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Biology of teak defoliator (*Hyblaea puera* C.) reared on teak (*Tectona grandis*, L.) leaves under laboratory conditions in semi: Arid region of Central India

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Abstract
A study on biology and life cycle of *Hyblaea puera* C. (Lepidoptera: Hyblaedae) was carried out during kharif season of 2020 under Laboratory conditions in Department of Entomology, Institute of Agriculture Sciences, Bundelkhand University, Jhansi (U.P). The common laboratory conditions *viz*., 30 °C temperature and 73% relative humidity (RH) were maintained during the current investigation. Results reveal that there were fifth larval instars. Average larval duration was 13.83 days and that of pre-pupa, male and female pupa were 2.29, 4.39 and 7.0 days, respectively when reared under common laboratory condition fed with teak foliage. The longevity of male and female adult was found as 6.05 and 7.50 days, respectively. The pre oviposition, oviposition and post oviposition duration were found as 2.22, 3.0 and 3.28 days, respectively. Average number of eggs laid by the female during its life cycle was found to be 119.21. The total life cycle of male and female was 25.95 and 26 days, respectively.

Keywords: Biology, life cycle, teak, teak defoliator

1. Introduction
Teak *"Tectona grandis* Linn. F" (family*:* Verbenaceae) known as "King of timber" which naturally occurs in India, Myanmar, Laos and Thailand (Roshetko *et al*., 2013) [19]. In India, the major teak growing states are Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Uttar Pradesh, Gujarat, Orissa and Rajasthan (Tewari, 1992) [20]. Teak plantation started in India in the 1840s and increased greatly after 1865. Its production in India is estimated to 0.25 million m^3 (Pandey, 2009) [15]. It is one of the most valuable timber tree species in the tropics where it is grown in over 2.25 million ha. There are many tree species having durable wood and used as timber e.g. *Tectona grandis*, *Dalbergia sissoo*, *Swietenia macrophylla* (Mishra *et al.* 2022) [13]. The reputation of teak timber is due to its long durability, strength, attractiveness, workability and superior seasoning capacity (FAO, 2016). Global forest area covers 3,999 million ha (30.6%) of land and about 299 million ha (7%) of this is planted in forest (FAO, 2016).Teak forest constitutes about 4.346 million ha and represents 75% of high tropical hardwood plantation, 83% of which is in tropical Asia (IUFRO, 2018). Recently, interest on the wood and wood-based products is being increased mainly due to environmental benefits such as carbon sequestration and various other ecosystem services provided by the trees. It has the highest capacity for carbon sequestration among trees in India. In its lifetime, a teak tree with a girth of 10-30 cm can absorb 3.70 lakh tonnes of carbon dioxide from the atmosphere (Pichhode and Kumar 2017) [16]. India's timber demand is increased day by day and natural forests are not in position to full fill its demand. Hence, to fulfil the needs, India is importing the timber from other countries. Now, the attention has also been shifted considerably towards the commercial agroforestry to fulfil the industrial demand. Teak is one of important species which most sought after and yields highly valued timber (Pandey and Brown, 2000) [14]. It is economically very important and does not require much management practices. Teak wood is an attractive, light, but strong timber having.
Natural resistance against many pests and diseases. Teak wood is also easy to work and process without any marked splitting, cracking or wrapping. Because of its superior quality wood and aesthetic value, the teak plantation attracts larger interest among the general public than any other tropical hardwoods. Over last few decades, many farmers have resorted to growing teak on their farmland along the boundaries.

Its plantation also promoted as block plantation as well as field bund plantation (Thulasidas and Bhat, 2009, 2012) [21-22]. However, long Gestation period, teak defoliator and leaf skeletonizers major drawback which hinders the adoption of tea plantations among the farming community.

Defoliation is a serious problem in nurseries, plantations and natural forests of teak and defoliators are main destructive pests of teak. The problem of severe epidemic defoliation is a regular phenomenon in teak, caused by larvae of two well-known pests of teak in India–*Hyblaea puera* Cramer (Lepidoptera: Hyblaeidae), popularly known as the teak defoliator, and *Eutectona machaeralis* (Walker) (Lepidoptera: Pyralidae), popularly known as the teak leaf skeletonizer (Tewari, 1992) [20]. In addition to defoliation, these insects also feed on the inflorescence and are responsible for poor seed formation and seed setting in teak during epidemic period (Roy Choudhury *et al.*, 2001) [18].

Unequivocal clarifications have been made on the distribution, biology, ecology, life history and population dynamics of *H. puera* and *E. machaeralis*, in different eco-zones of India (Nair, 1988) [12], including Madhya Pradesh (Khan *et al*., 1988; Jain *et al.*, 1995; Roy Choudhury *et al*., 1995) [8, 5, 5]. Potentiality of these insect pests on teak defoliation is a well-recognized problem in India, affecting adversely the tree growth and vigour, responsible for both qualitative and quantitative loss in timber production, besides causing certain abnormalities (Beeson, 1941) [1].

The teak defoliator (*Hyblaea puera* C.) is a one of important pest of teak in India. It is estimated that about 44% of teak growth is lost due to teak defoliator (Nair *et al.*, 1985) [10]. In India forest area is 24.56% of the total area (ISFR, 2019) [3] which are under threat due to various factors. This insect can cause the reduction of 3m^{3}wood volume in teak plantation. Thus, substantial gain can be obtained by controlling this insect at right time. With over 1.4 million ha of Teak plantations in the country and an average value of Rs.20, 000 for one m^3 of teak wood, the economic worth of the wood that can be saved is enormous. In many studies on the population dynamics of the teak, it was observed that the outbreak of this insect is usually collapsed after two to three waves if defoliation that may be due to some natural occurring disease. This insect also reported to have other adverse effect such as dieback of leading shoot resulting in forking of main stem and loss in height increment. However, many studies have been carried out on the control of this insect, but for developing effective and climatic conditions specific control measures, its biology need to be studied. Hence, in the present investigation an attempt is being made to study the biology of *Hyblaea purea* in the laboratory conditions in Bundelkhand region of Central India.

2. Materials and Methods

Study on biology and life cycle of teak defoliator (*Hyblaea puera* C.) was carried out during kharif season of 2020 under laboratory conditions in Department of Entomology, Institute of Agriculture Sciences, Bundelkhand University, Jhansi (India). The larva was collected from the teak plantation of Organic Agriculture Farm of Bundelkhand University, Jhansi, UP, India. The collected larvae were brought to the laboratory and kept in the perforated rearing boxes of 35 cm × 30 cm × 25 cm size. During study period, new and soft leaves were fed to the larva and boxes were also kept clean by removing the old and half fed leaves every day. After pupation of larva in silken cocoon, cocoons were shifted to separate rearing box of equal size with steerage to facilitate aeration. Newly and supple leaves of teak were provided as feed in the morning by replacing old leaves nonce pupation. After pupation of larva in silken cocoon, they were relocated to distinct rearing box of equal size. The pupae thus made were studied under binocular microscope and sexed by examining the position and distance between anal and genital slits. Male and female pupa was kept in distinct rearing box for the emergence of adults. Thereafter, newly emerged male and female adult for mating and egg laying. Cotton soaked with 10% honey solution was kept inside the rearing box to provide them food. The temperature was maintained 32 to 35 °C and light of the laboratory was switched-off during night time. Eggs laid by female were collected with the help of camel hair brush from inside the reared box. Total number of eggs laid per day was counted for studying the incubation period and hatching percentage of eggs. Freshly laid eggs were observed every day in morning and evening till hatching. Observations were recorded on average incubation duration and hatching percentage, duration of different larva instars, freshly hatched larvae. A set of five larvae was kept and provided with supple leaves of teak as their food. The food was provided to larva and observed day to day in the morning for the modification of instar till they attained last instar. The total larval duration was calculated from the date of egg hatching to the date of pupa. Full grown larva was underlay dormant and important to take food before entering pre pupa stage. The pre pupa duration was considered from the date of prevent feeding to the date of formation of cocoon. Pupa period was calculated on the basis of date of cocoon formation and the date of adult emerged. Newly emerged male and female moths were paired and straitened in a rearing box containing newly foliage of teak. A moist cotton swab of sucking sponge dipped in 10% honey solution was established as food to the adults. Pre oviposition duration was calculated from date of emergence of adult female to the date of commencing the egg laying.

3. Results and Discussion

Study on biology of *Hyblaea puera* (Fig. 1; Plate 3) indicates that lay eggs were mostly found on upper surface of inside rearing box under laboratory condition; however, some lay eggs were also noticed on lower surface of plastic box. It was further noticed that oviposition was observed during night hours and eggs were laid singly sticking to the side of upper side surface of plastic box. Incubation period under laboratory condition varied from 2 to 3 days with an average of 2.52±0.45 days. Meanwhile, the hatching percentage of *Hyblaea puera* was varied from 45.0 to 65.0% with an average of 55.18±5.16 under laboratory conditions (Table 1).

Results on newly hatched larvae reared individually on fresh leaves of teak till pupation revealed that neonate larva was greenish yellow (Fig. 1; Plate 4) with black coloured head. There were few hairs all over the body. Larva was sluggish which became active after some time and started moving on the leaves surface, and then settled at one place; feed on the chlorophyll content of leaves. The duration of first instar

larvae varied from 2 to 4 days with an average of 2.54±0.66 (Table1). Similar results were also reported by Javaregowda (2005) [6]. The second instar larva (Fig. 1; Plate 5) was greenish dark than earlier instar, shows scattered hair on all over the body and black coloured head. The larval period of second instar ranged from 2 to 3 days (Table1) with an average of 2.46±0.51 days. Nachane *et al.* (1999) [9] and Javaregowda (2005) [6] also recorded similar larval period for second instar. Third instar larva was pale greenish to grey in colour with black coloured head (Fig. 1; Plate 6). There were scattered hairs all over the body of third instar larva and segmentation was clearly visible. The duration of third instar larva ranged from 2 to 3 days with an average of 2.49±0.51 days. However, the appearance of the fourth instar was entirely different. The colour of the larva was purple grey dorsolateral and greyish green later ventrally with black coloured head (Fig. 1; Plate 7). The body was sparsely provided with short hair. These results are more or less in line with the earlier findings of Katagall (1991) [7] who reported that the fourth instar larva was purple grey dorsolateral and greyish green later ventrally. The duration of fourth instar larva varied from 2 to 3 day with on average of 2.49±0.51 days (Table1). Katagall (1991) [7] and Nachane *et al.* (1999) [9] also reported the 2 to 3 days duration of fourth instar larva. The fifth instar larva was dark purple grey dorsolateral and greenish yellow later ventrally with pale indistinct longitudinal line. Along with, the centre of the back and two clear zigzag sub dorsal white lines was found on each side of the central line (Fig. 1; Plate 8). Another clear white lateral line was observed just above the spiracles running along each side of the larva, which demarked the upper grey and lower yellow colour with black coloured head capsule. The duration of fifth instar larva varied from 3 to 5 days with an average of 3.86±0.88 days (Table 1). Total larval period (Table1) varied from 12 to 16 days duration with an average of 13.83±1.18 days. Though, last larva desists feeding and was found searching for a suitable place where it can remain sluggish. This stage indicates the beginning of pre pupa stage.

Results on pre pupa stage indicates that caudal region was firmly attached to the leaves. The body was shrunken during the formation of pre pupa with contraction at length and appendage. The larva formed flimsy white cocoon in a triangular leaf fold by adjoining leaves or dead fallen dried leaves and become quiescent. Thereafter, the larva became final moult and pupate. The colour of the pre pupa was pale yellowish (Fig. 1; Plate 9). Duration of the pre pupa stage varied from 1.10 to 3 days with on average of 2.29±0.56 days (Table 1). These observations are in close agreement with the finding of Javaregowda (2005) [6] who reported that pre pupa stage lasted for 1 day. The pupation took place underneath the leaves especially on the basal half portion. The larva cut the leaf in pieces and web out them with facial pallets. If there is absence of leaf litter on the ground, pupation may take place within leaves of under grown or on partially eaten teak leaves. The newly formed pupa was of object type and initially yellowish and gradually reached dark purplish brown colour (Fig. 1; Plate 10). The pupae were broadly rounded anterior, but tapering posteriorly. Abdomen was distinctly marked in to ten segments and well defined dark brown spiracles were visible on the fourth and ninth abdominal segments. Genital and aperture were also clearly visible. Genital aperture of male was situated on ninth abdominal segment, whereas that of female was on the eighth abdomen segment, anal aperture in both cases was on the tenth abdominal segment. These finding are more or less similar with those reported by Nachane *et al.* (1999) [9] and Javaregowda (2005) [6]. The duration of pupa stage ranged from 3 to 5 days with on average 4.39±0.64 days in case of male, while 6 to 8 days with on average 7±0.72 days in case of female (Table 1). Katagall (1991) [7] also reported 5.0 to 9.5 days duration for pupa.

Adult stage emerged immediately after pupa and took a rest for some time to stretch and hardened the wings and other body parts. Once the body has acquired normal structure and hardened, the adult moved about looking for the food. The female moth was bigger in size as compared to male moth. Both male and female moth were well developed with head and greyish red brown thorax and abdomen black brown with streaks and suffused bands of dark colour. While, hind wings were dark brown with a curved orange scarlet edged band transversally across the middle and a similar patch on the margin near the anal angle (Fig. 1; Plate11). These observations are in line with the earlier results reported by Katagall (1991) [7] and Nachane *et al.* (1999) [9].

Present investigation showed that pre-oviposition period varied from 2.0 to 3.50 days with on average 2.22±0.41 days. The oviposition period ranged from 1 to 5 days with an average of 3.0±1.25 days. The post oviposition period varied from 2 to 5 days with an average of 3.28±0.88 days. In laboratory (Table 1), the egg laying capacity recorded during the study was varied from 57 to 149 eggs with an average of 119.21±2.06 eggs per female. Longevity of female varied from 5.50 to 9.0 days with an average 7.50±0.87 days (Table 1), while it was varied from 4 to 8 days for female with an average 6.0±1.19 days. Katagall (1991) [7] also reported the 10.2 and 106 days longevity for unfed male and female, respectively. In case of adults fed with 10% honey, the total life cycle (eggs to adult of male) varied from 24 to 29 days with an average 25.95±2.03 days. Thus, there was non-significant difference observed in life cycle of male and female. Our findings are supported by the earlier results of Kattagall (1991) [7]. Nevertheless, 21 to 26 days for total life cycle of an adult was reported by Nachane *et al.* (1999) [9].

sTable 1: Biology and life cycle of teak defoliator (*Hyblaeapuera*) in semi-arid conditions of Bundelkhand region

Particulars		Period		Mean ± SD
		Minimum	Maximum	
Egg period (days)		2.00	3.00	2.52 ± 0.45
Hatching (Percentage)		45.00	65.00	55.18 ± 5.18
First instar larva		2.00	4.00	2.54 ± 0.66
Second instar larva		2.00	3.00	2.46 ± 0.51
Third instar larva		2.00	3.00	2.49 ± 0.51
Fourth instar larva		2.00	3.00	2.49 ± 0.51
Fifth instar larva		3.00	5.00	3.86 ± 0.88
Total larval period (days)		12.00	16.00	13.83 ± 1.83
Prepupal period (days)		1.10	3.00	2.29 ± 0.56
Pupal period (days)	Male	3.00	5.00	4.39 ± 0.64
	Female	6.00	8.00	7 ± 0.72
Longevity of adult (days)	Male	4.00	8.00	6.05 ± 1.19
	Female	5.50	9.00	7.50 ± 0.87
Pre-oviposition period		2.00	3.50	2.22 ± 0.41
Oviposition period		1.00	5.00	3.0 ± 1.25
Post oviposition period		2.00	5.00	3.28 ± 0.88
Fecundity (No. of eggs)		57.00	149.00	119.21 ± 22.06
Total life cycle (days)	Male	24.00	29.00	25.95 ± 1.60
	Female	25.00	29.00	26.00 ± 2.03

Fig 1: Developmental stages of the teak defoliator starting from eggs to adult
Plate: 1: Damaged leaves 2: Rearing box 3: Eggs 4: 1st Instar larva 5: 2nd Instar larva 6: 3rd Instar larva 7: 4th Instar larva 8: 5th Instar larva 9: Pre pupa 10: Pupa 11 adult

4. Conclusion

Based on the present study, it can be concluded that much difference was not observed in duration of total life cycle, including male and female longevity in populations of *Hyblaea puera* reared in teak leaves in the laboratory conditions. The total larval duration was 13.83 days. Mean longevity of male and female moths was 6.05 and 7.50 days, respectively. The mean pre-oviposition, oviposition and post oviposition period was recorded as 2.22, 3.0 and 3.28 days, respectively. Total number of eggs laid per female was 119.21. Life cycle of male and female adult was completed within 25.95 and 26.0 days. These findings will be helpful to develop the integrated pest management (IPM) strategy to control teak defoliator during early stages of larval growth as the late instar stages cause very high damage to the teak plants.

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