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Population dynamics of teak defoliator, *Hyblaea puera* Cramer at coastal Odisha, India

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Abstract
Among the insect pests attacking teak, the teak defoliator, *Hyblaea puera* Cramer (Hyblaeidae, Lepidoptera) is the most widespread and serious pest causing about 44.1% loss in increment volume of plants,. Hence, in the present investigation an attempt is being made to study the population dynamics of *Hyblaea puera* at the agro climatic situation of coastal Odisha situating at 19.2-21.4ºN Latitude and 84.9-86.9ºE Longitude. Highest population of this pest was recorded in larger teak plants during 2nd fortnight, July 2016 and during July, 2017respectively. *Spathodea campanulata* was recorded little higher population during July 2nd fortnight, 2016and the other studied host, *Vitex negundo* recorded highest larval population during August, first fortnight, 2016 respectively. The correlation co-efficient of larval population density recorded from different host plants during different months of the year was found to be statistically significant along with prevailing rainfall and relative humidity (%). Much difference was not observed in final instar larval weight and duration, male and female adult morphology and longevity in all the studied hosts. However, more male(237.20mg) and female(287.00mg) pupal weight was observed in population reared with *Spathodea campanulata* Sudden appearance of *Hyblaea puera* populations in coastal tract of Odisha coinciding with onset of monsoon may be due to wind aided migration of moths from southern Indian states witnessing large areas under plantation of teak. The end season population is subjected to natural mortality factors like predation and parasitism (63% in July 2017 collected population). Residual population surviving the stresses, either may be perished due to non availability of sufficient fresh leaves during that period or may be migrated to nearby mangrove forests.

Keywords: *Hyblaea puera*, mangroves, morphometry, population dynamics

1. Introduction
In India, teak grows naturally in 9 million hectares of southern tropical deciduous forests of Peninsular India situated below 24^0 N latitude, Seth and Kaul, 1978 [26] Currently1.5 million hectares of teak plantations exists in India and around 50,000 hectares are planted annually Subramanian *et al*., 2000 [28]. Thus, it is one of the top five tropical plantation species of the world as well as India. At present large-scale monoculture of teak has been practiced in different states of the country. The major growing states are Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala besides, Uttar Pradesh, Gujarat, Odisha and Rajasthan, Tewari, 1992 [29]. In Odisha, Teak is spread over 2030 km^2 of the total forest area of 58,135 km^2. It is also found growing in miscellaneous forests of area 21,024 km^2 and other plantation sites. About 187 insect species have been found feeding on living Teak tree in India. Hutacharim and Tubtim, 1995 [9]. Amongst the foliage feeders, the teak defoliator, *Hyblaea puera* Cramer (Hyblaeidae, Lepidoptera) and teak skeletonizer, *Eutectona machaeralis* Walker (Pyralidae: Lepidoptera) are the most widespread and serious pests. Outbreak of these pests occurs almost every year in Odisha as well as in other teak growing regions of India. During these outbreaks in the early flushing period of teak, trees undergoes total defoliation, sometimes there is partial defoliation is also observed during the later part of growth season (Nair, 1988 [17] *H. puera* has also become an economic pest in non-native teak countries such as Costa Rica and Brazil, where outbreaks appeared all of a sudden during 1995 and 1996, respectively Nair, 2007 [20]. Studies in young teak plantations at Nilambur of Kerala in South India showed that defoliation by *H. puera* caused loss of 44.1% of the potential wood volume increment over a 5 year cumulative period, Nair *et al*., 1996 [16]. One set of experimental plots set by Nair were exposed to natural insect defoliation and second set was fully protected by chemicals from insect infestation. The chief defoliating insect was *Hyblaea puera* as the second defoliating insect, *Eutectona machaeralis* appeared late in the season. However, no systematic

Study has been undertaken in Odisha regarding its biology, alternate hosts, population dynamics etc. to draw a definite IPM (Integrated Pest Management) strategy. Hence, the present investigation is aimed to study the population dynamics of *Hyblaea puera* in East and South East Coastal plain of Odisha.

2. Materials and Methods

Abundance of defoliator of teak was recorded at four different locations in and around Bhubaneswar as detailed in Table 03 and situating at 19.2-21.4ºN Latitude and 84.9-86.9ºE Longitude. Plants were divided into three categories such as (i) Seedlings- 0-1 year old (ii) Saplings with 1-3 year old (iii) Plants- more than 3 years old as like Pandey *et al.,* 2010[23]. For seedlings and saplings all the leaves were selected from 30 randomly selected plants and sampled. For more than 3 year old plants, five terminal twigs were randomly selected from the lower and middle crown of each plant and 10 plants were taken at each location. All leaves were sampled for observing number of healthy and damaged leaves, thus percent infestation due to defoliation was worked out by using the formula.

$$\% \text{ defoliation} = \frac{\text{Number of healthy leaves - Number of infested leaves}}{\text{Number of un infested leaves}} \text{ x } 100$$

Leaves with minor injury due to defoliator attack were also counted as infested leaf for all the three studied hosts. The other two host plants viz. *Spathodea campanulata* and *Vitex negundo* located in the near vicinity of the sampling sites were also observed thoroughly and sampled simultaneously in the same manner for presence of larva of *H. puera* and its infestation. Observations were recorded at fortnightly interval along with major weather parameter viz., temperature, relative humidity and rainfall at each location and linear correlation was worked out as per Gomez and Gomez, 1984 [7]. Field collected early and late season population eggs from teak were reared in the laboratory up to adult stage in teak leaves to ascertain the reasons and extent of mortality. The eggs were collected along with the reddish coloured succulent leave with water soaked cotton plugs given at the base to make them fresh at least for two days. The field collected larvae were brought to the laboratory and transferred carefully with a fine Camlin hair brush to rear individually in small perforated plastic jars (10cm x 10cm) with leads to facilitate aeration. Fresh and tender leaves of teak, *Spathodea* and *Vitex* were provided separately to each jar as food in the morning by replacing old leaves until pupation. After pupation of larvae in silken cocoon, they were transferred to separate plastic jars of same size. The pupae thus formed were examined under binocular microscope and sexed by examining the position and distance between anal and genital slits. Male and female pupae were kept in separate plastic jar (15cm x 15cm) for the emergence of adults. Thereafter, newly emerged male and female adults were collected in plastic jar and were transferred to separate fibre rearing cages (50cm x 50cm x50cm) for mating and egg laying, Tripathy *et al*, 2018. [30]. Different biological parameters like time taken to become adult, larval and pupal weight was recorded. Adult morphometry was also recorded in populations reared in the 3 different host plants to compare the effect of feeding of different hosts on the biology of this pest. Before taking the measurements across their expanded wings with the help of automatic slide callipers, they were differentiated into male and female. Care was taken to avoid any damage to the adults during measurement. All the sampling units were surveyed during 1st week of December, 2016 to access the extent of parasitisation in the field in the end season population. The infested leaves were examined to count the no. of folds made by *Hyblaea puera* and parasites recovered from such folds were identified from bio control laboratory of Entomology Dept. College of Agriculture, OUAT, Bhubaneswar. ANOVA and CD both at 5% and 1% label and DMRT from the biological parameter studies were calculated by using the software SPSS version 16.0.

3. Results and Discussion

Data presented in Table-1 revealed that mean percentage defoliation in teak plants at Bhubaneswar varied from a minimum of 2.51%(March, first fortnight) to 82.74%(July, second fortnight) The mean larval population of defoliator in teak seedlings were varied from 0.32/ seedling (Nov 2nd fortnight) to 12.03/ seedling(July second fortnight, 2017). Highest population per twig in larger teak plants belonging to 3rd category was recorded as 5.75/ twig during 2nd fortnight, July, 2016 and 5.05 during July, 2017 respectively. *Spathodea campanulata*, another important host plant present in the near vicinity was recorded little higher larval population (7.83/twig) during July 2nd fortnight, 2016 whereas the third host, *Vitex negundo* present in the vicinity recorded highest population of 6.78 no's larvae/twig during August first fortnight, 2016 (Fig2-5).However, the larval availability in both the other hosts are for shorter period in comparison to the main host teak. Data in Table 02 reveals the correlation co-efficient of larval population density recorded in different host plants during different months of the year and this was found to be statistically significant both at 5% and 1% level along with rainfall (mm) and relative humidity (%) at 14 hours for all the studied hosts.

All the sampling units were surveyed during 1st week of December, 2016 to observe the extent of parasitisation of this pest in the field and the results are presented in Table-3. All the locations were situated within 50km radius with the centre at College of Forestry seedling nursery located at OUAT, Bhubaneswar. The infested leaves were examined to count the no. of folds made by *Hyblaea puera*. This was varied from 4.2 to 8.6 in different places of sampling and percentage of larvae parasitized was ranged from 68.15% to 90.13% and the dominant parasite species was recorded as *Apantales sp* in all the locations except one where *Bracon sp*. was found. A study on field collected and laboratory reared eggs collected during July, 2017, recorded a total of 63.00% mortality at different stages of growth due to different mortality factors whereas eggs collected during. Oct,2016 in teak recorded 79.62% mortality (Table-3) The nematode species, *Hexamermis sp* was identified from laboratory reared final instar larvae of *Hyblaea puera* from Nematology Department, CA OUAT, Bhubaneswar. It is evident from data sited at Table-4 that initial mortality was higher in egg and first instar stage in both the time of collection. Hence, the late season collections are more subjected to mortality (39.21%). This also indicates that any variation in existing situation makes the population more susceptible. Hence, during the year of early dry spell the availability of this pest is reduced in subsequent period.

The biology of this pest was studied in detail in population collected from teak during August 2016 after being reared in leaves of teak and other host plants i.e., *Spathodea* and *Vitex*. Much difference was not observed in final instar larval weight and larval duration However, more male and female pupal

weight was observed in population reared with *Spathodea*. The final instar larval weight, duration from egg to adult in both the sexes and female longevity was not significantly different as stated in Table-5. Only larval duration (16.51days) and pupal weight (237.2mg) of males in populations reared in this *Spathodea* leaves differs significantly than that reared in other which are statistically at par. This observation shows that this pest has no special preference to teak than other studied alternate host which was available in the sample area and able to sustain the residual population if any or that could immerge after breaking of diapause if it is there. This leads to the assumption that the end season population either perish at the spot or migrate to elsewhere. But wind direction doesn't confirm the second assumption. Although its outbreak in mangrove is reported during September – October from Bombay, Chaturvedi, 1995 [3], 2002 [4].

Adult morphometry of male and female *Hyblaea puera* population collected from the field in three different months *ie*., July, 2016, July, 2017and Oct, 2016 as final instar larvae are presented in Table 6 and 7 respectively. Females recorded more length at wing expanse and abdomen length than males. Both male and female adults were smaller in size collected during October, 2016 than July, 2016and July, 2017 although the difference was less significant

In Bhubaneswar, the pest makes its initial appearance during June-July and in Gujarat it appears during the same month, Kabade *et al*., 2015 [10]. The present observations made on the peak incidence of *H. puera* also corroborate with the report of Khan *et al*. 1988[11] who have also observed its peak incidence during July and August while least active period was from September onwards. A correlation between the monsoon rains and the occurrence of *Hyblaea puera* outbreaks in teak is well established by observations from many places in India Bhowmik & Vaishampayan, 1986 [3]. Khan *et al*. 1988 [11]. Nair & Sudhendra Kumar, 1986; [20], Loganathan *et al*., 2001 [12]. The present study also followed the same pattern and correlation coefficient between rain fall and larval population of defoliator are also found as positive and statistically significant both at 5% and 1% level for all the hosts. As cleared from table 3, more than 63% of larvae are subjected to normal mortality in a single generation due to action of parasites, predators and pathogens etc. Again, during late season, more than 89% of the larval parasitisation occurs, very often pupation occurs inside the leaf fold. (Table-3). Nair *et al*. 1985[21] reported the migration of moths up to 10 km for suitable host trees. This report is also in agreement with Nair and Sudheendra kumar, 1986 [20]. Who reported the migration of moths from one locality to other. Beeson 1941 [2]. and Mathur 1960 [14]. Have opined that the variation in population abundance is possibly controlled by factors such as rainfall and temperature of a locality. The occurrence of higher population of larvae during June and July in the present study was also in agreement with the report of Nair and Sudheendrakumar (1986) [20], Nair and Mohandas (1996) [15] opined that the outbreak of *H. puera* occurred on teak following the early seasonal shower during May-June.

Our morphometry studies indicates that population collected from reared larvae in end of season are relatively less stout than early season as given in table 5&6 Probably early season collections are arrived due to migration in which immunity is diluted in subsequent generations. As viewed by earlier workers like Vaishampayan Jr and Singh, 1996 [33], the migratory form of *Helicoverpa* are larger in size with higher amount of fat bodies From June to October, the *Hyblaea puera* population in the studied localities might have passed four to five generations and this must coincide with larval emergence during each generation. Teak seedlings present in the nursery of the sampled area are sprayed with 4-5 times to control its population. But a survey of other hosts (Table-1) during the lean period never shows any larval population although other hosts like *V. negundo*, *Spathodea campanulata* and *Millingtonia hortensis* were available. But when the larval population recorded its peak in teak during July-August, during that time the nearby *V. negundo* and *Spathodea campanulata* plants also harboured *Hyblaea puera* larval population. If the residual population undergoes diapause there must be moth emergence and egg laying in suitable hosts after summer rain fall which has not been noticed. From meteorological data it is found that the average rainfall received in the studied location during March 1st fortnight is 45.4mm and April 2nd fortnight is 29.2mm. However, the population started appearing during the following June 1st fortnight i.e., after onset of premon soon rainfall in the area. Our laboratory investigations on effect of feeding of different host plants on biology of this pest also corroborate the findings of earlier workers like Baksha and Crawley 1995 [1]. Who reported that much difference was not there in the biological parameters while fed on different hosts. It was also confirmed that teak seedlings are infested severely during each year immediately after monsoon rain fall and after a short gap large outbreaks occur over the large area of plantation. The wind direction during South-West monsoon shows that wind flows from South side *i.e.* Kerala and it reaches Odisha on 2nd week of June which might be supporting wind aided migration of moths (Table-1). Locally it is also observed that the incidence is being started from initiation of monsoon rain during each year. Earlier workers also viewed that the moths reaches through monsoon wind system by a combination of active flight and passive transport. Monsoon linked long range migration has been observed using radar and aircraft in other moths like *Spodoptera exempta* from Africa and many noctuids as well as pyralids in Australia (Drake and Farrow, 1985 [6], China, Chen *et al*., 1989 [5] and Central America, Miller, 1987 [13]., Wolf *et al.,* 1990 [34]., Rose *et al,* 1985 [25]., Riley *et al.* 1983 [24]. One of our sampling location i.e Hi-tech forest nursery located near about 50 K.M from Bhubaneswar and located within forest ecosystem might be the centre for epicentric spread after which infestation is gradually spreads towards North side as the period of first notice in north side locations is delayed.. However, not all the plantations of an area is attacked simultaneously although sufficient red coloured tender leaves and twigs are available as the mode of feeding by the pest is erratic. Much difference in physiology of the pest is not observed when fed under different hosts in the laboratory (Table-5), so it can be ascertained that the population could thrive in alternate hosts in case of their diapauses termination, but it is not observed in the present case. The possibility of migration was reported earlier from India Vaishampayaa and Bahadur 1983 [31]. Vaishampayan *et al*. 1987 [32]. Nair, 2000 [18]. And Kenya Sevatopulo, 1978 [27]. Nair & Sudhendra Kumar 1986 [20]. Reported that the majority of moths that emerge from an outbreak site did not oviposit in the same area even when suitable host plants are available. They can congregate for a shorter period and move away from the site. Hence frequent outbreaks on the same site is not observed. Nair, 1988, [16]. Nair and Mohandas 1996 [15]. But

migration whether short or long range is an essential feature of the life system of *Hyblaea puera*. If they are ovipositing in the same area then out breaks in the near vicinity could have been checked after application of pesticides in the main centre which has not been seen. The origin of moths in southern most tips of Kerala which gradually spreads towards North was also viewed as uncertain. Nair, 2007 [19]. Although in India most of the workers reported the availability of *Hyblaea puera* is up to October. But in Bhubaneswar, it was available in very low numbers up to December 1st week particularly in saplings of one of the sampling locations. Delayed rainfall recorded during 2016-17 *i.e.* up to October last week might be the reason for this.

Table 1: Defoliation dynamics and larval population densities of *Hyblaea puera* in different hosts during the experimental period (June, 2016-July, 17) at Bhubaneswar, Odisha.

Observation week no.	Mean percentage defoliation (%)in teak	Mean Larval population (teak)		*S. campanulata*	*V. negundo*
		No. per seedling	No. per twig	No. per twig	No. per twig
June I	33.64±2.04 (20.54-42.07)	0.34±0.60 (0.00-2.00)	0.25 ± 0.32 (0.00-1.00)	0.00	0.00
June II	44.28± 1.61 (31.75-52.75)	1.36±1.08 (0.00-3.00)	0.43± 0.54 (0.00-1.00)	0.00	0.00
July I	71.19±1.42 (59.96-84.33)	7.87± 1.09 (2.00-15.00)	2.15± 1.06 (0.00-3.00)	3.45±0.78 (0.00-5.67)	3.66±1.06 (0.00-7.88)
July II	82.74± 1.37 (70.23-92.06)	11.23± 2.03 (4.00-18.00)	5.75± 2.86 (2.00-7.00)	7.83±0.65 (3.00+10.55)	5.95±0.75 (2.98-7.65)
Aug I	72.23± 2.20 (61.89-81.53)	6.28± 2.86 (2.00-12.00)	4.12± 1.24 (1.00-6.00)	4.48±0.78 (2.00-5.67)	6.78±1.28 (2.95-7.65)
Aug II	73.69± 2.17 (51.04-74.24)	5.87±2.57 (1.00-8.00)	1.71± 1.27 (0.00-4.00)	3.05±0.71 (02.50-0.67)	4.78±1.18 (2.98-7.65)
Sept I	35.23± 1.72 (25.06-46.75)	1.50± 1.16 (0.00-4.00)	1.43± 1.46 (0.00-3.00)	1.44±0.78 (0.00-5.67)	2.78±1.32 (1.91-5.65)
Sept II	32.49± 4.01 (21.35-47.75)	1.27± 0.85 (0.00-3.00)	1.12± 0.86 (0.00-2.00)	2.55±0.48 (0.00-6.63)	3.78±0.80 (2.93-7.65)
Oct I	54.68± 4.58 (48.90-63.56)	1.58± 1.04 (0.00-3.00)	0.45± 0.48 (0.00-2.00)	2.45±0.54 (1.00-5.17)	1.78±0.28 (0.98-3.65)
Oct II	67.34± 6.35 (60.54-73.71)	1.81±3.24 (0.00-3.00)	0.82± 0.28 (0.00-1.00)	1.45±0.78 (0.00-5.67)	0.78±1.08 (0.80-4.65)
Nov I	16.32±6.15 (12.34-20.21)	0.42± 0.43 (0.00-2.00)	0.31± 0.29 (0.00-1.00)	0.43±0.38 (0.00-4.07)	0.38±0.58 (0.98-5.65)
Nov II	16.75± 6.43 (13.58-19.87)	0.32± 0.34 (0.00-1.00)	0.25± 0.22 (0.00-1.00)	0.45±0.48 (0.00-2.17)	0.00
Dec I	15.34± 5.51 (12.32-19.67)	0.35± 0.37 (0.00-1.00)	0.12± 0.14 (0.00-1.00)	0.45±0.78 (0.00-2.67)	0.00
Dec II	8.78± 3.31 (6.47-9.57)	0.00	0.00	0.00	0.00
Jan I	5.27± 7.15 (2.81-8.40)	0.00	0.00	0.00	0.00
Jan II	5.84± 2.8 (3.78-9.83)	0.00	0.00	0.00	0.00
Feb I	4.21± 2.49 (2.07-8.73)	0.00	0.00	0.00	0.00
Feb II	3.57± 3.24 (0.00-8.29)	0.00	0.00	0.00	0.00
Mar I	2.51± 2.34 (0.00-8.43)	0.00	0.00	0.00	0.00
Mar II	3.54± 4.32 (0.00-7.35)	0.00	0.00	0.00	0.00
Apr I	4.25± 3.87 (0.00-8.21)	0.00	0.00	0.00	0.00
Apr II	2.14± 2.11 (0.00-4.65)	0.00	0.00	0.00	0.00
May I	2.36±1.64 (0.00- 5.32)	0.00	0.00	0.00	0.00
May II	3.18±1.86 (0.00-5.12)	0.00	0,00	0.00	0,00
June I	20.64±2.04	0.28 ±0.32	0.28 ± 0.32	0.00	0.00

	(15.54-36.27)	(0.00-2.00)	(0.00-1.00)		
June II	39.78±1.76 (21.45-64.75)	1.06±1.08 (0.00-3.00)	0.43± 0.54 (0.00-1.00)	0.00	0.00
July I	82.19±1.56 (59.96-84.33)	8.36± 2.09 (2.00-15.00)	2.15± 1.06 (0.00-3.00)	2.08±0.67 (0.00-4.32)	2.58±0.31 (0.00-5.33)
July II	78.74±2.37 (45.86 -90.66)	12.03 ± 2.03 (3.00-18.00)	5.05± 2.46 (2.00-7.00)	2.25±0.46 (0.00-4.33)	3.55±0.67 (0.00-4.31)

*Each figure denotes Mean ±*S.D;* figures in parenthesis are range values. I-first fortnight, II-second fortnight

Table 2: Co-relation co-efficient of *Hyblaea puera* larval *population* density collected from different hosts along with weather parameters at Bhubaneswar, Odisha during 2016-2017

Weather parameter Host plant	RH (%) 14hrs	Temperature(ºC)		Rainfall (mm)
		Max	Min	
Tectona grandis	0.659**	-.257ns	0.359ns	0.758**
Vitex negundo	0.732**	-.315ns	0.329ns	0.701**
Spathodia campanulata	0.689**	-.298ns	0.342ns	0.688**

*significant at 5% level** significant at 1% level ns-nonsignificant

Table 3: Percentage parasitisation of *Hyblaea puera* in teak fields at different survey locations during December 2016.

Place of observation	Percentage of leaves infested (%)	Average no. of folds per leaf with *Hyblaea puera* infestation	Average no. of folds with parasitized larvae	Percentage of leaf fold harbouring parasitized larvae (%)
Poplar field Site-1,BBSR	85.20±4.12a	7.30±0.68b	6.15±0.83a	90.13±1.57
Silvicultural research station Site-2,BBSR	79.50±3.56b	8.50±1.23a	7.27±1.51a	73.71±1.23
Live stocks farm Site-3,BBSR	73.30±4.23c	4.2±0.53c	3.00±1.22b	68.15±2.77
Hi-techforest nursery, KHURDA Site-4,	81.27±4.71a	8.61±1.37a	7.81±0.53a	88.35±1.83
±SEm	1.293	0.340	0.759	6.509
Cd (0.05)	4.472*	1.178*	2.626*	22.519^{NS}
Cv%	2.80	8.24	21.70	14.08

*Each figure denotes Mean ±*S.D,*

Mean with same superscript within the column do not differ statistically at DMRT test.

Table 4: Age specific mortality of field collected eggs (n=200) of *Hyblaea puera* Cramer collected from Taratua hi-tech forest nursery, Khurda, during 2016-2017

Stage of the pest	Date of collection 05.07.2017		Date of collection03.10.2016	
	Percentage mortality	Reasons	Percentage mortality	Reasons
Egg	12.00±1.52bc	Sterility and others	16.67±2.02b	Sterility and parasites
1st instar	21.00±2.53a	Parasitism	22.54±2.58a	Parasitism
2nd instar	13.00±1.25b	Parasitism	15.68±0.76b	Parasitism
3rd instar	5.00±0.53de	Pathogen and parasite attack	6.78±0.68cd	Pathogen and parasite attack
4th instar	2.00±0.28e	Pathogen attack	4.88±1.25d	Pathogen and parasite attack
5th instar	8.00±0.59cd	Nematode, Pathogen and parasite attack	9.52±2.20c	Pathogen and parasite attack
Pupa	2.00±0.20e	Unknown reasons	3.55±1.34d	Pathogen and parasite attack
Adult	-------	-------	-------	------
Total	63.00±1.64	--	79.62±1.55	
±SEm	1.394		1.203	
CD (0.05)	4.296*		3.707*	
CV%	26.84		18.32	

*Each figure denotes Mean ±*S.D*

Mean with same superscript within the column do not differ statistically at DMRT test.

Table 5: Biology Parameters of *Hyblaea puera* Cramer reared in laboratory in different host plants at Bhubaneswar (2016-2017)

Sl. No	Name of the host	Biology Parameters											
		Final instar larval weight (mg)	Larval duration (days)	Pupal Weight(mg)		Days taken from egg to adult		Adult size(mm) male		Adult size(mm) female		Adult longevity (days)	
				Male	Female	Male	Female	Across wing	Body Length	Across wing	Body Length	Male	Female
1	Teak leaves	280.75 ±1.48 (240.00-400.00)a	15.31±1.18 (11.00-19.00)b	230.50±0.60 (190.00-250.00)b	280.00±0.50 (240.00-320.00)b	21.35±0.68 (18.00-23.00)a	23.54±0.76(19.00-24.00)a	30.42±2.86 (27.00-34.20)a	14.05±1.73 (12.00-16.75)b	32.42±2.06(28.50-34.50)a	15.04±2.11(13.50-17.40)b	8.05 ±1.26b	8.80 ± 0.88a
2	*Spathodia* leaves	289.75±2.38 (260.00-400.00) a	16.51±1.54 (12.00-19.00) a	237.20±0.68 (190.00-260.00) a	287.00±0.50 (250.00-320.00) a	20.85±0.58 (18.00-23.00) a	22.35±0.71 (19.00-24.00) b	30.12±2.44 (27.50-34.00)b	14.45±1.13 (12.00-16.65)a	32.72±2.52 (28.80-34.50) a	15.94±1.81(13.50-17.80) a	8.25 ±1.23 a	8.90 ± 0.78 a
3	*Vitex negundo* leaves	270.75±1.41 (255.00-410.00) a	15.33±1.37 (11.00-19.00) b	225.52±0.49 (190.00-250.00) b	273.00±0.50 (240.00-310.00) c	20.45±0.92 (18.00-23.00) a	22.95±0.98 (19.00-24.00) b	30.22±2.06 (27.00-34.50)b	13.56±2.53 (12.40-16.75)c	32.02±2.16 (28.50-34.00) a	14.54±2.37(13.00-17.40) c	8.35 ±1.21 a	8.40 ± 0.58 a
	±SEm	44.535	0.088	1.394	1.528	0.389	0.219	0.058	0.058	0.318	0.067	0.033	0.333
	CD (0.05)	174.838ns	0.346*	5.474*	5.997*	1.526 ns	0.858*	0.227*	0.227*	1.248 ns	0.262*	0.131*	1.309ns
	CV%	24.59	0.97	1.05	0.94	3.22	1.65	0.33	0.71	1.70	0.76	0.70	6.64

Each figure denotes Mean of 50 samples ±*S.D;* figures in parenthesis are range values.
Mean with same superscript within the column do not differ statistically at DMRT test.

Table 6: Adult morphometry of female *Hyblaea puera* Cramer reared with teak leaves from field collected final instar larvae during different months of experimental period (2016-2017).

Month and year	Length at wing expanse (mm)			Abdomen length (mm)		
	Max.	Min.	Mean± S.D	Max.	Min.	Mean ±S.D*
July, 2016	38.00	24.00	31.57±3.07a	19.00	11.00	15.04±2.31b
Oct, 2016	38.00	24.00	30.42±3.04b	19.00	11.00	14.74±2.74c
July, 2017	39.00	24.00	32.42±2.86a	19.00	11.00	15.34±2.45a
±SEm			0.310			0.058
Cd (0.05)			1.217*			0.227*
Cv%			1.71			0.66

*Each figure denotes Mean ±*S.D*
Mean with same superscript within the column do not differ statistically at DMRT test.

Table 7: Adult morphometry of male *Hyblaea puera* Cramer reared from field collected larvae during different months of experimental period.

Month and year	Length at wing expanse (mm)			Abdomen length (mm)		
	Max.	Min.	Mean± S.D	Max.	Min.	Mean ± S.D
July, 2016	36.00	18.00	29.51±1.37b	17.00	13.00	14.05±1.73a
Oct, 2016	35.00	16.00	28.13±1.89c	18.00	13.00	13.56±2.53a
July, 2017	38.00	17.00	30.39±2.11a	19.00	14.00	14.75±1.82a
±SEm			0.033			0.300
CD (0.05)			0.131*			1.178NS
Cv%			0.20			3.69

*Each figure is the mean value of 50 samples ±*S.D.*
Mean with same superscript within the column do not differ statistically at DMRT test

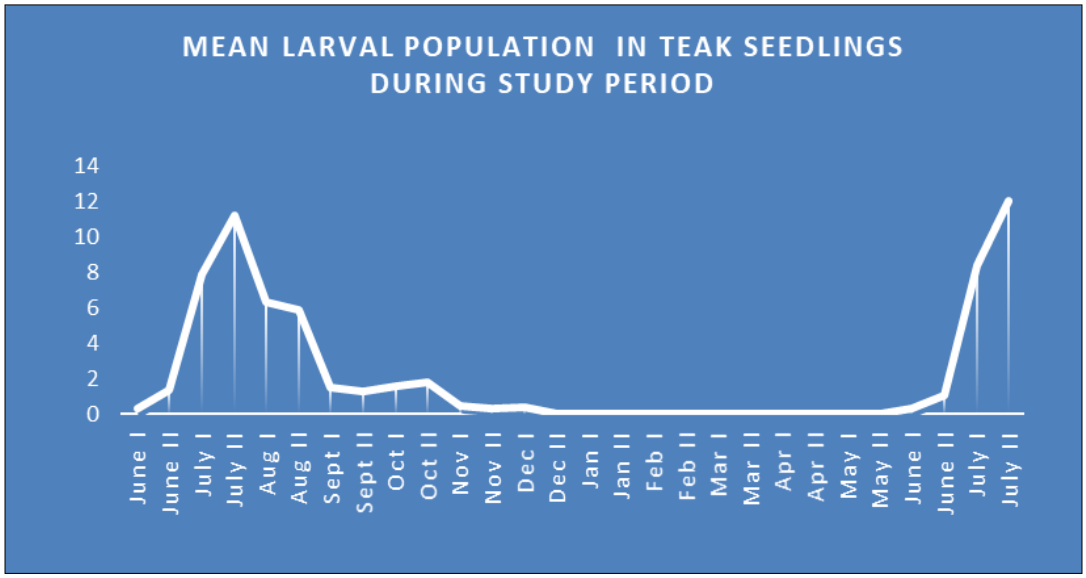

Fig 1

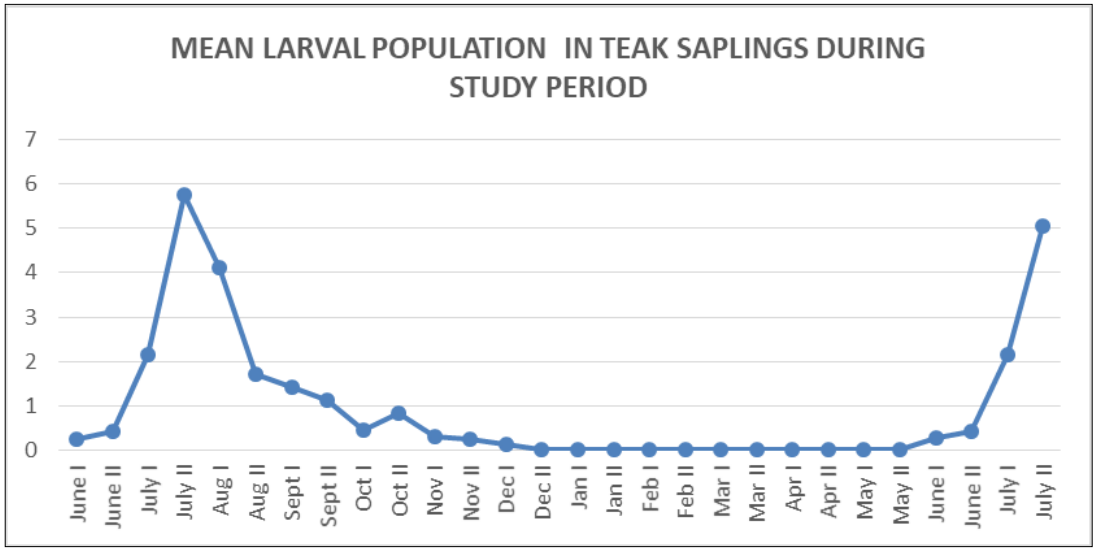

Fig 2

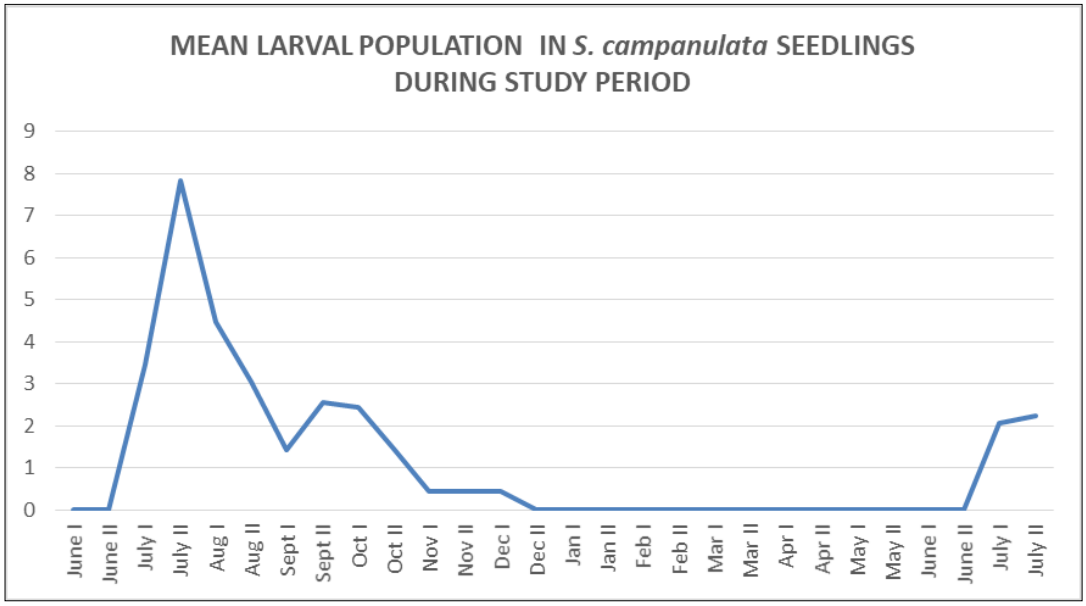

Fig 3

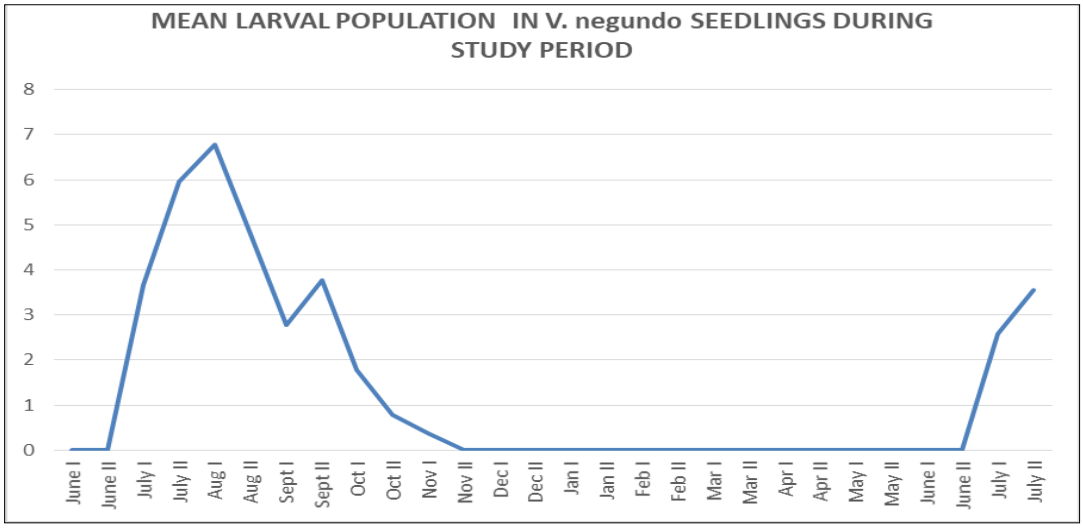

Fig 4

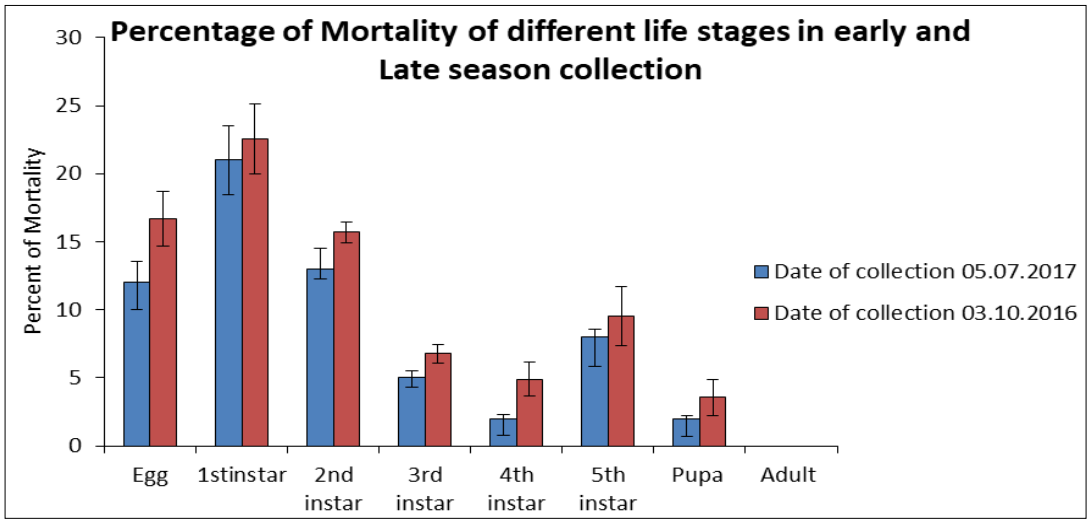

Fig 5

(a) Adult

(b) Second instar larva

(c) Final instar larvae in teak

(d) Final instar larvae in *Vitex negundo*

(e) Pupa

Plate 1: Life stagsof *Hyblaea p uera*

Plate 2: Mass rearing (a) larva in natural medium (b) Adult rearing in plastic cages

Plate 3(a): Pole size plants damaged (b) Leaves for collection of 1st instar

(c) Field collected eggs along with leaves and kept in lab for two days.

4. Conclusion

So it can be concluded from the present study that sudden appearance of *Hyblaea puera* populations in coastal tract of Odisha is due to wind aided migration of moths from southern Indian states of Kerala, Tamil Nadu and Andhra Pradesh which witnesses large areas under plantation of teak. The end season population may be subjected to natural mortality factors like predation and parasitism. Residual population surviving the stresses, either may be perished due to non-availability of sufficient fresh leaves during that period or may be migrated to nearby mangrove forests located at about 200 km aerial distance. However, it needs to investigate in detail regarding availability of this pest in mangroves during the period of its non-availability in teak and other host plants ie., from January to May of each year.

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