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Influence of abiotic factors on seasonal and non-seasonal emergence of Tasar silkworm, *Antheraea mylitta* Drury

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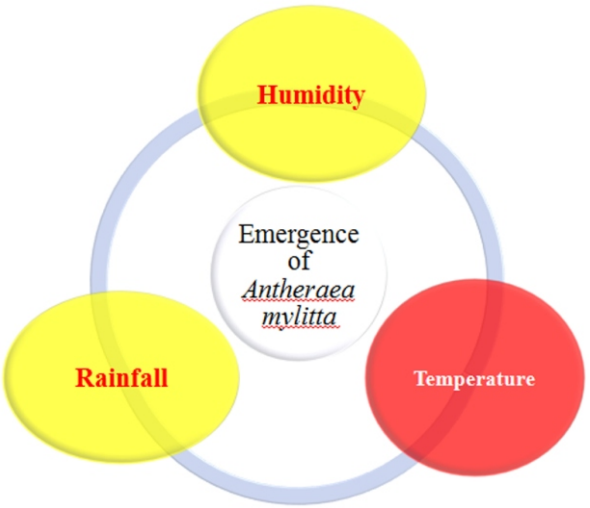
Abstract

Aim: The present study was carried out to introspect the effect of temperature, humidity and rainfall on the emergence of *Antheraea mylitta* Drury.

Methodology: An experiment on seasonal and non-seasonal emergence was carried out in 2019 and 2020 at Kathikund and Kharsawan of Jhakhand, India. Meteorological parameters (temperature, humidity and rainfall) were noted twice daily. Similarly number of adult moths emerged were age-graded and segregated as male and female. They were counted twice in a day within the grainage buildings (preservatory of seed cocoons).

Results: The emergence of *Antheraea mylitta* varied month wise following: June to September, March to May, and November to February. Although the emergence of male individuals was more compared to females, no significant difference was observed statistically. Further increase in rainfall (57%) – humidity (15%) triggered more non-seasonal emergence of females. A strong positive correlation between humidity and rainfall with the emergence of adult moths compared to temperature throughout the year across both the seasonal (June-October) and non-seasonal (November-May) months was observed. The erratic/non-seasonal emergence was strongly correlated with humidity (0.75) compared to rainfall (0.32) and temperature (0.19). Daily emergence differed significantly ($p<0.01$) between the seasonal and non-seasonal months.



Interpretation: During seasonal months, the number of adult moths emerged remained almost constant; however in non-seasonal months, the pattern of adult emergence exhibited a non-linear interrupted by sudden intervals of zero emergence. The intervals corresponded significantly to the effect of humidity and rainfall ($p<0.001$), however, no significant effect of temperature ($p>0.05$) was observed.

Key words: Abiotic factors, *Antheraea mylitta*, Seasonal emergence, Tasar silkworm

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Introduction

Antheraea mylitta Drury, a lepidopteran, polyphagous insect found across the several tropical Indian states is of significant economic importance (Bhatia and Yousuf, 2014). Wild in nature, it is semi-domesticated to certain extent. Although polyphagous, the main food plant of Tasar silkworm includes *Terminalia tomentosa* (Asan), *Terminalia arjuna* (Arjun) and *Shorea robusta* (Sal) (Jolly *et al.,* 1974; Jolly *et al.,* 1979). Besides, other food plants are Sidha (*Lagerstroemia parviflora*), Jarui (*Lagerstroemia speciosa*). Kinjal (*Terminalia paniculata*), Saoni (*Lagerstroemia indica*), Haritaki (*Terminalia chebulal*), Jamun (*Syzygium cuminii*), Ber (*Zizyphus mauritiana*) Anjan (*Hardwickia binata*), Bahera (*Terminalia belerica*), Mahua (*Madhuca indica*) etc. (Suryanarayana *et al.,* 2005). The economics of the silkworm lies in its ability to spun silk cocoons known as Tasar silk, hence, the insect is commonly named as Tasar silkworm. Besides farming practice, the livelihood mission of the tribes dwelling in the forest-borne difficult patches across India depends heavily on Tasar sericulture (Vishaka *et al.,* 2020).

Approximately, 3.5 lakh tribal farmers over 44.50 million ha of forest area embrace Tasar sericulture. Besides rearing, reeling spinning, dyeing and weaving are other associated activities were farmers often engaged. The ecological habitat of the insects ranges between 72-96°E and 12-31°N (Jolly *et al.,* 1974). The commercially exploited eco-race of all the available *A. mylitta* is DABA (both bi-voltine and tri-voltine). Synchronization of all the activities like emergence, mating, oviposition and rearing are pivotal to success of sericulture (Jolly *et al.,* 1979). Unlike other silkworms viz., *Bombyx mori*, the major problem in *A. mylitta* is erratic emergence across the season. Emergence has been observed during pre-monsoon, monsoon, post-monsoon and even during diapausing phase (Shapiro, 1993; Sharma and Ali, 2013). The influence of bioclimatic conditions on the emergence of insects is a well-known fact. Erratic and non-seasonal emergence was strongly correlated with humidity and rainfall (Siddaiah *et al*., 2014). Influence of bioclimatic condition on the emergence of insects (including silkworm) has been reported (Messenger, 1958). Specific events or phases of insect development are critically dependent on one or several climatic factors (Messenger, 1958). Likewise, the emergence of *A. mylitta* mainly depends on the temperature, humidity and rainfall (Jolly *et al.,* 1974; Shapiro, 1993). The normal emergence of *A. mylitta* in bivoltine population occurs during June to October, which is deemed as seasonal months.

The climatic parameters vary across the geographical locations of *A. mylitta* and hence, a delayed or early emergence of adult insect is observed (Bhatia and Yousuf, 2014). The population of *A. mylitta* appears to be segregated due to attainment of sexual maturity at different time owing to difference in the emergence schedule. Early emergence has been observed in South Jharkhand (Kharsawan, Chaibasa and Chakradharpur) whereas a delay of 5-10 days in emergence has been observed in the North-eastern Jharkhand (Dumka, Pakur). These small intra-specific differences within the sub-local population caused due to differences in the schedule of emergences accumulate and further amplify, thereby hindering the flow of genetic information across the species ultimately leading to diversification of the population and make a temporal barrier to divide the population. The present study was carried out in 2019 and 2020 at Kathikund and Kharsawan (Jharkhand) to observe the interaction of climatic factors (temperature, humidity, rainfall) on seasonal and non-seasonal emergence patterns of *Antheraea mylitta* Drury, 1773 (Lepidoptera: Saturniidae). The observational study was done on cocoons harvested after rearing from managed and unmanaged plantations.

Materials and Methods

Description of collection: The study was conducted at the Basic Seed Multiplication and Training Centre (BSM&TC), Kharsawan and Kathikund under the aegis of Central Silk Board during 2019 and 2020. Kharsawan is located in Saraikela-Kharsawan districts in South Jharkhand bordering Orissa at the foot of Saranda ranges. Kathikund is a part of Santhal Pargana in the North-east Jharkhand bordering West Bengal (Fig. 1). Both the sites are unique due to voluminous plantations of *T. arjuna* and *T. tomentosa*, thereby contributing to prosperity of Tasar sericulture. The normalized difference vegetation indexes (NDVI) of both the sites were calculated using ArcGIS (Fig. 1). The observational study was done on cocoons harvested after rearing from managed and unmanaged plantations. At both the sites, the Daba bivoltine (BV) stocks were maintained. The number of male and female moth emergence was counted on daily basis in forenoon and afternoon. Similarly the indoor and outdoor weather parameters (temperature, humidity and rainfall) were recorded using the digital meteorological data logger (Metravi-L) which provided maximum and minimum temperature and humidity in a day. The stocks were usually replenished bi-annually. Unavailability of cocoons during August and October due to mass rearing, no emergence data could be recorded during the aforesaid months.

Statistical analyses: The emergences of *A. mylitta* across the seasons were analyzed through Agglomerative Hierarchical Clustering (AHC), following dissimilarity index in XLSTAT (Addinsoft, 2010). Principal Component Analysis (PCA) was applied to estimate the exact combination of parameters critical for emergence of *A. mylitta*. Pearson's correlation test was performed to assess the relation of emergence (response variable) with rainfall, humidity, temperature (explanatory variable). The graphs were plotted with the help of Origin Pro 8.0 and maps were developed with the help of ArcGIS.

Results and Discussion

The emergence data of *A. mylitta* were subjected to AHC to cluster the seasonal and non-seasonal months of emergence of Lepidopteran moths. Calculation was based on the dissimilarities among the total number of moths emerged were

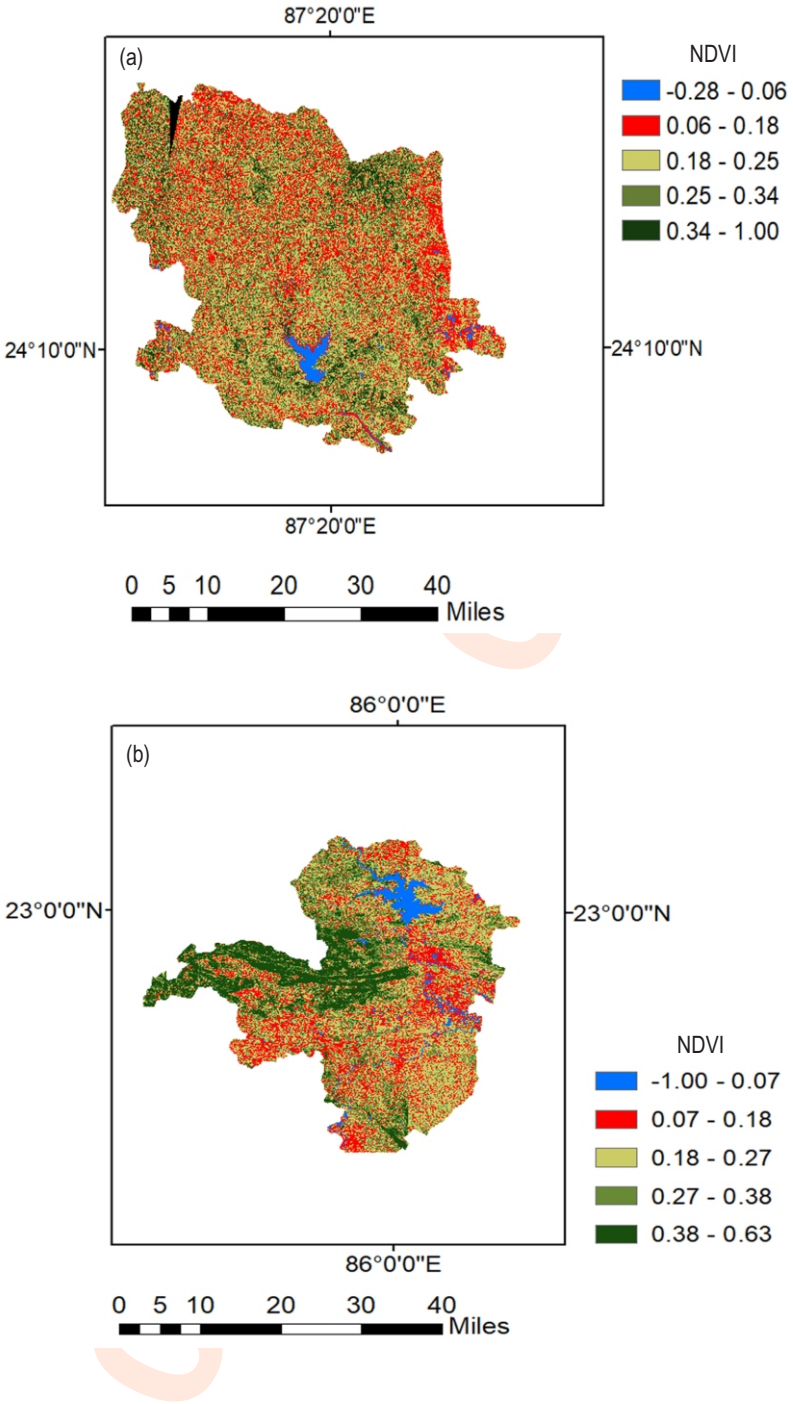

Fig. 1: NDVI (Normalized Difference Vegetation Index) of (a) Kathikund and (b) Kharsawan.

estimated through AHC with the Euclidean distance supported by Ward's method (Legendre and Legendre, 1998). The AHC results (Fig. 2) clearly depicted 3 clusters: the seasonal months (June, July, September); the non-seasonal months with erratic emergence (March, April, May) and non-seasonal months without emergence or negligible emergence. The non-seasonal months were further subdivided into two clusters: months with relatively less emergence (March, April and May) and months with negligible emergence (November, December, January and February). Especially, the emergence during March to May was termed as erratic emergence. Following the results obtained through AHC, the entire data were segregated into clusters

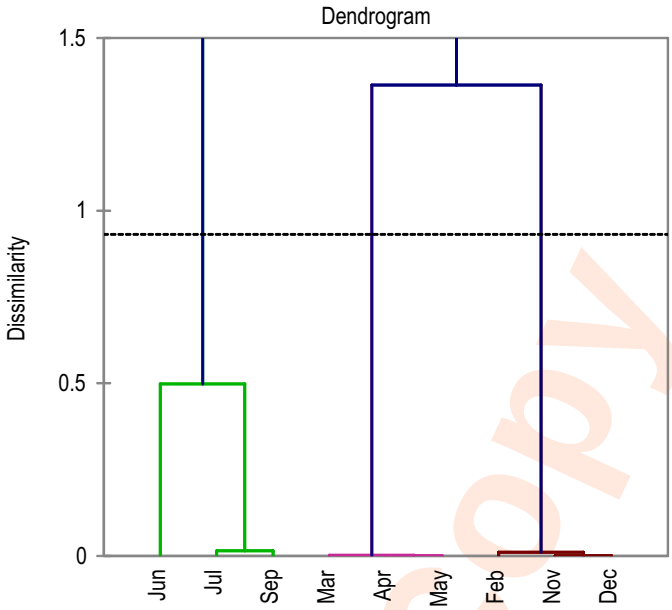

Fig. 2: Dendrogram depicts dissimilarities (Euclidean distance based on Ward's method) between different monthly emergences of *A. mylitta*. The solution resulted in three classes: class (i) June, July, September, (ii) March, April, May and (iii) November to February.

(seasonal versus non-seasonal) and subjected to descriptive statistics: The mean value during seasonal months was 221.43 ± 26.47 mm (range 140-328 mm) for rainfall, 79.91± 2.92 % (66.68-88.66 %) for relative humidity, 30.79°C (29.5-32.5°C) for temperature and 46808 ±10574.68 individuals (6008-75605 individuals) for emergence. In non-seasonal months, the mean value of rainfall was 16.14 ± 5.31 mm (range 1-78 mm), relative humidity 55.39± 2.66 % (36.74-68.00 %), temperature 26.89°C (21.00-33.5°C) and emergence 96.00 ±26.31 individuals (13-240 individuals), respectively (Fig. 3). A comparative box plot representation of humidity, rainfall, temperature and emergence of *A. mylitta* between seasonal and non-seasonal months is depicted in Fig. 4. Pearson's correlation test was performed to estimate the association of factors with the emergence of *A. mylitta*. Although, all the factors exhibited a positive correlation on annual emergence, rainfall (0.810, $p<0.01$) and humidity (0.750, $p<0.0001$) were relatively more critical compared to temperature (0.210, $p>0.05$). Correlation matrix (seasonal and non-seasonal) depicted rainfall and humidity as two most important factors (Table 1). In both the cases (seasonal versus non-seasonal), temperature was observed of minimum importance for causing emergence of adult Lepidopteran moths.

The observations of correlation matrix were further validated through PCA, which is depicted in Table 2. Eigenvalues suggested considering PC1 and PC2 for further introspection. Factor loading validated humidity (0.867) and rainfall (0.901) as key factor for the emergence of *A. mylitta* population. The observation from the present study suggested that the significance of weather parameters as a controlling measure

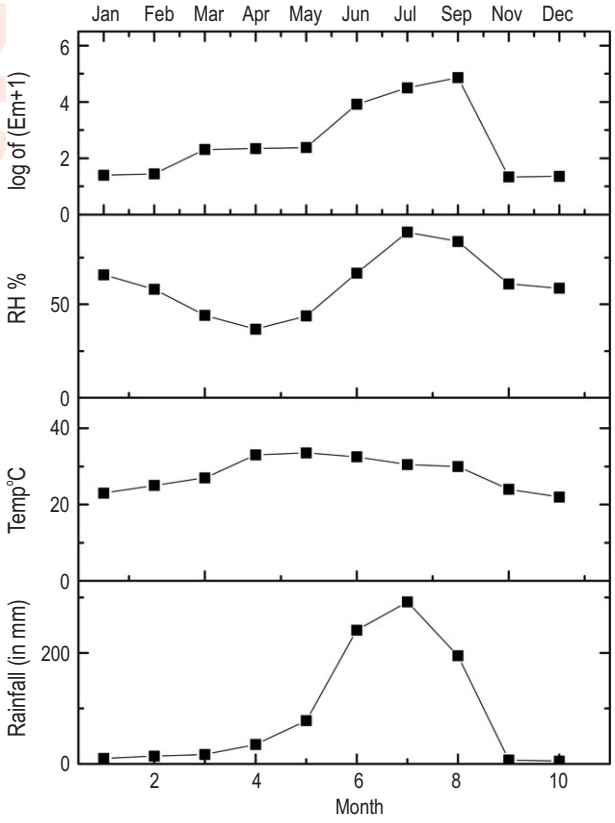

Fig. 3: Monthwise variations in humidity (RH), temperature (Temp), rainfall with the emergence (Em) of *A. mylitta* observed at Kathikund and Kharsawan, Jharkhand, during the year 2019 and 2020.

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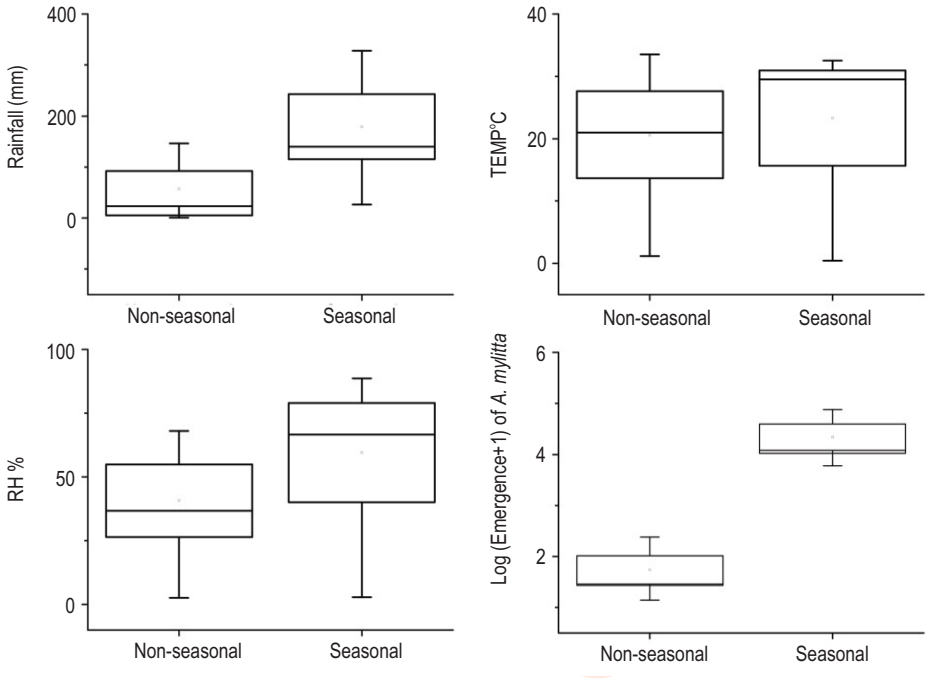


Fig. 4: A comparative box plot representation of humidity, rainfall, temperature and emergence of *A. mylitta* between seasonal and non-seasonal months at Kathikund and Kharsawan during 2019-2020.

Table 1: Correlation matrix of weather parameters (rainfall, temperature and humidity) considered as source of variation on emergence of *A. mylitta* as response variable during the study.

Correlation matrix		**Summary**
Variables	**Emergence (R^2)**	**Significance(p<0.05)**
Rainfall (ppt)	0.810	0.001
Temperature	0.210	0.102
RH	0.750	< 0.0001
Correlation matrix		**Non-seasonal months**
Variables	**Emergence (R^2)**	**Significance(p<0.05)**
Rainfall (ppt)	0.320	0.001
Temperature	0.190	0.115
RH	0.750	< 0.0001
Correlation matrix	**Seasonal months**	
Variables	**Emergence (R^2)**	**Significance(p<0.05)**
Rainfall (ppt)	0.413	0.001
Temperature	0.077	0.189
RH	0.637	< 0.0001

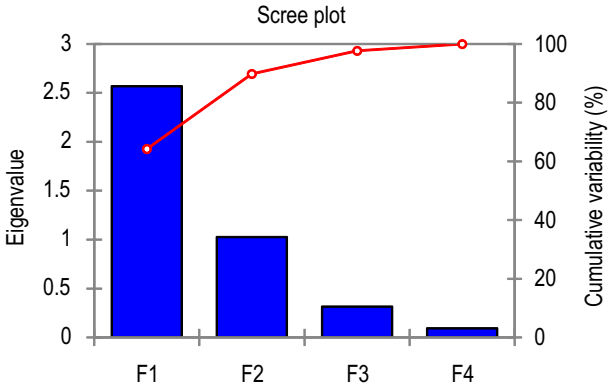
influence the life cycle of *A. mylitta*, substantiating the documentation of Shapiro (1993) to certain extent. This study was carried out in the regions native to *A. mylitta* populations. Although, it is a known fact that insect life-cycle critically depends on the weather parameters, but further analysis of the contribution of each factors on the emergence of *A. mylitta* was imperative due to the economic importance of the species (Du Plessis *et al.,* 2020, CTR and Ti, 2010). The result obtained in the present study suggested that there were two different patterns for emergence of *A. mylitta*. The pattern was observed during the non-seasonal months, *i.e.,* March to May (pre-monsoon), November to February (post-monsoon and diapause period) and seasonal months, i.e., June, July and September were entirely different. Humidity and rainfall was observed to be predominant factors that affeced the emergence of *A. mylitta* compared to temperature. During their scheduled time of emergence (seasonal emergence), both humidity (R^2= 0.64) and rainfall (R^2= 0.41) equally played a significant role (p<0.001). Whereas during non-seasonal time, erratic emergence was more depended on humidity (R^2=0.76) than rainfall (R^2=0.32), especially during cooler months (over wintering phase of *A. mylitta*).

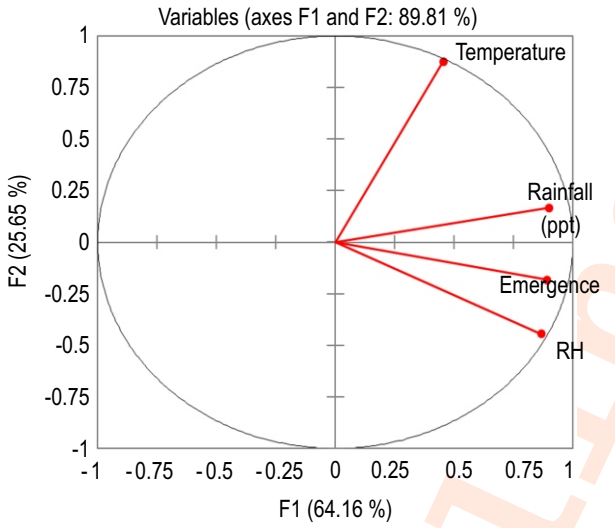
The reason may be attributed to the fact that during seasonal months (June, July and September), humidity was positively correlated with rainfall (0.31) whereas during non-seasonal months, humidity was not positively correlated with rainfall (-0.49) or rather both the factors (humidity and rainfall) exhibited quasi-independence during non-seasonal periods. Temperature was equally less relevant during emergence in either of the time. The plausible explanation may be attributed to the fact that seasonal emergence of insect is an imprinted behaviour (Morohoshi, 2001) which is fine tuned by the ambient humidity and rainfall. Shapiro (1993) demonstrated that high temperature and humidity results in emergence of *A. mylitta.*

Online

Table 2: Principal component analysis (PCA) of weather parameters with their effect on emergence of *A. mylitta* during study period

	F1	F2	F3	F4
Eigenvalue	2.567	1.026	0.315	0.093
Cumulative %	64.163	89.810	97.686	100.000





However, the present study highlights that fluctuation in humidity along with rainfall provides final trigger of emergence. The less influence of temperature could be due to the fact that most of the regions where tasar sericulture is practised in India fall under tropics and sub-tropics, where range of temperature variation is narrow. The average temperature in the non-seasonal months was 26.9°C compared to the average temperature of seasonal months 30.8°C. Therefore, it can be concluded that there has been no significant difference in the range between the two phases (seasonal and non-seasonal months). A difference of 10°C is necessary to delay the process of emergence in various insects from *A. mylitta* to *Homoeosoma electellum* (Rogers and West-brook, 1985). However, in the present study it was observed that there has been a difference of 4°C only across the season, thereby emphasizing little effect of temperature on the emergence of *A. mylitta* in the tropical and sub-tropical region.

The present study corroborates with the observation of Shapiro (1993) regarding the highest emergence of *A. mylitta* in September, when maximum rainfall occurs, implying the significance of rainfall and monsoon for the final emergence of adults of *A. mylitta* from the pupal stage. On the contrary, a high temperature coupled with low humidity and rainfall results, no emergence of *A. mylitta* rather it affects adversely resulting in death of *A. mylitta* in pupal stage. Although life table of *A. mylitta* has been reported (Bajpeyi *et al.,* 1995), it lacks exhaustive field evaluation study on the assessment of the meteorological conditions and their impact on the growth and development of tasar silkworm larva.

Thus, it can be inferred that duration of diapause of silkworm moth (*A. mylitta*) is greatly delimited by humidity and rainfall compared to temperature and schedule of brushing of eggs for rearing. The present study emphasizes that fluctuation in humidity and rainfall was more critical to emergence of *A. mylitta* in this sub-tropical ambience. The information may be translated at farmers' level amidst the growing concept of private grainuer or seed producers. Preventive measures may be adapted to reduce the fluctuating effect of humidity within the grainage houses (building preserving seed cocoons) to minimize the erratic or delayed emergences. Usages of automated humidifier or silica gel or lime stacks within grainage are some of the many options available to maintain constant humidity.

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Authors' contribution: S.M. Mazumdar: Data collection, interpretation, manuscript writing; **B.T. Reddy, M. Chandrashekharaiah:** Data collection; **N.B. Chowdary, S. Chattopadhyay, M.S. Rathore:** Revised manuscript draft; **K. Sathyanarayana:** Proof reading and editing the manuscript.

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Ethical approval: No animals were harmed during the study. It was an observational approach.

Conflict of interest: The authors declare that there is no conflict of interest.

Data availability: Not applicable.

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