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Biology of *Hyblea purea* (Cramer) reared in laboratory with teak (*Tectona grandis*, Linn) leaves at coastal Odisha, India

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Abstract
Biology of *H. puera* was studied both at normal laboratory condition and in BOD Incubator with 14:10 photoperiod, 32:18 ºC temperature (Day: Night) and 70% RH. The study revealed that there are five larval instars and duration as well as weight of larvae and pupae did not differ much in both the cases of study. Mean larval period was 15.31 days and that of pre pupa, male and female pupa were 1.35, 5.45 and 6.82days respectively, when reared in normal laboratory condition fed with teak leaves. Female and male adults longevity were found as 8.80 and 8.05 days respectively. The pre oviposition, oviposition and post oviposition periods were found as 2.35, 6.50 and 2.18 days respectively. Average number of eggs laid by the female during its lifecycle was found to be 417.66numbers. Weight of a final instar larva was found nearly to 1000 times more than that of neonates. Weight of excreta daily collected and weighed was also found to be more than gain in daily body weight of larvae in final instar stage.

Keywords: Teak defoliator, teak skeletoniser, biology, preoviposition period

1. Introduction
In India, teak grows naturally in 9 million hectares in southern tropical deciduous forests of Peninsular India situated below 24^0 N latitude, Seth and Kaul, 1978 [10]. Currently1.5 million hectares of teak plantations exists in India and around 50,000 hectares are planted annually. Thus, it is considered as one of the top five tropical plantation species of the world. Large-scale monoculture of teak has been practiced by the Forest Department and the Forest Development Corporation in different states of India. The major growing states are Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka and Kerala besides, Uttar Pradesh, Gujarat, Orissa and Rajasthan Tewari, 1992 [13]. In 0disha, Teak is spread over 2030 $km^2$of the total forest area of 58,135 km^2. It is also found growing in miscellaneous forest of area 21,024 km2 and at other plantation sites. About 187 inset species have been found feeding on living Teak tree in India, Hutacharern and Tubtim, 1995 [2]. 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 usually suffer a total defoliation, sometimes there is partial defoliation later in the growth season, Nair, 1988 [6]. Studies in young teak plantations at Nilambur of Kerala in Southern India showed that defoliation by *H. puera* caused loss of 44.1% of the potential wood volume increment, Nair *et al*. 1998 [7] However, no systematic study has been undertaken in the state regarding its biology, alternate hosts, population dynamics to draw a definite location specific IPM strategy. The population disappeared in the month of Nov The most probable reason is the end season population is more subjected to action of predators and parasites. Hence, in the present investigation an attempt is being made to study the biology of *Hyblea puera* fed with teak leaves in the laboratory conditions at Bhubaneswar, Odisha and in the incubator simulated the climatic situations prevailed at Bhubaneswar.

2. Materials and Methods
Studies on biology of *H. Puera* were undertaken in the Post Graduate Laboratory of College of Forestry, OUAT. The pests were collected from the unsprayed trees of teak from Hi-Tech forest nursery and plantation sites as well as from College of Forestry campus.

The field collected larvae were brought to the laboratory and reared individually in small perforated plastic jars (10cm x 10cm) with leads to facilitate aeration (Plate-1). Fresh and tender leaves of teak were provided as food in the morning by replacing old leaves until pupation. After pupation of larvae in silken cocoon, they were transferred to separate plastic jar 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 (Plate-1). A seedling containing red colour tender leaves was kept inside the cage for egg laying. Cotton soaked with 10% honey solution was kept inside the cage to provide them food. The seedlings along with leaves containing eggs were collected and fresh seedling containing red colour tender leaves were placed in the rearing cage. The eggs were examined under digital microscope. The rearing was carried out under normal temperature of 27±2 ºC and light of the laboratory was switched off during night time. The eggs were examined under microscope and sex determination as well as other measurements was carried out after examination under Digital Stereoscopic microscope, Photographs of eggs and 1st and 2nd instar larvae were taken using Digicam software connected to the microscope.

Rearing inside the incubator was carried out in second instar larvae directly collected from field and reared in succulent leaves of teak with a photoperiod 14: 10 (light: dark) and RH 70%. The dark period was maintained with 18±2 ºC and light period with 32±2 ºC which coincide the prevailing temperature of the Nov 1st week to Nov. last week. Weight of faecal matters excreted and weight of leaves consumed and larval weight in each day was taken by Contech precision balance. Eggs laid by female were collected gently with the help of fine camel hair brush from the leaves and were observed under microscope for their size, shape and colour. Total number of egg laid per day was counted gently, for studying the incubation period and the hatching percentage of eggs, freshly laid eggs were observed on leaves under the microscope daily in the morning and evening till hatching. Average incubation period and hatching percentage was then calculated based on total number of eggs kept under observation. To study the number and duration of different larval instars, freshly hatched larvae were confined individually in plastic specimen box (diameter: 15.0 cm, height: 10.0 cm) with the help of a wet camel hairbrush. One set of fifty larvae was kept and provided with tender leaves as their food. The food was provided to larvae and observed daily in the morning for the change of instars till they attained last instar. The exuviae and head capsule left either on the leaves of teak or inside the specimen box was considered as indication for change in instar. The larva of each instar was observed under binocular research microscope for their colour, shape and size. The breadth of the head capsule of all the instars and length and breadth of first and second instar were measured with the help of ocular and stage micrometer while length and breadth of the remaining instars were measured by automatic slide callipers. The duration of each instar's was considered for the period between two successive exuviae. The total larval period was calculated from the date of egg hatching to the date of pupation. The weight of larvae (sample size-50) and pupae (sample size-50) was taken by weight machine (Contech precision balance). Amount of leaf consumed and weight of the faecal materials produced daily after attending 3rd instar was taken by weight machine (Wensar high precision balance). A control was maintained separately during each day of observation period to know the weight loss in leaves for moisture loss. Full grown larvae were found sluggish and discontinued to take food before entering prepupal stage. The pre pupal period was considered from the date of desist feeding to the date of formation of cocoon. Measurements were also taken regarding weight, length and diameter of prepupa. The method of pupation as well as colour of pre pupa was also recorded during the observation. Silken cocoon was examined for their colour, shape and size. Pupae were also removed from the silken cocoon and examined under microscope to study the morph metrics. Measurement of length and breadth was also recorded by using automatic slide callipers. Pupal period was calculated on the basis of date of cocoon formation and the date of adult emergence. Adults emerged from the pupae were critically observed for their colour, shape and size. The male and female moths were measured across their expanded wings with the help of the standard scale. Male and female moths were differentiated on the basis of their morphological characters. Freshly emerged male and female moths were paired and confined in a modern cage (50cm × 50 cm x 50cm) containing tender leaves of teak. A wet cotton swab of absorbent sponge dipped in 10% honey solution was placed as a food to the adults. Pre-oviposition period was calculated from the date of emergence of adult female to the date of commencing the egg laying. Moths emerged from laboratory reared larvae were sexed out on the basis of their morphological characters and sex ratio was worked out accordingly. The mean and standard deviation in each case was calculated as per Gomez and Gomez, 1984 [1]

Collection of larvae

Infested plant

Rearing of Larvae **Study of ovi position**

Plate 1

3. Results and Discussion

As per data in Table-1 the mean egg period was 1.62 days and durations of different instars were 2.25, 2.56, 2.44, 2.68, 3.58 days for 1st, 2nd, 3rd, 4th and 5th instars' respectively. The mean total larval period was 15.31 days where as the mean pre pupal and male as well as female pupal duration was 1.35 days, 5.45 days and 6.82 days respectively. Mean larval weights were 44.84, 185.40 and 280.75 mg for 3rd, 4th and 5th instars respectively. The corresponding body lengths were 12.54, 21.26, 32.40 mm. Our finding in biological parameters is in conformity with earlier workers like Kabade and Patel 2015 [5]. Diameter of body (mm) and head capsule (mm) at 5th in star stage was recorded as highest. The biology of *Hyblaea puera* was also studied in detail reared after 2nd instar in BOD incubator up to adult emergence and the data has been presented in Table 2.Much difference was not observed in all the studied parameters reared under both the conditions. A study on adult parameters emerged from larvae reared under normal laboratory condition has been presented in Table-3.The sex ratio was 1.00:1.46 (M: F). the mean longevity of male and female moths was found to be 8.05 and 8.80 respectively. The mean pre-oviposition, oviposition and post oviposition period was recorded as 2.35, 6.50 and 1.18 days respectively. Total number of eggs laid per female was 417.66 on an average lifecycle of male moth was completed within 25.65 days and that of female moths in 26.08 days. Our finding is in full agreement with the findings of workers like Sudhendrakumar, 2003 [11] who also reported the same duration of adults for oviposition and others etc.

Effect of host plant consumption on body physiology of *Hyblaea purea* in term of weight gain, leaf consumption and daily faecal matter produced was presented in Table-4, 5, & 6 respectively. The data revealed that the larval weight was maintained below 20 mg up to 6th day of hatching. The percentage weight gain was highest on 8th day of rearing (59.18%) followed by 10th day of rearing (39.54%). Highest larval weight was recorded in 14th day old larvae (292.12 mg) after which 9.89% decrease in body weight was recorded before entering into pupal stage. The same trend was also repeated for leaf consumption. Highest leaf consumption was noticed in 8th day of rearing (33.33%) followed by 10th day of rearing (23.07%). However the leaf consumption was drastically reduced before entering of the larvae into pupation. Faecal weight was also recorded as 55.18 mg on 7th day of rearing. However, up to 6th day of rearing the excreta weight as weighed daily was very low and the mean value was less than 50 mg. The increase was substantial (33.48%) during 8th day of rearing highest faecal weight was recorded during 13th day of rearing (380.00 mg) which was 18.93% more than that recorded on the previous day.

The biology of *H. puera* was studied in BOD incubator at temperature of 18 ^{0}C and 32 ^{0}C (night: day) and photoperiod 10:14hrs (light: dark) and 70% Relative humidity. The conditions were so chosen in the incubator is to provide the temperature and RH prevailed during November first week to November last week at Bhubaneswar and to know its effect on biology of *H. puera* The female *H. purea* was found to lay eggs on upper and lower surface of tender leaves but mostly on lower surface of medium staged leaves (Plate-2). Some eggs were laid on the plastic boards and on the GI mesh sheet of the rearing box fitted for ventilation purpose. Females were found to seat frequently on the leaf surface and touch the surface with ovipositor. oviposition was done during night hours and eggs were laid singly on veins and midribs which were oblong and pale white in colour. The larva did not feed on egg shell. Our findings also corroborate the findings of other workers like), Nachane *et al*. 1999 [9]. And Javaregouda, 2006 [3]. And Sudhendrakumar 2003 [11]. The length and diameter of eggs was recorded in the present study (Table-2) are in close proximity of workers as named above. The duration of egg stage and each larval instar are in accordance to those workers. The neonates were greenish yellow (Plate-2) with black colour head and sparse hair over the body. After a few time of sluggishness it became active and started moving on the surface and settle at one place, feed on chlorophyll of leaves. The second instar larva was greenish dark than earlier instar (Plate-2) with scattered hairs all over the body with a black head. The mean length and diameter recorded were 4.65 mm and 0.80 mm respectively. The mean head capsule diameter was recorded as 0.48 mm. This finding was in close accordance with findings of Katagall, 1991[4]. who measure the head capsule of second instar, from 0.60 mm to 0.72 mm, but contrast the findings of Javaregouda, 2006 [3], who reported this, 1.5 to 2.3 mm in length and 1.3 to 2.2 mm in width. Varied climate and host plant including soil conditions in which teak is grown and certain genetic conditions may be responsible for this.

The appearance of 4th instar larva was entirely changed which was purple grey dorso-laterally and greyish green latero-ventrally (Plate-2) with black coloured head and sparsely

hairy body. The mean length of 4th instar larvae was found as 21.26 mm and that of full grown 5th instar larvae was 32.40 mm, the head capsule diameter was 1.08mm and 1.52 mm respectively. The 5th instar larvae was dark purple grey dorso-laterally greenish yellow latero-ventrally with a pale on distinct longitudinal line along the centre of the back and two clear zig zag sub dorsal white lines on each sides of the central line (Plate-2). Another clear white lateral line was observed just above the spiracles running along each sides of larva which demarked the upper gray and lower yellow colour with black coloured head capsules. The body is full of short hairs. Similar type of description for 4th and 5th instar larvae was also given by Javaregouda 2006 [3] and Sheetal Sharma (2013) [12]. The length of 4th and 5th instar larvae is in close proximity to that reported by Nachane *et al.* 1999, [9]. Who reported it to be varied between 28-35 mm. The duration of 5th instar larva was reported as 3.58 days in the present study which is in close agreement with the findings of Katagall, 1991[4]. and Nachane *et al.* 1999 [9]. The number larval instar in the present case which is five is firmly confirmed by the above two earlier workers. The total larval period in the present study is 15-31 days is also in strong agreement with the above two workers earlier.

The last larval instar ceases feeding and found searching for a suitable place, where it can remain sluggish which is the indication for beginning of pre pupal stage. The formation of prepupa begins with contraction of length and appendages. The larvae form white cocoons in triangular leaf fold or formed with the adjoining leaves or dead fallen dried leaves and become quiescent. After that larval moulting took place and larvae were pupate. The colour of the prepupa was pale yellow (Plate-2). The mean duration of pre pupal stage in the present study was in close agreement with the workers like Nachane *et al.* 1999 [9]. The pupation of *H. puera* took place under the leaf pieces in the plastic vials especially at the base. The larva made webs of leaf pieces with faecal pallets. The newly formed pupa of *H. puera* was of obtect type, initially yellow and gradually turns dark brown due to chitinisation (Plate-2). Pupa were broadly rounded anterior end but tapering posterior. Abdomen was distinctly marked into 10 segments and spiracles were clearly visible on 4th-9th segments as dark brown spots. Genital apertures in both the sexes were present on the 8th abdominal segment and anal apertures in both the sexes were present on the 10th abdominal segment. The present findings also corroborate the findings of earlier workers like Nachane *et al.* (1999) and Javaregouda 2005 [3]. It is observed from Table-4, 5, 6 that the average weight of final instar 15 days old larvae was about 265 mg which was more than 800-1000 times than neonates. Likewise the excreta deposited by larvae per day is also more than its body as observed from 8th day onwards in laboratory rearing. Our finding is in full agreement with finding of Nair (2007) who stated the same fact regarding weight gain of *H puera* A fully developed larva was observed to consume leaves of 0.5gm weight of leaves per day and during the total life period it can consume near about 4gm of fresh succulent leaves and damages much more in egg laying, pupation etc. So the extent of damage during the 4-5 generation passed during Kharif can be easily understood. The chronological damage symptoms developed due to feeding of *H. puera* in different dates of its larval period and observed in the laboratory in the present experiment is summarized below:

Table 1: Biology of *Hyblaea puera* Cramer reared in teak leaves at room temperature in laboratory at Bhubaneswar (2016-2017)

Life stages	Duration (days)	Weight (mg)	Length (mm)	Diameter (mm)	Head capsule diameter (mm)
Egg stage	1.62±0.32 (1.00-2.00)	----	0.82 ± 0.03 (0.78-0.86)	0.42±0.03 (0.38-0.47)	--
1st instar	2.25±0.41 (2.00-3.00)	----	1.90±0.04 (1.50-2.30)	0.34±0.24 (0.22-0.62)	0.30±0.01 (0.28-0.34)
2nd instar	2.56±0.56 (2.00-4.00)	----	4.65±0.42 (1.65-4.80)	0.80±0.08 (0.65-0.85)	0.45±0.01 (0.42-0.48)
3rd instar	2.44±0.52 (2.00-3.00)	44.84±0.80 (42.00-50.00)	12.54±1.42 (10.28-15.65)	1.88±0.08 (1.70-1.90)	0.98±0.01 (0.96-0.99)
4th instar	2.68±0.62 (2.00-4.00)	185.40±1.24 (110.00-230.00)	21.26±1.46 (16.64-24.82)	3.06±0.25 (2.80-3.20)	1.08±0.01 (1.06-1.09)
5th instar	3.58±0.75 (3.00-5.00)	280.75±1.48 (240.00-400.00)	32.40±1.24 (25.86-34.58)	4.24±0.28 (4.00-4.50)	1.52±0.01 (1.50-1.54)
Total larval period	15.31±1.18 (11.00-19.00)	----	-----	----	----
Pre pupa	1.35±0.28 (1.00-2.00)	250.50±0.58 (220.00-270.00)	22.54±2.32 (16.10-26.00)	6.28±0.28 (5.46-6.88)	--
Male Pupa	5.45±0.40 (5.00-6.00)	230.50±0.60 (190.00-250.00)	16.45±0.85 (14.80-17.85)	4.25±0.42 (3.50-4.50)	--
Female Pupa	6.82±0.40 (6.00-7.00)	280.00±0.50 (240.00-320.00)	18.02±1.22 (16.80-19.20)	5.24±0.40 (4.60-5.60)	--

*Figures in parenthesis are range values. Each figure is the mean of minimum 50 samples ± *S.D.*

Table 2: Biology of *Hyblaea puera* Cramer reared in teak leaves in BOD incubator in control condition at Bhubaneswar (2016-2017)

Life stages	Duration (days)	Weight (mg)	Length (mm)	Diameter (mm)	Head capsule diameter (mm)
3rd instar	2.42±0.52 (2.00-3.00)	45.84±0.80 (42.00-50.00)	12.54±1.42 (10.28-15.65)	1.88±0.08 (1.70-1.90)	0.98±0.01 (0.96-0.99)
4th instar	2.75±0.62 (2.00-4.00)	175.40±1.24 (110.00-230.00)	21.26±1.46 (16.64-24.82)	3.06±0.25 (2.80-3.20)	1.08±0.01 (1.06-1.09)
5th instar	3.85±0.75n (3.00-5.00)	260.75±1.48 (240.00-360.00)	29.40±1.24 (25.42-31.28)	4.04±0.58 (3.00-4.20)	1.52±0.01 (1.50-1.54)
Male Pupa	5.35±0.41 (5.00-6.00)	210.50±0.50 (190.00-250.00)	16.45±0.85 (14.80-17.85)	4.10±0.38 (3.50-4.40)	-----
Female Pupa	6.20±0.40 (6.00-7.00)	250.00±0.50 (240.00-320.00)	17.65±1.22 (16.50-18.10)	5.02±0.40 (4.60-5.20)	----

Each figure is the mean of minimum 50 samples ± *S.D.* Figures in parenthesis are range values.

Table 3: Adult parameters of *Hyblaea puera* Cramer reared in teak leaves at room temperature in laboratory (2016-2017)

Parameters		Maximum	Minimum	Mean ± S.D*
Sex ratio (male: female)		---	---	1:1.46
Adult blongevity (days)	Male	9.00	5.00	8.05 ±1.26
	Female	9.00	6.00	8.80 ± 0.88
Pre-oviposition period		2.00	1.00	2.35±0.45
Oviposition period		8.00	3.00	6.50±1.45
No. of eggs laid per day	1st	108.00	78.00	87.45±1.42
	2nd	92.00	80.00	85.26±0.85
	3rd	46.00	40.00	42.00±0.41
	4th	140.00	95.00	128.58±1.65
	5th	62.00	40.00	54.12±1.24
	6th	30.00	10.00	20.25± 0.78
Total no. of eggs		478.00	343	417.66±1.54
Post oviposition period		3.00	1.00	2.18±0.85
Total life cycle	Male	30.00	24.00	25.65±1.56
	Female	30.00	25.00	26.08±1.87

Each figure is the mean of minimum 50 samples±*S.D.*

Table 4: Weight gain by *Hyblaea puera* larvae reared in teak leaves in laboratory condition at Bhubaneswar (2016-2017)

Observation period (day) from the 1st day of 1st instar to 5th instar	Weight of larvae (mg) per day			Percentage increase or decrease (%) Per day
	Mean ±S.D*	Max.	Min.	
1st to 6th	< 20.00	< 20.00	<1.00	-----
7th	45.12±3.67	50.00	35.00	-----
8th	110.54±2.46	115.00	54.00	59.18
9th	133.21±3.15	155.00	110.00	17.01
10th	220.33±3.64	240.00	165.00	39.54
11th	230.36±2.81	262.00	195.00	04.35
12th	285.27±3.12	320.00	250.00	19.24
13th	287.54±2.54	322.00	270.00	0.78
14th	292.12±2.72	310.0	285.00	1.56
15th	265.81±2.63	280.00	250.00	-9.89

Each figure is the mean of minimum 50 samples ± *S.D.*

Table 5: Teak leaf consumption (in gm) by *Hyblaea puera* during the larval period, reared in teak leaves in laboratory conditions at Bhubaneswar (2016-2017).

Observation period (day) from the 1st day of 1st instar to 5thinstar	Weight of leaf consumed (gm) per day			Percentage increase or decrease (%) Per day
	Mean ±S.D*	Max.	Min.	
1st to 6th	< 1.00	< 1.00	….	-----
7th	0.18±0.21	0.21	0.09	-----
8th	0.27±0.30	0.33	0.12	33.33
9th	0.30±0.31	0.36	0.18	10.00
10th	0.39±0.32	0.45	0.27	23.07
11th	0.42±0.32	0.45	0.30	7.14
12th	0.45±0.32	0.54	0.33	6.67
13th	0.48±0.27	0.54	0.36	6.25
14th	0.49±0.30	0.56	0.42	2.04
15th	0.43±0.25	0.48	0.38	13.95

Each figure is the mean of minimum 50 samples ± *S.D.*

Table 6: Faecal weight (mg) of *Hyblaea puera* larvae during the larval period, reared in teak leaves in laboratory conditions at Bhubaneswar (2016-2017)

Observation period (day) from the 1st day of 1st instar to 5th instar	Faecal Weight (mg) per day			Percentage increase or decrease (%)
	Mean ± S.D*	Max.	Min.	
1st to 6th	< 50.00	< 60.00	--	--------
7th	55.18±2.67	72.00	40.00	--------
8th	124.54±2.46	148.00	70.00	55.69
9th	187.25±3.15	240.00	150.00	33.48
10th	250.33±3.64	340.00	130.00	25.20
11th	278.54±2.81	422.00	180.00	10.12
12th	308.27±3.12	420.00	160.00	09.64
13th	380.36±2.54	550.00	180.00	18.93
14th	296.81±2.72	330.00	170.00	28.14
15th	265.27±2.63	280.00	150.00	11.88

Each figure is the mean of minimum 50 samples ± *S.D.*

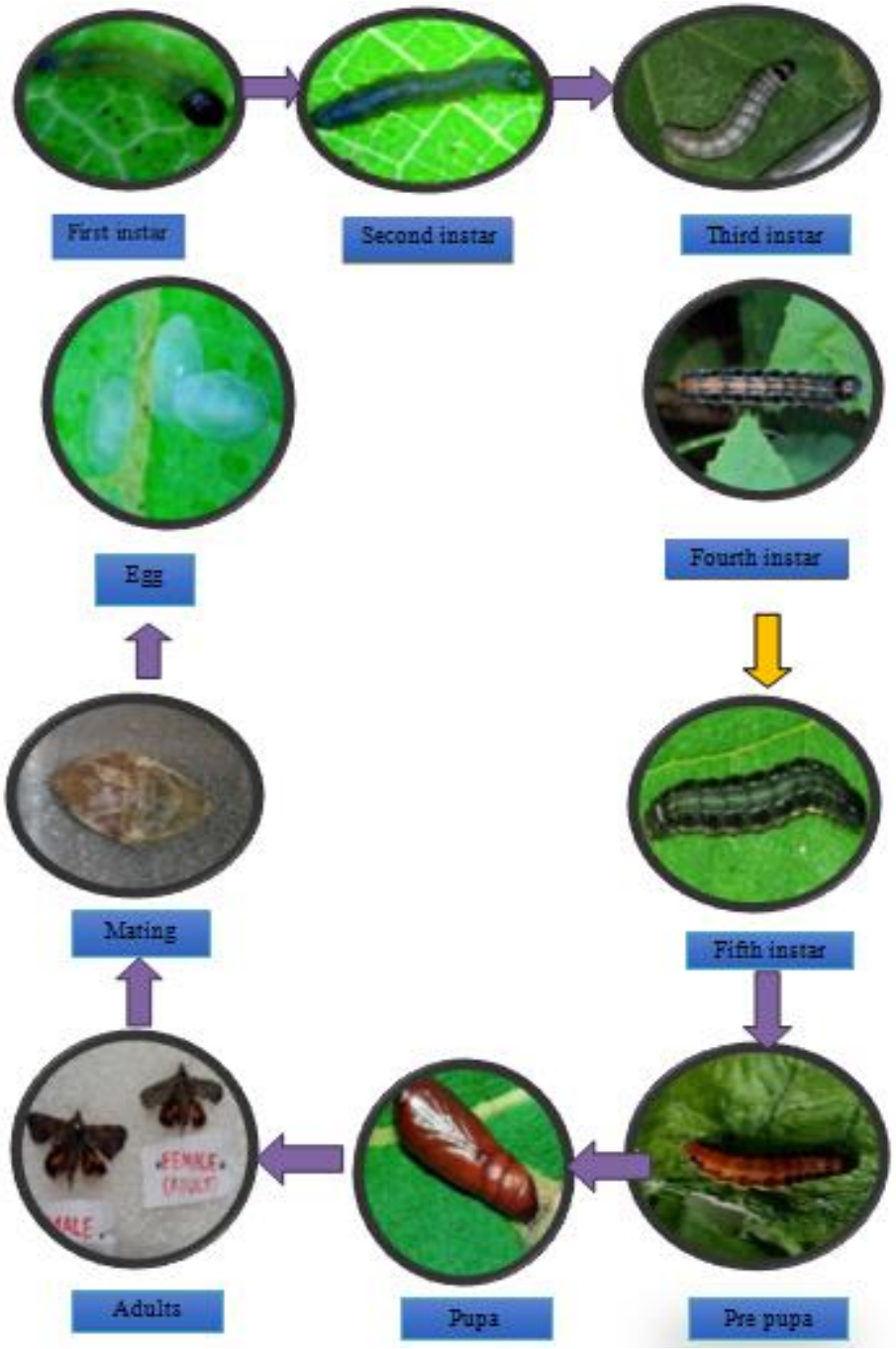

Plate 2: Life cycle of *Hybleae puera*

S. No	Days	Nature of damage and symptoms on host (Teak seedlings)
1	1st	Nibbling of leaves with very minute holes, feed upon the chlorophyll matter, weight was very low *i.e.* < 1mg.
2	2nd	Puncture holes become prominent, weight gain is not measurable and <1 mg.
3	3rd	Causes partial netting of red coloured leaves, weight gain and colour change was observed.
4	4th	Migration to leaf edges and making folds by cutting edges, weight was near about 1 mg.
5	5th	Weight gain was prominent, it is near about 3-4 mg, excretal pallets in black coloured globule form were observed on leaves.
6	6th	Weight and size gain was much significant along with colour changes. Feeding damage spreads more quickly and more excretal pallets were deposited in leaves.

4. Conclusion

So it can be concluded from the present investigation that much difference is not observed in duration of total life cycle, including male and female longevity in populations of this pest reared in teak leaves in the laboratory as well as in the BOD incubator. So the end of season population is not expected to undergo diapauses rather perished by action of natural enemies or want of fresh leaves. The average weight of final instar 15 days old larvae was about 265 mg which was more than 800-1000 times than neonates. The mean longevity of male and female moths was 8.05 and 8.80 days respectively. The mean pre-oviposition, oviposition and post oviposition period was recorded as 2.35, 6.50 and 1.18 days respectively. Total number of eggs laid per female was 417.66 and lifecycle of male moth was completed within 25.65 days and that of female moths in 26.08 days. Hence IPM strategy

should be formulated to control teak defoliator during early stages of larval developments as the late instar stages are more damaging with more than 1000 times more robust than early instars

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