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ASSESSMENT ON CLIMATIC SUITABILITY OF NEW FOREST, FRI, DEHRADUN TO INTRODUCE FOREST BASED REARING OF TROPICAL TASAR SILKWORM, *ANTHERAEA MYLITTA* DRURY IN UTTARAKHAND, INDIA

by

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Abstract

We are intended to introduce forest based commercial rearing of tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) in Uttarakhand to create a new livelihood opportunity for forest dependent people in this Himalayan state of northwest India. Understanding the climate of a prospective habitat is critical to predict its manifestation on biological success of any insect species. In the current study, we assessed the climatic suitability of New Forest, Forest Research Institute (FRI), Dehradun by comparing its main weather variables with district Surguja of Chhattisgarh state in central India; where, *A. mylitta* is well established and forest dependent people traditionally rear its bivoltine Daba ecorace on different forestry host plants for small house hold income twice in a year. Analysis of the data by using Fisher's *t* test indicated that is no climatic difference between Dehradun and Surguja, as none of the variables differ significantly at P= 0.05. It is therefore, inferred that *A. mylitta* would not face any major ecological constraint to acclimatize the new habitat conditions of the Uttarakhand. This kind of quick and easier indicative study could be undertaken in other forested areas of the developing countries to stimulate a beginning of location specific forest insect industry to expand the livelihood delivery of the forests to their dependents.

Keywords : Tropical forests, forest dependent people, creating new livelihood opportunity, forest based sericulture, poverty alleviation, socioeconomic development.

Introduction

In recent years, numerous actions for sustainable exploitation of forest resources have been undertaken (Muafor *et al.*, 2012), but only few actions deals with commercialization of forest insects (De Foliart, 1992 & 1997). Most of the studies on tropical forest insects in Uttarakhand have traditionally been focused on their distribution, abundance and the environmental goods and services they provide to humans. Forest based rearing of tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) has never been tried in Uttarakhand; however there is a huge availability of its forestry host plants up to an altitudinal range of 640 m in tropical moist deciduous and tropical dry deciduous forest areas of the state (Thangavelu, 2004; Anonymous, 2011a; Anonymous, 2011 b). Many people and some forest managers still consider insects mainly as a pest; however, they tend to be much less aware of the poverty alleviation potential of commercial forest insects.

Tropical tasar silkmoth is a polyphagous silk producing forest insect of commercial importance, widely distributed throughout a wide geographical range of 12 – 31^0 N latitude and 72

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– 96^0 E longitude in varied agro climatic conditions of India (Jolly *et al.,* 1968; Rao, 2001; Sengupta *et al.,* 1993; Singh and Srivastava, 1997); and across this range, its voltinism and diapause behaviour is variable based on the climatical conditions of the habitat. In India, *A. mylitta* behave differently in different geographical conditions: it is single brooded in Similipal forests of Mayurbhanj district in Odisha; bivoltine in tropical forest areas of Chhattisgarh, Uttar Pradesh; and trivoltine in hotter zones of Chhattisgarh, Madhya Pradesh, Jharkhand and Odisha.

In nature, *A. mylitta* has opted forty-five forest tree species as primary, secondary and tertiary food plants (Srivastav & Thangavelu, 2005) and has built up sixty-four different forms of ecological populations called ecoraces (Rao *et al.*, 2003). It completes its life cycle twice or thrice in a year depending on the biotic and abiotic factors, and accordingly, the race is recognised as bivoltine (BV) or trivoltine (TV). Daba (BV) and Sukinda (TV) are the most commercially exploited ecoraces of *A. mylitta* in India.

Climatic variables, such as temperature, humidity, rain, sunshine and winds can have enormous consequences on ecological success of an insect, because host exploitation, insect growth and development, reproduction and dispersal are fundamentally influenced by these abiotic factors. Season indicates the inter-annual variation in temperature, humidity, sunshine, rain fall etc. of a particular place that is governed by different geographical parameters. Studies have shown the importance of these seasonal variables in the biology and development of the insects (Odum, 1983; Ouedraogo *et al*., 1996). Among climatic variables, temperature influences everything that insects do (Clarke, 2003); humidity affects their embryonic development (Tamiru *et al.* 2012); and rainfall affects the both. Environmental temperature, being major abiotic factor, regulates the body temperature of caterpillar that determines feeding rate and its duration, fertility and fecundity, natality and mortality (Casey, 1981; Wellington *et al*., 1999). Studies have also indicated the combined effects of temperature and relative humidity (Getu, 2007; Tamiru *et al.* 2012). Rainfall alters the functioning of microhabitat, which along with soil and other environmental factors, affects foliage and water levels that ultimately influence the performance of insects (Mattson & Haack, 1987). The role of food plants, photoperiod, temperature, and humidity on the growth and development of insects have been clearly demonstrated (Danilevskii, 1961; Tyschenko, 1977; Zaslavski, 1984; Tauber *et al*., 1986; Danks, 1987). However, the success of an insect largely depends upon an optimal diet in both quantity and quality (Hassell & Southwood, 1978) that provides energy, nutrients, and water to carry out life's activities (Slansky, 1993). Larval period as well as pupal and cocoon characters are known to be influenced by seasonal variations in different silkworm species viz., *A. mylitta* (Srivastava *et al.,* 1998), eri silk worm, *Samia ricini* (Kar *et al.,* 1998) and muga silk worm, *A. assama* (Sahu *et al.,* 1998).

Oxford English Dictionary defines 'climate' as the prevailing atmospheric phenomenon and conditions of the temperature, humidity, wind etc. of a region. However, 'weather' is the condition of atmosphere at a given place and time with respect to heat, cold, sunshine, rain, cloud and wind (Speight *et al*., 2008). According to Murthy *et al.* (1996), climate is the average state of weather over long periods, which is one of the basic elements of natural environment that affects landforms, soil and vegetation. To study the climate or weather conditions of a place, the elements to be considered are: temperature, rainfall, winds, air pressure, humidity, sunshine etc. The estimates of climate, based on these observations represent the general or microclimate that deals with the large vertical gradients of temperature, wind, humidity etc. of the layer of air, close to the ground up to 2 m high, where life thrives. Both climate and weather are controlled by latitude, altitude, distribution of land and water bodies, direction of mountain range and ocean currents (Ramdas, 1974). The climate of Uttarakhand is affected by two seasonal winds, the South-West Monsoon and North-East Monsoon. The South-West Monsoons commonly known as summer monsoons blows from the sea to land after crossing the Indian Ocean, whereas the North-East Monsoon known as winter monsoon blows from land to sea (Murthy *et al.,* 1996).

Understanding the effects of climatic variations on insects is critical to predict their activity and population density (Speight *et al.,* 2008). Owing to huge availability of tropical tasar flora in Uttarakhand and upward correction in the temperature regime due to climate change, there exists a fare chance for good survival and proper nourishment of tropical tasar silkworm, *A. mylitta* in tropical and sub tropical forest areas of the state.

In the present study, we assessed the climatic suitability of New forest, FRI, Dehradun by comparing its meteorological data with district Surguja, Chhattisgarh, in Central India, where tropical tasar silkworm, *A. mylitta* is well established and forest dependent people traditionally rear Daba ecorace of *A. mylitta* for small house hold income twice in year.

Materials and Methods

Antheraea mylitta Drury has been reported to have adjusted in a wide range of climatic condition in different part of the country. In Surguja district of Chhattisgarh state, *A. mylitta* thrives well at existing temperature range of 4^0C to 46^0C. We compared the meteorological data of New Forest, FRI Dehradun, which is situated at 28° 42' 34.40'' N to 31° 28' 02.04'' N latitude and 77° 34' 31.45'' E to 81° 02' 34.61'' E longitude with district Surguja, located between 23° 37' 25'' to 24° 6' 17'' N latitude to 81° 34' 40'' to 84° 4'40'' E longitude. Monthly meteorological data of both the places on temperature, relative humidity and rainfall for last eleven years (from 2000 to 2010) were compared with each other. Weather data of New Forest, FRI, Dehradun was obtained from Forest Ecology & Environment, Forest Research Institute, Dehradun, whereas data for district Surguja was taken from Annual Reports of Basic Seed Multiplication and Training Center (BSMTC), Central Silk Board, Ministry of Textiles, Government of India, Ambikapur, Surguja, Chhattisgarh.

Selected variables for the study were: minimum temperature (T_{min}), maximum temperature (T_{max}), average temperature (T_{av}), Minimum relative humidity (H_{min}), Maximum relative humidity (H_{max}), Rain fall (RF) and Number of rainy days. Data of other weather variables like Vapour Pressure, Evaporation, Bright sunshine and wind velocity could not be compared, as these were not available in the reports of BSMTC Ambikapur, Surguja. Prior to the statistical analysis, distributions of all the variables were examined by using statistical software STATISTICA 10 (Stat Soft Inc, UK), and none required a transformation to achieve normality. We employed descriptive statistics and tested the significance of difference in the means of climatic variables by using Fisher's *t* test (Fisher, 1922). The level of significance for the study was fixed at P=0.05. Microsoft Excel 2007 was used to analyse the data as per following formula.

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\sigma^2\left(\frac{1}{n1} + \frac{1}{n2}\right)}}$$

Results

It was found that the climate of New forest, FRI Dehradun is moderate due to its location at the foot of the Himalayas, where summer starts by March and lasts up to mid of the June, when the south-west monsoon sets in over Uttarakhand. Month of the May and early part of the June are the hottest period. Winter starts in November and continues up to February. Most of the precipitation is received during July to September. July and August are the wettest months, and in November to January, both the districts receive winter rainfall. Results on analysis of selected climatic variables are detailed as under;

Temperature

Null hypothesis (H_0) for no difference in minimum, maximum and average temperature of New Forest, Dehradun and district Surguja was accepted by Fisher's *t* test, as calculated value

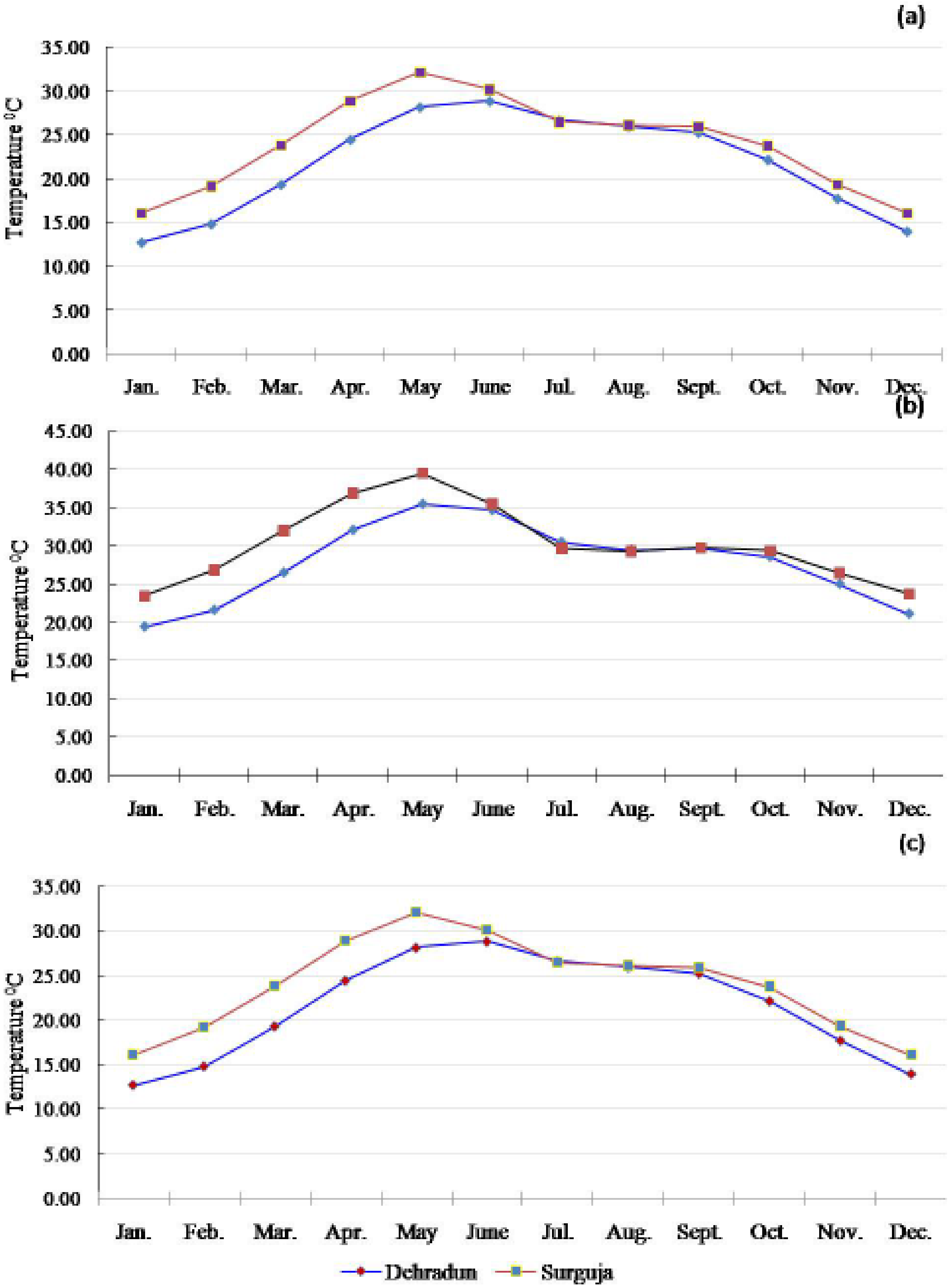

Fig. 1: a) Minimum (T_{min}); **b)** Maximum (T_{max}); and **c)** Average (T_{av}) temperature of New Forest, FRI, Dehradun and district Surguja, Chhattisgarh

of *t* statistic do not differ significantly at set level of significance (P = 0.05). Table 1, denoting the mean temperature of both the districts indicated an identical trend in minimum, maximum and average temperature (Fig 1a, b, & c). Descriptive statistics showed that standard deviation (SD) of T_{min} of Dehradun (6.58) was very close to Surguja (6.22), and similar trend prevails for rest of the variables also. Likewise, coefficient of variation of all the variables of both the places also varied with little margin, except to T_{min}, where CV (%) of Dehradun (42.52) was found a bit higher than Surguja (35.03%). Perusal of data indicated that Surguja is slightly warmer than Dehradun as for as minimum temperature is concerned.

Relative humidity

Null hypothesis (H_0) for no difference in minimum, maximum and average relative humidity of New Forest, Dehradun and district Surguja was also accepted by't' test (Table 2). Over all, relative humidity of the New Forest, FRI Dehradun was found a bit higher than that of district Surguja. From January to July, the minimum relative humidity (RH_{min}) of New Forest, Dehradun remains a bit higher than the Surguja,

Table 1: Mean temperature (^{0}C) of New Forest, FRI Dehradun and district Surguja from 2000 to 2010

Month	Minimum (T_{min})		Maximum (T_{max})		Average (T_{av})	
	Dehradun*	Surguja*	Dehradun*	Surguja*	Dehradun*	Surguja*
January	6.0	8.7	19.4	23.5	12.7	16.1
February	8.0	11.4	21.6	26.9	14.8	19.2
March	12.1	15.7	26.5	32.0	19.3	23.9
April	16.8	20.9	32.1	36.9	24.5	28.9
May	20.8	24.7	35.5	39.5	28.2	32.1
June	23.0	24.8	34.7	35.5	28.9	30.2
July	22.9	23.2	30.5	29.7	26.7	26.5
August	22.4	22.9	29.5	29.3	26.0	26.1
September	20.8	22.1	29.7	29.8	25.3	26.0
October	15.7	18.1	28.6	29.4	22.2	23.8
November	10.4	12.2	25.0	26.5	17.7	19.4
December	6.8	8.5	21.1	23.7	14.0	16.1
Mean	15.48	17.77	27.85	30.23	21.66	24.00
SD	6.58	6.22	5.25	5.01	5.77	5.32
SE of mean	1.90	1.80	1.52	1.45	1.67	1.54
CV (%)	42.52	35.03	18.85	16.58	26.65	22.18
Min.	6.00	8.50	19.40	23.50	12.70	16.10
Max	23.00	24.80	35.50	39.50	28.85	32.10
DF	22	22	22	22	22	22
t' at P=0.05	0.87		1.13		1.03	
't' at Error DF	2.07		2.07		2.07	
Test result	Non Significant		Non Significant		Non Significant	
*Values represents the mean of 11 years w.e.f. 01.01.2000 to 31.12.2010						

Table 2: Mean relative humidity (%) of New Forest, FRI Dehradun and district Surguja from 2000 to 2010

Month	Minimum (RH_{min})		Maximum (RH_{max})		Average (RH_{av})	
	Dehradun*	Surguja*	Dehradun*	Surguja*	Dehradun*	Surguja*
January	47.45	37.86	96.91	87.64	72.18	62.75
February	44.73	33.55	96.09	87.55	70.41	60.56
March	37.09	27.77	88.73	82.55	62.91	55.17
April	28.18	21.82	70.09	74.27	49.14	48.06
May	37.00	24.59	69.45	76.09	53.23	50.35
June	52.27	36.45	77.09	93.41	64.68	64.94
July	73.18	67.09	91.55	96.18	82.36	81.65
August	74.91	73.00	93.36	96.41	84.14	84.21
September	68.64	69.07	92.18	93.91	80.41	81.50
October	52.27	51.45	93.64	92.09	72.95	71.79
November	46.55	45.18	96.09	89.36	71.32	67.29
December	45.82	39.32	97.36	87.68	69.55	63.52
Mean	50.67	43.93	88.55	88.10	69.44	65.98
SD	14.73	17.63	10.31	7.27	10.74	12.00
SE of mean	4.25	5.09	2.98	2.10	3.10	3.46
CV (%)	29.06	40.12	11.64	8.25	15.46	18.18
Min.	28.18	21.82	69.45	74.27	49.14	48.06
Max	74.91	73.00	97.36	96.41	84.14	84.21
DF	22	22	22	22	22	22
t' at P=0.05	1.01		0.12		0.74	
't' at Error DF	2.07		2.07		2.07	
Test result	Non Significant		Non Significant		Non Significant	
*Values represents the mean of 11 years w.e.f. 01.01.2000 to 31.12.2010						

but from August onwards it becomes almost equal (Fig 2 a). RH_{min} at both the places began to decrease from January onwards and reaches its minimum in April. RH_{min} of Surguja showed high variability (CV=40.12%), whereas in Dehradun it was comparatively consistent (29.06%). Maximum relative humidity (RH_{max}) in both the districts decreased from February onwards and began to increase by June with onset of the monsoon. Except to the month of June, where there exists a variation of 16.32 % between RH_{max} of Dehradun (77.09) and Surguja (93.41), rest of the period varied closely (Fig. 2b). The average relative humidity (RH_{av}) of both the places showed a decreasing trend from January onwards, and an increasing trend from June. Fig 2a, b & c showed that from April onwards RH_{av} of both the place varied closely. Overall, RH_{av} of New Forest, FRI Dehradun was found a bit higher by 4% than the district Surguja, but was found non-significant.

Rain fall

Perusal of the data shown in table 3 indicated that New Forest, FRI, Dehradun receives 455.34 mm more rains than district Surguja. Similarly, number of rainy days of Dehradun was also higher by 11.3 days. However, null hypothesis (H_0) for

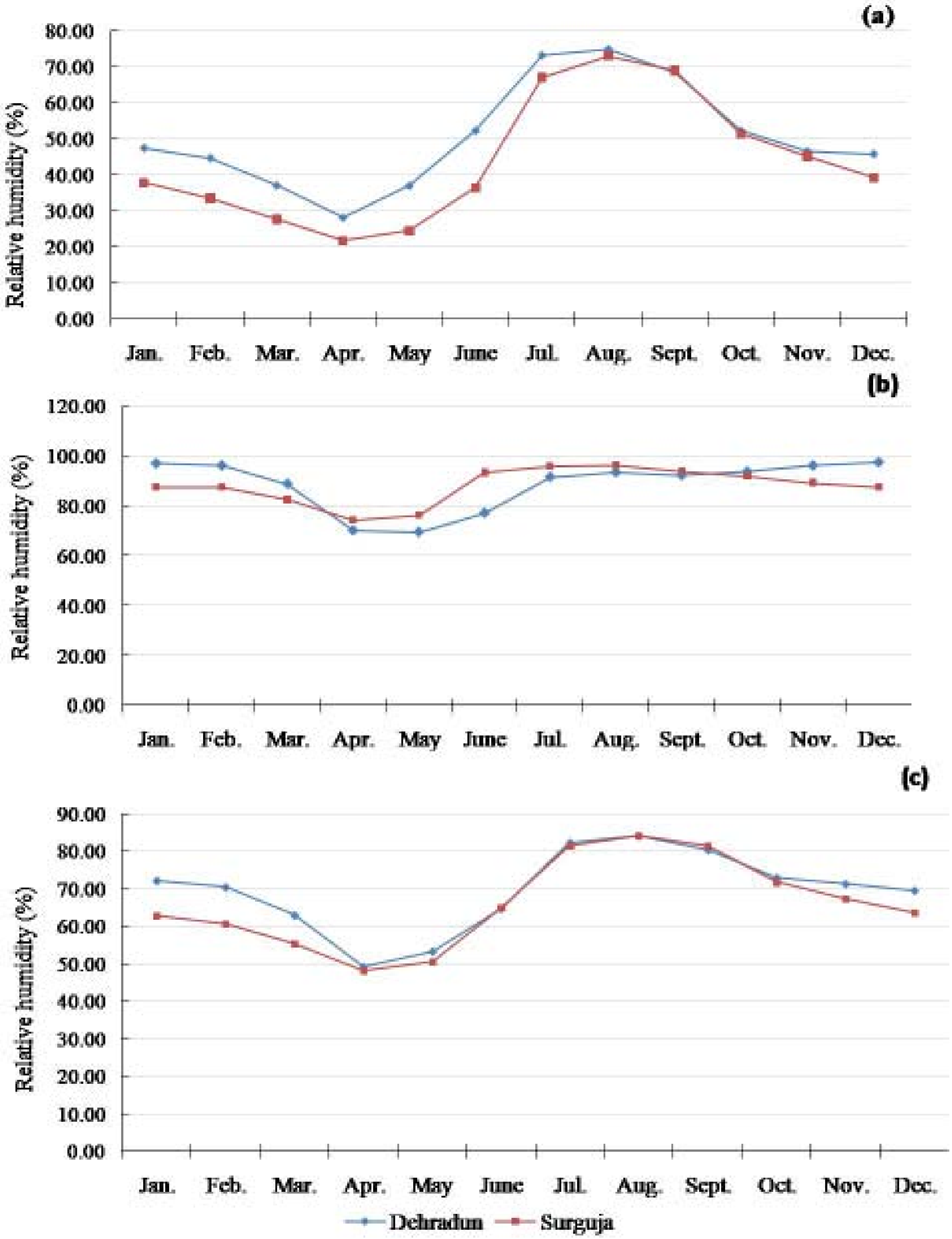

Fig. 2: a) Minimum (RH_{min}); **b)** Maximum (RH_{max}); and **c)** Average (RH_{av}) relative humidity of New Forest, FRI, Dehradun and district Surguja, Chhattisgarh

Table 3: Mean rainfall (mm) and number of the rainy days of New Forest, FRI Dehradun and district Surguja from 2000 to 2010

Month	Rain fall (mm)		Number of Rainy Days	
	Dehradun*	Surguja*	Dehradun*	Surguja*
January	37.40	22.80	4.90	3.10
February	58.40	22.70	5.80	3.70
March	53.50	24.70	5.60	3.40
April	23.66	13.40	4.10	2.80
May	67.26	19.40	6.00	3.30
June	201.77	212.40	12.80	13.40
July	557.20	428.00	24.10	23.30
August	547.44	383.20	23.50	22.50
September	278.52	225.40	15.40	15.40
October	36.51	55.60	3.40	5.30
November	5.93	8.90	1.40	1.00
December	10.55	6.30	2.70	1.20
Total	1878.14	1422.80	109.7	98.40
Mean	156.51	118.57	9.14	8.20
SD	201.97	154.53	7.94	8.22
SE of mean	58.31	44.61	2.29	2.37
CV (%)	129.05	130.33	86.88	100.23
Min.	5.93	6.30	1.40	1.00
Max	557.20	428.00	24.10	23.30
DF	22	22	22	22
t' at P=0.05	0.51		0.28	
't' at Error DF	2.07		2.07	
Test result	Non Significant		Non Significant	
*Values represents the mean of 11 years w.e.f. 01.01.2000 to 31.12.2010				

no difference in mean rain fall and number of rainy days for both of the places was accepted by Fisher's't' test. Data also revealed that the average annual precipitation at New Forest, FRI, Dehradun was 1878.14 mm, and most of the rains were received during July to September (1383.16 mm); whereas, in Surguja it was 1422.80 mm and from July to September, district receives 1036.60 mm rainfall, annually. In November and January, both the districts received winter rainfall of 53.88 mm and 38 mm, respectively.

Discussion

Climate is the most fundamental and vital element of the nature. It influences all the abiotic and biotic factors that decide the extent and variety of vegetation of a region. The climate of a place is influenced by variety of local physical features, such as exposure, the slope of the land and the vegetation (Ramdas, 1974). Tropical forest in Uttarakhand is an environmentally sensitive area that calls for much better knowledge of climatic features and trends, before introduction of any commercial insect species in the state.

Among all the variables, *Temperature* is the most important factor of the climate. It is the term which is used to express the intensity or degree of heat. The differences in the elevation

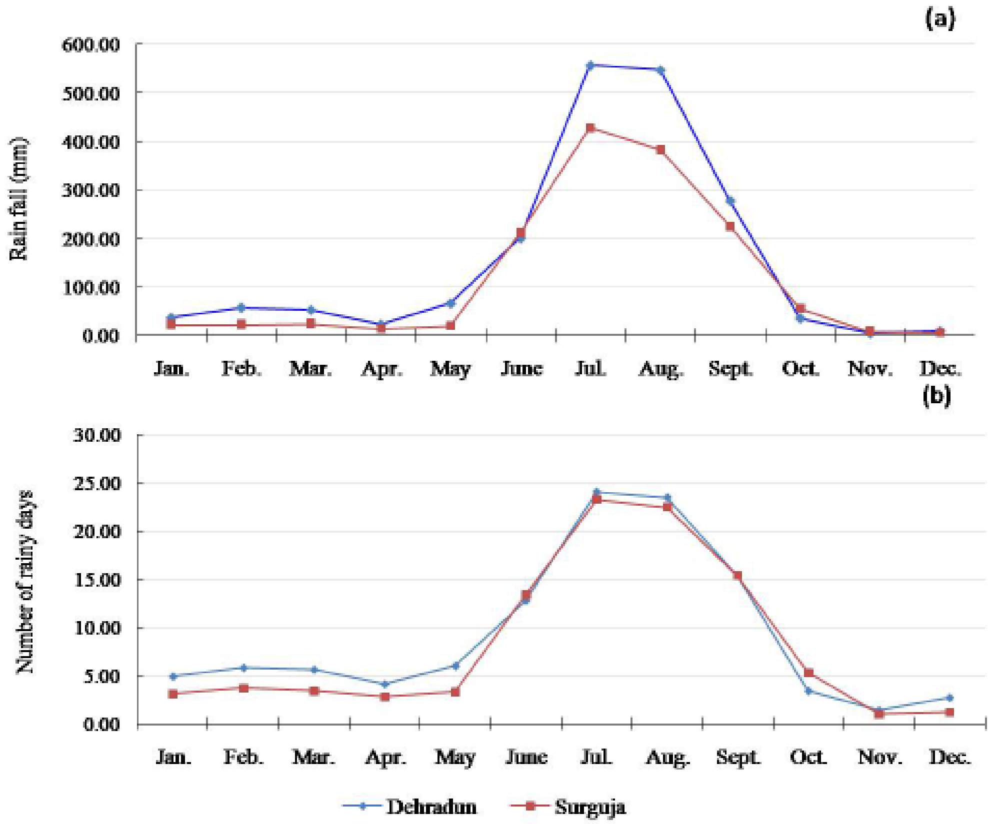

Fig. 3: a) Mean rainfall; and **b)** mean number of rainy days of New Forest, FRI, Dehradun and district Surguja, Chhattisgarh.

of the sun cause differences in the heating of the earth surface. Uttarakhand receives its maximum amount of solar radiation during May-June, and minimum during December-January. The factors such as latitude, altitude, humidity, winds etc. have an influence on temperature. The effect of altitude varies with conditions; a 1000 m rise in the hills, there is roughly a fall of 6 ^{0}C in temperature (Murthy *et al.,* 1996).

All insects can be considered to be poikilothermic, that is their body temperature varies with that of their surroundings. Insect's basic metabolism is a function of the temperature: higher the temperature - the faster the metabolic reactions. Developmental time in insects is essentially the reciprocal of development rate; it means development rate of larvae increases as development time decreases. Similarly, the ecologies of predators and parasitoids are also affected by temperature, because activity and foraging success of predators and parasitoids can be temperature dependent (Speight *et al.,* 2008).

Results of temperature data indicated that Surguja is a bit warmer than Dehradun, but statistically, it was negated. However, *A. mylitta* being poikilothermic, may indicate an increased larval span in Dehradun, especially during second crop rearing of September to November, and this may increase the risk of natural enemies, hence cocoon productivity may decrease in comparison to Surguja. However, during first crop rearing of July-August, the temperature of Dehradun (26.00 ^{0}C to 26.7 ^{0}C) and Surguja (26.10 ^{0}C to 26.5 ^{0}C) is quite identical, which indicates that performance of first crop rearing in Dehradun would be normal.

Temperature is also known to be regulated by photoperiod. The length of daylight during a 24 h day-night cycle is known as photoperiod, which may not exactly qualify as a climate factor per se, but it has some fundamental influence on the development and ecology of insects. The day length experienced by an insect provides information about the progression of the seasons. The durations of the various stages in the lifecycle from egg to adult vary according to the photoperiod and temperature (Leimar, 1996).

One of the most interesting and controversial topics in applied insect ecology today is that of *climate change and global warming*. A considerable raise in temperature may affect voltanism pattern of *A. mylitta*, which is a direct function of temperature and photoperiod. Further, their reproduction rate is also bound to increase on such variations in temperature. Several other insect pest and predator may also extend their geographic ranges as climate warms (Parmesan, 2006). But what concerns many entomologists today is that elevated temperature may have serious consequences for outbreak of insect pests, but as far as, tropical tasar silkworm, *A. mylitta* is concerned, temperature increase will facilitate them to find out new habitat in cooler areas of Indian states like Uttrakhand, Himachal Pradesh and Jammu and Kashmir, where they are not established yet. This will depend, off course, on concurrent responses of its forestry host plants and simultaneous population build up of their natural enemies upon such climate changes.

Relative humidity is also an important climatic factor that refers to the amount of water vapour in the air. The amount of water vapour present in the atmosphere depend on temperature and increases with increase in temperature. When temperature falls, the excess water vapour condenses into water droplets which form cloud, rain, mist or fog, known as *precipitation*. The primary source of atmospheric humidify is the oceans. The water is evaporated from these water bodies by winds through diffusion method. The secondary sources are the moist land surfaces, the vegetation cover and the minor water bodies (Murthy *et al.,* 1996). Results indicated that relative humidity of district Dehradun is almost at par with Surguja; therefore, its effect on biological success of *A. mylitta* would not normally be deleterious.

Rainfall is another climatic parameter that affects life cycle of *A. mylitta* in tropical forests. The South-West Monsoons and the North-East Monsoons bring good rains in Uttarakhand. The direction of mountain ranges greatly influences the distribution of rainfall in the country. The effect of rainfall on insects can be direct or indirect. Heavy rain can knock newly brushed larvae of *A. mylitta* off their host plants. Seasonal rains influence the ways in which host plants grow and provide foods to insects (Hale *et al.,* 2003). Droughts can stress forestry tree species, rendering them unfit for feeding by silkworm larvae. Rainfall also affects humidity, which combines with temperature and wind and dictates the local microclimatic conditions. Rainfall patterns can influence the long-term abundance of insect population. *A. mylitta* may get benefit from luxuriant growth of new foliage due to consistent rains; and a good link between high rainfall, healthy host plants, and better performances of *A. mylitta* may exist in Uttarakhand. But at the same time, this will also influence population of its natural enemies, which may reverse these ecological influences on *A. mylitta* in Uttarakhand.

Conclusion

The outcome of this study indicated that owing to climatic similarities of New Forest, FRI Dehradun with tropical forest areas of district Surguja, tropical tasar silkworm, *A. mylitta* may complete its life cycle in tropical forest areas of Uttarakhand. However, in order to explore the possibility of commercial field rearing of this silk producing forest insect by forest dependent people in Uttarakhand; evaluation of *A. mylitta* on different host plants of forestry importance is necessary, which is under way at FRI, Dehradun. It is also concluded that this kind of quick and easier indicative study could be undertaken in other forested areas of the country to stimulate the beginning of location specific forest insect industry to expand the livelihood delivery of the forests to their dependents.

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