STUDIES ON THE EMERGENCE BEHAVIOUR OF THE OAK TASAR SILKMOTH, *ANTHERAEA PROYLEI* JOLLY

Yumnam Debaraj*, N. Ibotombi Singh, T. K. Biswas* and K. Chaoba Singh*****

* Regional Sericultural Research Station, Jorhat-785005, INDIA. E-mail: yumnamdebaraj@yahoo.com
** Central Muga Eri Research and Training Institute, Jorhat-785700, INDIA.
*** Regional Tasar Research Station, Imphal-795002, INDIA.

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ABSTRACT: The Indian oak tasar silkworm, *Antheraea proylei* Jolly behaves uni- and weak bivoltinism depending upon the prevailing environmental conditions. The silkworm undergoes pupal diapause for about eight months (June to January) after spring crop. During prolonged preservation, large quantity of seed cocoons are lost due to erratic emergence, pupal mortality, decrease in vigour, etc. The main reason behind erratic emergence could be attributed to weak voltinism of the silkworm. However, the maintenance of suitable environmental conditions during the preservation of cocoon plays a key role for emergence of moths. The summer or autumn crop can be taken up by breaking the pupal diapause subjecting to photoperiodic treatment of the seed cocoons. Considering the problems in relation to emergence of moths encountered by the silkmoth, observations were made exclusively on different aspects of emergence pattern of *A. proylei* during normal grainage period in spring crop and long preservation (pupal diapausing) period in the present study.

KEY WORDS: Emergence behaviour, oak tasar silkmoth, *Antheraea proylei*, pupal diapause.

In India, the oak tasar culture has been widely practiced in the sub-Himalayan belt extending from Manipur in the east to Jammu and Kashmir in the west where oak flora is grown abundantly in nature. The Indian oak tasar silkworm, *Antheraea proylei* Jolly is wild in nature but becomes semi-domesticated after exploitation. The silkworm behaves uni- and weak bivoltinism depending on the prevailing environmental conditions. The insect exhibits facultative diapause in pupal stage under short-day (8 hr and below) and long-day (10-14 hr) photophase condition and tends towards univoltinism under the short day regime of sub-Himalayan belt under the low temperature (below 20^{o}C). In the north eastern region the spring crop is the main seed / commercial crop which start during the first week of March coinciding with the natural sprouting of oak plant, *Quercus acutissima*, the main food plant of the silkworm. However, summer or autumn crop can also be taken up by breaking the pupal diapause subjecting to photoperiodic treatment to the seed cocoons.

The emergence of adult moths in general is governed by a circadian rhythm and this behaviour is very common among the lepidopterans (Matthews & Matthews, 1988; Horodyski, 1996). Photoperiod may be one of the key factors controlling the onset of adult behaviours. The *A. proylei* undergoes pupal diapause after spring crop extending through about eight months period from June to January. During this long preservation period seed cocoons were lost due to erratic emergence. The main reason behind erratic emergence may be due to weak voltinism of the silkworm. However, the maintenance of suitable environmental conditions during the preservation of cocoons played key role for

emergence of moths. Due to long period of diapause and exposure to varied climatic conditions, substantial percent of seed cocoon loss was reported in *Antheraea mylitta* D. (Kapila et al., 1992). In tropical insects, environmental regulators, such as day length, temperature and rainfall regulate their diapause (Denlinger, 1986) and even higher temperature blocks initiation of development (Hackett & Gatehouse, 1982). Onset of rains is directly linked to diapause termination and synchronised adult insects availability (Wolda & Denlinger, 1984; Denlinger, 1986). Impact of temperature on growth, development and reproduction of insect has been studied by many workers in different insects (Malik, 2001; Ahmad et al., 2008). The moth emergence behaviour of tropical tasar silkworm, *A. mylitta* D. was studied in different preserved conditions and worked out its suitability for synchronizing seed production (Dinesh Kumar et al., 2012). However no study has been made on the emergence behaviour of the oak tasar silkmoth, *A. proylei*, both in the grainage period and long preservation period for synchronised seed production and its correlation with the climatic factors. Considering the problems in relation to emergence of moths encountered by the oak tasar silkmoth during normal grainage period in spring crop and long preservation (pupal diapausing) period, a series of observation were made exclusively on different aspects of emergence pattern of *A. proylei* in order to make grainage performance successful, such as less span of emergence, synchronised moth emergence, higher coupling percentage, less pupal mortality, high seed recovery, etc.

MATERIALS AND METHODS

The univoltine lot of oak tasar silkworm, *A. proylei* Jolly was reared during spring crop in the outdoor condition as normal practice providing bush plantations of oak plant, *Quercus acutissima*. The cocoons were harvested during the last week of April to middle of May. After sorting, the diapaused seed cocoons were preserved under semi-dark condition in the grainage building of Regional Tasar Research Station, Imphal for prolonged preservation up to eight months, *i.e.*, June to January till the grainage for seed preparation of next spring crop. In another set of experiment, the seed cocoons selected from the prolonged preservation lot were kept in another grainage building for seed preparation of spring crop rearing. For conducting the spring crop grainage, the grainage house is maintained at 24-26^{o}C temperature and 70-80% R. H. The emergence behaviour of the silkmoth was recorded from both the conditions of prolonged preservation and spring crop grainage. Data were recorded for daily emergence percentage of male, female and total from both the lot. The temperature (minimum & maximum) and relative humidity were recorded from both the preserved conditions.

The data on pattern of erratic emergence for five years in both the preserved lots (prolonged and spring crop grainage) were also analyzed to see the behaviour of the moth emergence. Besides, such studies may also provide valuable information on the behaviour of the adults because of nocturnal habit of the moths. The response of the silkworm reared under different photophase to erratic emergence was also investigated. The correlation studies between erratic emergence and abiotic factors (temperature and relative humidity) were also worked out and analysed statistically. In another experiment, every two hourly emergence of male and female moths were also recorded to study the rhythm of emergence through hours of the day. The investigations were conducted at Regional Tasar Research Station, Central Silk Board, Imphal.

RESULTS AND DISCUSSION

Pattern of erratic emergence from the diapausing cocoons: Figure 1 showed the five years data on the weekly trend of erratic emergence of oak tasar silk moths from the diapausing cocoons. It was found that about 7-15% of moths were emerged erratically during the period of about eight months (June-January). During the period, the fluctuating emergence was observed with slight fluctuating temperature but variable relative humidity. However, it was found that higher the temperature, higher the emergence and vice-versa. The emergence started in the first week of June to a negligible extent but it suddenly increased reaching 0.89% in the fourth week of June. The second highest peak was observed in the second week of July with 0.90% emergence. The emergence of male moths (0.51%) was comparatively more than the females (0.39%) up to the second week of July. Further the decreasing and increasing trend of emergence was observed with peaks in alternate weeks and finally a higher peak of emergence (0.87%) in the second week of October. During the peak period the weather factors like minimum and maximum temperature and relative humidity ranged from 20.86-25.59^{o}C, 26.01-29.44^{o}C and 70.01-81.80% respectively. The emergence declined gradually from the third week of October onwards and continued sporadically (0.5%) up to the third week of January where minimum and maximum temperature and relative humidity ranged from 10.05-20.14^{o}C, 17.40-24.67^{o}C and 67.48-75.09% (Fig. 1). Thereafter, the diapause in the prolonged preserved seed cocoons is observed to be terminated with the increase of temperature and photoperiod.

Pattern of emergence during spring crop grainage operation: In oak tasar culture, spring crop is the only successful crop where the prevailing climatic condition is suitable for the silkworm rearing. Besides, brushing of worm is coincided with the natural sprouting of the oak plants. Five year's data on weekly pattern of moth emergence during spring crop grainage revealed that moth emergence started from the last week of January with a total emergence of 1.38% (0.55% male and 0.84% female) and continued up to the last week of March with 2.82% (0.82% male 2.00% female). The peak emergence was obtained during the third week of February with 26.54% emergence and declined gradually (Figure 2). The span of emergence during grainage ranged from 59 to 75 days and the average total emergence was recorded as 87.73%. The sex ratio of the emerged moths was 1 : 0.78 (male: female).

Correlation studies between erratic emergence of moths and abiotic factors: The correlation studies between moth emergence and abiotic factors revealed that the temperature and relative humidity exhibited positive correlation with the emergence of moth from the diapausing cocoon (Table 1). Minimum temperature exhibited significant positive correlation with both male ($r=0.478$) and female ($r=0.509$) emergence but highly significant with total emergence ($r=0.566$, $P<0.001$). Significant correlation was also obtained between maximum temperature and emergence (Table 1). However, the correlation was non-significant between relative humidity and both male and female emergence separately. But it was significant with the total emergence ($r=0.412$, $P<0.05$). From the above studies, it can be inferred that temperature played significant role in influencing the erratic emergence of moths. Moreover, minimum temperature is responsible to minimise the emergence. Our finding corroborates the finding of Malik (2001); Ahmad et al. (2008) which indicated that temperature has an impact on growth and development of insect. During the period of about four months, *i.e.*, October to January, there was a decreasing trend of emergence with

minimum temperature ranging from 10.05-20.14°C (Fig. 1). It was reported that the environmental regulators, like day length, temperature and rainfall played main role for regulating their diapause in tropical insects and even higher temperature blocks initiation of development (Denlinger, 1986; Hackett & Gatehouse, 1982).

In another set of experiment, a batch of seed cocoons was preserved in four different photophases, *i.e.*, L : D 16 : 8, 12 : 12, 8 : 16 and 0 : 24 and another batch was preserved in L : D 16 : 8 photophase only to see the emergence response of the worms reared under different photophases. Grainages of both the batches were conducted separately in both the conditions. The rearing also conducted in the respective photophases separately as mentioned above. The cocoons were harvested in the middle of April and kept in different photophases to observe the emergence response. The moth emergence started in the second week of May in all the photo-treatments and continued up to the second week of July. The worms reared at L : D, 16 : 8 responded nicely with 99.8% emergence within 45 days. Maximum emergence was recorded during the second and third week of May (93.5%) but other treatments showed irregular emergence in variable span (Table 2).

Rhythm of emergence, *i.e.*, the pattern of emergence over the hours of the day was also studied for three consecutive days. It was recorded that most of the moths emerged between 17.00 h and 23.00 h with 78.2% emergence and highest peak was observed at 19.00 h (31.90%). However, sporadic emergence continued throughout the hours of the day in negligible amount (Fig. 3).

Sufficient seeds can be prepared at different intervals out of the erratically emerged moths from the prolonged preservation of cocoons. The maximum of them are unutilized due to non-availability of good foliage. The rearing of these dfls during second crop (summer/ autumn) as trial was almost a failure in general at lower altitude whereas successful at middle and high altitude during June to October months. Some of the workers also have studied the problems of erratic emergence during prolonged preservation of oak tasar silkmoth and opined to preserve the seed cocoons at higher altitudes (above 2000 m MSL) from November to February so that the problems can be resolved considerably. However, heavy loss of seed cocoons was encountered due to pupal mortality up to 15-20% during transportation of seed cocoons from lower to higher altitudes. Among the abiotic factors, temperature and photoperiod are considered as the two main factors controlling diapause. If these factors are manipulated without breaking diapause, the cocoons can be preserved for a considerable period of time without any emergence.

Till recently, attempts have been made to preserve the seed cocoons at the place of harvest after rearing in respective places preferably in middle and high altitudes to minimise the stray emergence pattern during long term preservation after spring crop rearing. Therefore, it is encouraging that in oak tasar culture the silkworm rearing as well as seed cocoon preservation can be done at the same agro-ecological zones by manipulating the suitable environmental factors. After repeated rearing, the silkmoths will be acclimatized in the respective locality and suitable technique of seed cocoon preservation should be worked out according to the locality so as to check the erratic emergence of moths.

Therefore, in order to check erratic emergence of moths during prolong preservation period, a suitable preservation technique is to be worked out with different methods at different places considering the role of abiotic factors mainly temperature and photoperiod. Prolonged preservation of seed cocoons leads to low fecundity and low hatchability (Singh *et al.* 2003). Regarding the emergence

of moths during spring crop grainage, efforts are to be made to shorten the grainage span as much as possible so as to coincide the brushing with the availability of good foliage of oak sprouts and also to avoid preservation of eggs in cold storage which often leads to loss of seed and low hatchability. During spring crop grainage, seed cocoons should be consigned and treated as and when required only. From the present study, it is deduced that photophase and temperature play vital role in regulating the pupal diapause of the oak tasar silkmoths. During prolonged preservation of cocoon, high temperature to the tune of 26.01 to 29.44°C induces higher sporadic emergence and lower temperature ranged from 10.05 to 20.14°C is found to be suitable to maintain the pupal diapause.

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Table 1. Correlation studies between erratic emergence of moths with abiotic factors in *Antheraea proylei* J.

Sl. No.	Combination (variables)	a	b	'r'
1.	Min. Temp. vs. Male emergence	-0.012	0.013	0.478**
2.	Min. Temp. vs. Female emergence	0.054	9.167	0.509**
3.	Min. Temp. vs. Total emergence	0.066	0.021	0.566***
4.	Max. Temp. vs. Male emergence	-0.142	0.015	0.432*
5.	Max. Temp. vs. Female emergence	-0.068	0.012	0.521**
6.	Max. Temp. vs. Total emergence	0.148	0.014	0.500**
7.	Relative humidity vs. Male emergence	-0.737	0.013	0.334 NS
8.	Relative humidity vs. Female emergence	-0.419	8.878	0.342 NS
9.	Relative humidity vs. Total emergence	-1.137	0.022	0.412*

* P<0.05; ** P<0.01; *** P<0.001; NS: Non-significant

Table 2. Emergence response of *Antheraea proylei* J. moths after rearing and preservation of cocoons under different photophases.

Photophase during silkworm rearing (L : D)	Photophase during cocoon preservation (L : D)	Weekly Emergence (%)									Total Emergence (%)	Span of emergence (days)
		MAY			JUNE				JULY			
		II	III	IV	I	II	III	IV	I	II		
16 : 08	16 : 08	58.0	35.5	0	2.1	2.1	0	2.1	0	0	99.8	45
12 : 12	12 : 12	2.2	0	0	0	0	0	2.2	0	0	4.4	45
08 : 16	08 : 16	2.1	0	0	0	0	0	0	2.1	0	4.2	52
00 : 24	00 : 24	31.0	0	0	0	0	0	0	0	0	31.0	08
16 : 08	16 : 08	58.0	35.5	0	2.1	2.1	0	2.1	0	0	99.8	45
12 : 12	16 : 08	0	0	0	0	3.2	16.6	53.0	14.0	3.2	90.0	32
08 : 16	16 : 08	4.4	0	0	0	0	8.8	75.5	2.2	2.2	93.1	60
00 : 24	16 : 08	14.6	16.6	0	2.1	6.3	25.0	10.4	2.1	8.3	85.4	60

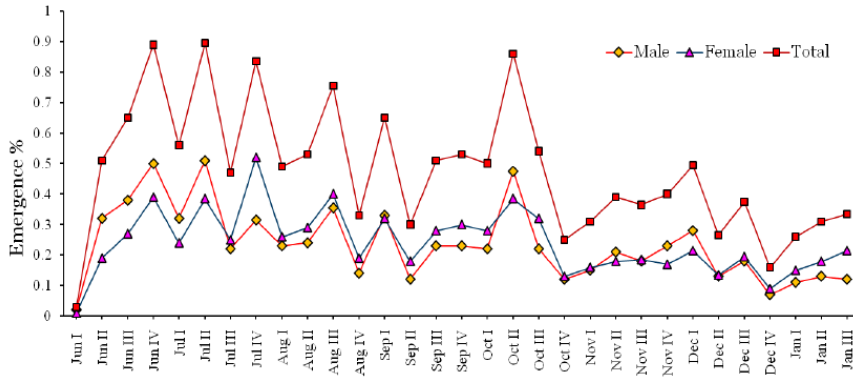

Figure 1. Weekly pattern of erratic emergence from the diapausing cocoons of *Antheraea proylei* J.

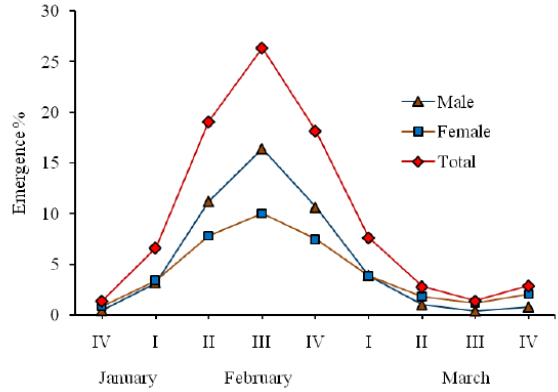

Figure 2. Weekly emergence pattern of *Antheraea proylei* J. During spring crop grainage operation.

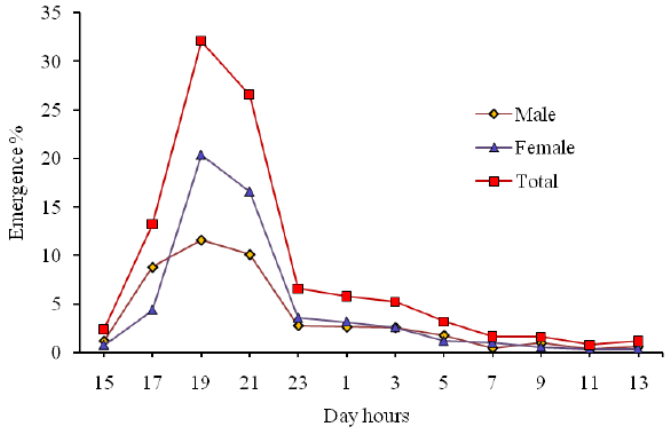

Figure 3. Rhythm of emergence in univoltine stock of *Antheraea proylei* J.

(a) (b)

Figures 4. a) Oak tasar silk moths in the cocoon garland, b) Moth (close up view).

(a) (b)

Figures 5. a) Female moth, b) Male moth.

(a)

Figures 6. a) Oak tasar cocoon garlands inside the cage in the grainage.