

Figures in parentheses are ± SD values

to UV type. Similarly, with respect to each season or each crop the above commercial traits increased from TV to UV form. With regard to altitude the percentage of ERR increased from lower altitude to higher altitude and from TV to UV. With respect to season the ERR% is higher in rainy season than the autumn in TV form but the reverse trend is found in BV form. This value is highest in winter crop of TV type. The same trend is found in weights of pupa and shell as that of cocoon weight in an altitudinal gradient within different crop seasons. The productive efficiency and biometry such as ERR %, cocoon weight, pupal weight, shell weight, shell ratio and total shell production of Modal ecorace are increased from lower altitude to higher altitude in each crop season and from TV to UV type (Table 3). Thus it is clear that the commercial traits of cocoons increase with increase of altitude at SBR.

DISCUSSION

Impact of environmental factors on reproductive efficiency of Modal ecorace of *Antheraea paphia*

The climatological parameters (environmental factors) such as temperature, relative humidity (RH) and photoperiod are presented in Table 4. It is seen that in lower altitude, the mean values of temperature, RH and photoperiod in rainy season stand in the order of 29.88ºC, 89.00% and 150.80 hrs/month. These values are found to be higher compared to their corresponding values of 25.25ºC, 85.50% and 76.35 hrs/ month in higher altitude. The same pattern is observed both in autumn and winter seasons. In middle altitude the mean values of temperature, RH and photoperiod are lower than the values at lower altitude.

It is also found that the mean value of temperature has decreased from 29.88ºC in rainy season to 28.40ºC in autumn and further to 21.01ºC in winter in lower altitude. The same pattern is observed both in middle and higher altitudes. In contrast to this, photoperiod is found to have increased from 150.80 hrs/month in rainy season to 160.05 hrs/month in autumn and further to 278.50 hrs/month in winter in lower altitude. The same pattern is observed both in middle and higher altitudes.

The fecundity and hatching percentages of Modal ecorace (Table 1) show increasing trend both in altitudinal (lower to higher) and seasonal (rainy through winter) gradients. Since temperature and, fecundity and hatching show the reverse trend across altitudinal and seasonal gradients there is indirect relationship between temperature on one hand and fecundity and hatching on the other. In other words, with a decrease in temperature fecundity and hatching increase or vice versa.

It is observed that fecundity and hatching increase with a decrease in photoperiod with respect to altitude whereas they increase with an increase in photoperiod with respect to season. Thus, fecundity and hatching are directly related to photoperiod across season and indirectly related to photoperiod across altitude. This is corroborated by the findings of Benchamin *et al.,* (1990) that photoperiod has influence on emergence, fecundity and fertility of mulberry silkmoth, *B. mori*.

Table 3: Productive efficiency of Modal ecorace of wild tasar silk moth, *Antheraea paphia* reared on Asan (*T. alata*) food plant in different seasons at different altitudes in SBR

Sl. No.	Study sites (Altitude)	Rearing season	ERR (%)	Cocoon weight (g)	Pupal weight (g)	Shell weight (g)	Shell ratio (%)	Total shell production (g)
1	100 - 200 m ASL	Rainy	38.46(1.82)	7.68(0.42)	6.30(0.58)	1.14(0.12)	14.60(1.20)	45.35(5.34)
		Autumn	31.68(2.15)	8.40(0.32)	7.10(0.25)	1.25(0.12)	15.40(0.60)	41.52(5.36)
		Winter	54.32(3.96)	8.86(1.00)	7.20(0.81)	1.72(0.20)	19.36(1.32)	95.46(9.64)
2	500 – 600 m ASL	Rainy	47.58(4.35)	11.34(1.02)	9.68(0.62)	1.75(0.21)	15.12(0.75)	83.12(9.10)
		Autumn	54.30(5.35)	12.75(0.12)	10.20(0.65)	2.46(0.25)	20.08(1.10)	141.60(10.25)
3	700 - 800 m ASL	Rainy	53.81(4.76)	15.00(0.15)	12.05(0.20)	2.95(0.25)	19.70(1.05)	161.60(10.30)

Figures in parentheses are ± SD values

Table 4: Mean value of environmental parameters at different altitudes in different rearing seasons of Modal ecorace of wild tasar silk moth, *Antheraea paphia* in SBR

Parameters	Altitude(m ASL)		Rainy(July – Aug.)	Autumn (Sept. – Oct.)	Winter(Nov.-Dec.)
Maximum temperature(^{0}C)	100-200	(Lower altitude)	36.50 (1.10)	34.55 (1.10)	27.20 (1.50)
	500-600	(Middle altitude)	33.60 (1.00)	30.70 (0.20)	25.05 (1.55)
	700-800	(Higher altitude)	31.35 (1.55)	28.50 (0.20)	22.60 (0.16)
Minimum temperature(^{0}C)	100-200	(Lower altitude)	23.25 (0.45)	22.25 (0.25)	15.00 (0.70)
	500-600	(Middle altitude)	20.85 (0.15)	20.46 (0.05)	12.80 (1.10)
	700-800	(Higher altitude)	19.15 (0.45)	18.35 (0.15)	10.45 (0.95)
Average temperature(^{0}C)	100-200	(Lower altitude)	29.88 (0.75)	28.40 (0.30)	21.10 (1.10)
	500-600	(Middle altitude)	27.23 (0.55)	25.57 (1.00)	18.93 (0.15)
	700-800	(Higher altitude)	25.25 (1.00)	23.43 (0.15)	16.53 (0.95)
Relative humidity(%)	100-200	(Lower altitude)	89.00 (3.20)	92.25 (1.15)	85.60 (1.70)
	500-600	(Middle altitude)	80.45 (0.45)	84.50 (2.10)	69.35 (1.15)
	700-800	(Higher altitude)	85.50 (4.20)	86.75 (0.35)	73.15 (3.05)
Duration of sunshine (photoperiod) (hrs/month)	100-200	(Lower altitude)	150.80 (28.40)	160.05 (12.25)	278.50 (10.85)
	500-600	(Middle altitude)	93.55 (8.15)	118.70 (6.70)	236.70 (5.40)
	700-800	(Higher altitude)	76.35 (11.95)	99.95 (2.65)	193.60 (5.20)

Figures in parentheses are ± SD values

The emergence of moth in rainy season occurs with the onset of monsoon and is influenced by rain. Before experiencing first monsoon, the pupa of this ecorace has to pass through a prolonged period of diapause under influence of extreme climatic conditions of winter and summer. Therefore, at the onset of monsoon, it is likely that the animal is unable to adjust itself to the changing environmental conditions. This may be the cause behind observed lower emergence and coupling in rainy season in comparison to other seasons (Table 1). The other possibility is that there may exist a "switch off" (during diapause period) and "switch on" (for emergence) mechanism of genes which are under the direct influence of environmental factors. But this needs further investigation which is beyond the scope of the present study. On the contrary these are highest during autumn season, since the diapause period is very short and there is an urge to enter into next generation by the pupa. Further, comparatively cold climate, medium duration of photoperiod and high humidity are found in autumn season. It is observed that the above reproductive parameters are lower in winter season than autumn because in winter the photoperiod is high but the temperature is very cool. So the wild tasar silkmoth unable to get sufficient heat energy for effective emergence and coupling as this insect is poikilotherm in nature.

The fecundity and percentage of hatching of eggs are increased in each crop season at an altitudinal gradient and progressive crop seasons of each altitude. The lowest percentage of reproductive efficiency during rainy season is attributed in all the altitudes due to prevalence of higher temperature. All aspects of the reproductive parameters of this wild tasar silkmoth increase with increase of altitude and occurrence of cooler season and vice versa.

From the above analysis it is obvious that the cooler climatic condition prevailed in higher altitude during rainy season and in middle altitude during autumn season is conducive for higher reproductive efficiency in comparison to the silkmoth at lower altitude where the environmental temperature is higher. Moreover, the reproductive efficiency increases with decreasing voltinism of the wild tasar silkmoth at the higher altitude and by which vigour of the species appeared to be restored. Again diapause with lower metabolism and energy save with check of multigeneration.

Impact of environmental factors on life history of Modal ecorace of *Antheraea paphia*

It is observed that a change in season and a change in altitude have a great influence on the life history and reproductive capability of the wild tasar silkmoth *A. paphia*. At higher altitudinal zones the life cycle of Modal ecorace of *A. paphia* begin with onset of rain and completed in that season. But further generation of Modal is possible in autumn season in lower altitude and middle altitude. A third generation in winter season is found only in the lower altitude. Thus the life cycle of wild silkmoth is TV in lower altitude, BV in middle altitude and UV in higher altitude. This result showed us that the eco-climatic conditions prevailed at 700 - 800 m ASL, 500-600 m ASL and at 100-200 m ASL (Table 4) are conducive for UV, BV and TV form, respectively. Hence, the voltinism of Modal ecorace of wild tasar silkmoth changes with changing eco-climatic conditions prevailed in an altitudinal gradient. In the present study it indicates that the life cycle of TV form of *A. paphia* at lower altitude is 51-61, 52-67 and 215 - 231 days for 1st (rainy season), 2nd (Autumn season) and 3rd (Winter season) crops, respectively (Table 2). However, in the previous study (FAO, 1976) the days taken to complete the life cycle of *A. mylitta* for 1st (30 – 35 days), 2nd (40- 45 days) and 3rd (60 - 70 days) crops is almost half of the days spent by *A. paphia*. This may be due to difference in rearing conditions as *A. paphia* is wild variety and *A. mylitta* is semi-domesticated variety.

The voltinism is observed to be a peculiar reproductive behaviour in the wild tasar silkmoth, *A. paphia*. The voltinism regulated the diapause period of silkmoth. The diapause is a resting stage of the silkmoth in the form of pupa (chrysalis) where further growth is arrested. Moreover, diapause is an adaptive phenomenon in the life cycle of silkmoth, permitting the survival of individuals during inclement seasons and insuring the synchrony of activities with periods favourable for growth and reproduction. Voltinism in Modal ecorace of wild tasar silkmoth, *Antheraea paphia* may occur due to a number of factors such as environmental (Danilevsky, 1961), nutritional (Nagamori, 1930) and physiological (Takeda *et al.*, 2002).

Impact of environment on productive efficiency of Modal ecorace of *Antheraea paphia*

Comparatively higher temperature and higher humidity regime during autumn season at lower altitude (100 - 200 m ASL) affect the rearing efficiency whereas comparatively cooler climatic condition during rainy season at middle altitude (500-600 m ASL) (Table 4) give rise to moderate rearing performance. The cooler climatic condition at middle altitude during autumn season and at higher altitude (700 - 800 m ASL) during rainy season appear to be conducive for the highest silk synthesis and highest rearing efficiency. The lowest rearing performance during autumn season at lower altitude is due to high temperature, high humidity, stormy weather and incidence of more predators and parasites (Nayak *et al.*, 1993). Further, high temperature (Ullal and Narasimhanna, 1987) and high relative humidity (Tanaka, 1964) are related to the production of poor quality of cocoons in *Bombyx mori*.

Climatic conditions differed at different altitudes, which very well influenced the rearing efficiency of this wild tasar silkmoth. Silkmoth being cold-blooded animal was not capable of adjusting its physiological requirements under temperature fluctuations. Temperature played a decisive role on growth, mortality, cocoon quality, fecundity, hatching, voltinism and also on future generations. So in congenial environmental conditions a good harvest is always expected and vice versa.

There is very little information on the genotype variability of the commercial traits such as cocoon weight, shell weight, silk ratio etc. of tasar silkmoth. Because the commercial characters of the tasar silkmoth is not fixed characters; rather these characters mostly depend upon the type of food plant, altitude and climatic conditions. Thus, it may be interpreted that the commercial cultivation for higher income should be carried out at lower altitude (100-200 m ASL) during winter season, in middle altitude (500-600 m ASL) during autumn season and

at higher altitude (700-800 m ASL) during rainy season only.

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