J. Hortic. Sci.
Vol. 20(2), 2025

https://doi.org/10.24154/jhs.v20i2.3024

Original Research Paper

Documentation and taxonomic studies of Lepidopteran fruit borers infesting Litchi in Nagaland, India, with a new distributional record for the country

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ABSTRACT

An extensive roving survey was conducted across Nagaland to document the insect-infesting litchi fruits during 2021-2023. During the survey, a total of five identified species, namely *Conogethes punctiferalis* (Guenée, 1854), *Conopomorpha sinensis* Bradley, 1986, *Cryptophlebia ombrodelta* (Lower, 1898), *Deudorix epijarbus* (Moore, 1857) and *Thaumatotibia zophophanes* (Turner, 1946) were recorded. Notably, the species *T. zophophanes* was a new record from India, while, *C. ombrodelta* and *D. epijarbus* were new distribution records from Nagaland state of India. Furthermore, all five species have been described with quality images. In addition, damage symptoms of each species, along with larvae, have been given. The article provides fundamental information that would enable quick identification and formulating species-specific pest management strategies.

Keywords: Damage symptoms, identification key, new record, roving survey, taxonomy

INTRODUCTION

Litchi stands as a pivotal commercial fruit crop in North Eastern India, boasting significant export potential and offering livelihood opportunities to several million people. Despite its economic importance, the production and quality of litchi fruits are hindered by numerous challenges arising from both biotic and abiotic factors. Apart from abiotic challenges, biotic threats such as insect pests may be formidable to litchi production in India, especially in Nagaland (Srivastava et al., 2019). Several studies have documented approximately 42 insect and mite pests affecting litchi trees and fruits at various growth stages (Srivastava & Choudhary, 2022). Insect species infesting litchi predominantly belong to the order Lepidoptera and Coleoptera, followed by Hemiptera (Srivastava & Choudhary, 2022). Of these insect pests, lepidopteran fruit borers like *Conopomorpha sinensis* (Bradley, 1986) and *Conopomorpha litchiella* (Bradley, 1986) pose a significant challenge for litchi growers in India (Choudhary et al., 2013). The impact of these pests is evident in estimated fruit loss and leaf infestation ranging from 24-32% and 7-70%, respectively (Hameed et al., 2001). Additionally, litchi fruits are infested by other lepidopteran borers such as *Cryptophlebia ombrodelta* (Lower, 1898), *Deudorix epijarbus* (Moore, 1857), *Conogethes punctiferalis* (Guenée, 1854), *Gatesclarkeana* sp. and *Blastobasis* sp. (Srivastava et al., 2018). Earlier studies documented that *C. cramerella* was the prevailing fruit borer species that affected litchi fruits in India (Singh, 1975; Lall & Sharma, 1978; Kumar et al., 2011). Updated host-based morphological and molecular identification techniques revealed that the major litchi fruit borer species was *C. sinensis* (Srivastava et al., 2018). The majority of taxonomic studies were carried out predominantly by simple taxonomic descriptions (Bradley, 1953; Bradley, 1986; Horak & Komai, 2016; Sohn et al., 2016), and very few of them studied host-based taxonomy (Jayanthi Mala et al., 2017). In the North eastern region of India, the information pertaining to the fruit borer species complex was found to be scanty despite its significance. The primary constraint in formulating effective management practices lies in the challenge

of identifying the borer species, a pivotal aspect in entomological science. Recognizing this, the present study aims to address this issue by providing damage symptoms, distribution, and taxonomic descriptions of lepidopteran fruit borers infesting litchi.

MATERIALS AND METHODS

A roving survey was carried out during fruiting season April-July 2022 & 2023 across districts of Nagaland to collect the infested and fallen fruits from litchi orchards. The fruits were brought to the Department of Entomology, Medziphema campus, Nagaland University, Nagaland, India, and reared on its host up to the adult stage. After the emergence, the adult moths were killed by keeping in refrigerator for 2-3 hrs. These preserved adults were utilized to study the morphological and genital characteristics. The dissected specimens were preserved in the Department with a label containing details such as date of collection, locality, altitude and the collector's identity. To prepare the genitalia, the moth abdomens were delicately separated from the thorax using a fine needle and then placed into a test tube filled with a few milliliters of 10 per cent potassium hydroxide (KOH) solution. The mixture was gradually heated in a water bath until convection currents were observed, after which it was allowed to cool down. After being cooled, the abdomen was transferred to a glass cavity dish filled with water, and the softened tissues were carefully removed using a pair of curved needles. After several rinses in water, the abdomen was transferred to glycerin in another glass cavity dish for further dissection and examination under a stereoscopic microscope. Male and female genitalia were stained with eosin and acid fuschin, respectively. The prepared permanent slides of genitalia were duly labeled and deposited in the Department for future reference.

The general terminology used in this study is based on Diakonoff (1954) and terminology for genitalia has been adopted from Tuxen (1970) and Scoble (1992). The morphological characters of the adults were studied following Bradley (1953); Bradley (1986); Horak & Komai (2016); Shashank et al. (2018); Pasam et al. (2023) with slight modifications. The taxonomic classification of the specimen under study was based on Mitter et al. (2017). Similarly, the classification of specimens within each family into respective subfamilies was based on Stempffer (1967); Kawahara et al. (2017); Regier et al. (2012); Hu et al. (2023). Prior to genital dissection, adult specimens were photographed using a Canon EOS 70D attached with 100-mm macro lens. Images of adult characteristics, including forewings, hindwings, palpi, as well as male and female genitalia, were captured using a Leica M 205C Stereo Zoom Trinocular microscope equipped with auto-montage.

RESULTS AND DISCUSSION

A total of 565 specimens were collected from the host plant and reared during the survey, comprising five identified species. Further observations revealed that the identified species represented four different families, *viz*., Crambidae, Gracillariidae, Lycaenidae, and Tortricidae. Within these families, Crambidae, Gracillariidae, and Lycaenidae were each represented by a single species *viz*., *C. punctiferalis*, *C. sinensis,* and *D. epijarbus*, respectively. Meanwhile, Tortricidae was represented by two species, namely *C. ombrodelta* and *T. zophophanes* (Table 1). All these species have shown variations with respect to adult morphological and genital characteristics, as represented in Table 2.

Family Crambidae Latreille, 1810

Genus *Conogethes* Meyrick, 1884

***Conogethes punctiferalis* (Guenee, 1854)**

(Figs. 1-3, 16-17, 26-27, 40, 45)

Distribution

Throughout India (Andhra Pradesh, Assam, Arunachal Pradesh, Delhi, Gujarat, Haryana, Karnataka, Kerala, Khasis, Maharashtra, Madhya Pradesh, Meghalaya, Punjab, Nagaland, Manipur, Sikkim, Rajasthan, Tripura, Tamil Nadu, West Bengal, and regions of West Himalayas) (Snellen, 1890; Sevastopulo, 1956; Sanyal et al., 2018; Chandra et al., 2019; Das et al., 2020a; Das et al., 2020b; Reddy et al., 2020; Komal et al., 2021; Reddy & Shankaramurthy, 2021; Sondhi et al., 2021; Singh et al., 2022; Pasam et al., 2023).

Material examined: INDIA: Nagaland: Medziphema, 25.75° N, 93.86°E, 09.05.2022, 3♂, 4♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 04.06.2022, 3♂, 3♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 05.06.2023, 1♂, 2♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 12.06.2023, 1♂, 3♀, on litchi fruits, P. Mahesh.

Table 1 : Species of lepidopteran fruit borers collected and reared on litchi from Nagaland, India through the survey

Common Name	Scientific name	Family	Subfamily	Damaged parts	Previous reports referred to it as a pest on litchi fruits across the world
Castor capsule borer / yellow peach moth	*Conogethes punctiferalis* (Guenée, 1854)	Crambidae	Spilomelinae	Fruits (pulp and seeds)	Singh & Kaur (2015); Singh et al. (2018); Srivastava et al. (2019).
Litchi shoot and fruit borer / stem end borer	*Conopomorpha sinensis* (Bradley, 1986)	Gracillariidae	Ornixolinae	Leaves, shoots and fruits	Bradley (1986); Waite & Ilwang (2002); Bai et al. (2009); Srivastava et al. (2015); Yao et al. (2015); Jayanthi Mala et al. (2017); Srivastava et al. (2018); Srivastava & Choudhary (2022).
Litchi fruit moth / macadamia nut borer	*Cryptophlebia ombrodelta* (Lower, 1898)	Tortricidae	Olethreutinae	Fruits (pulp and seeds)	Bradley (1953); Waite & Ilwang (2002); Horak & Komai (2016); Sohn et al. (2016); Srivastava et al. (2018); Pathania et al. (2020).
Anar butterfly / fruit borer	*Deudorix epijarbus* (Moore, 1857)	Lycaenidae	Lycaeninae	Leaves, flowers, fruits (pulp and seeds)	Waite & Hwang (2002); Srivastava et al. (2019); Reddy et al. (2016); Gupta & Tara (2019)
Avocado fruit borer / nut borer	*Thaumatotibia zophophanes* (Turner, 1946)	Tortricidae	Olethreutinae	Fruits (pulp and seeds)	Horak & Komai (2016)

Damage symptoms: The larvae were observed boring the fruits either from the peduncle end or from the lateral side of the fruit apex. The presence of granular faecal matter, entangled in the webbing, at the entrance hole was the typical symptom (Fig. 1). The larvae were observed to be feeding on pulp as well as the nut of the fruits (Fig. 2). As the larvae grew, they were observed to make a tunnel in the center of the nut and pupate inside. Later, the adults were found emerging from these tunnels through the entrance hole (Fig. 3).

Description: Adult 16-20 mm, bright straw-yellow coloured; labial palpi black at sides (Fig. 26); collar and patagia spotted black; dorsal metathorax with three black spots (Fig. 27); abdomen with series of black spots on dorsal and lateral sides; male with anal tuft of hairs, more or less black; forewing with black spot at base of costa; three sub-basal black spots and three antemedial; an oblique medial series from lower angle of cell to inner margin; a post medial sinuous series with the spots on veins 5 and 2 displaced inwards; a sub marginal series with the spot-on vein 5 displaced inwards; hindwing with disco cellular spot; a median series highly excurved between veins 2 and 5, and a sinuous sub marginal series (Figs. 16-17).

Male genitalia: Uncus slender, curved ventrally, apical one-third swollen and evenly covered with bifurcate setae dorsally; gnathos pointed at tip; lateral arms of tegumen narrow; saccus U-shaped; juxta narrow, elongate, tapering dorsally; valva broad, ovate at the apex and gradually narrowed towards the base; costa broad, tubular; cucullus with tuft of long hairs at distal end; clasper slim, short, sclerotized, oriented anterior ventrad; sacculus rather narrow, sclerotized and tapered with fringed hairs; aedeagus very long, slender, strongly curved, robust near the base, distally with narrow tip, vesica with a thin needle shaped cornutus of almost the length of aedeagus (Fig. 40).

Female genitalia: Ovipositor triangular and covered with mixture of long and short setae; anterior apophyses about as long as posterior apophyses; ostium narrow, membranous, funnel shaped; antrum sclerotized, tubular; ductus bursae narrow, very long, membranous; ductus seminalis originates anterior to antrum; corpus bursae generally ovate, irregular in shape, posterior part granulated slightly, with a membranous appendix bursae attached laterally, signum absent (Fig. 45).

Remarks: *C. punctiferalis* is a minor pest of litchi fruits (Singh & Kaur, 2015). It is easily distinguished from the sympatric *C. sahyadriensis* by the second segment of labial palpi narrowly tinted with black fuscous while, broadly tinted in *C. shayadriensis* and

Table 2 : Important identification characters of lepidopteran fruit borers of litchi of Nagaland, India

Character	Lepidopteran fruit borer species				
	Deudorix epijarbus	*Conopomorpha sinensis*	*Conogethes punctiferalis*	*Cryptophlebia ombrodelta*	*Thaumatotibia zophophanes*
Adult size	Large; 38-42 mm	Small; 12-15 mm	Medium; 16-20 mm	Medium; 15-21 mm	Medium; 13-16 mm
Adult colour	Male scarlet red; female fulvous brown	Greyish brown with metallic markings on forewings	Pale straw yellow with numerous small black spots	Brown to reddish brown in colour with a darker subtriangular pre-tornal spot distinctive in females, but faded in males	Greyish red-brown to blackish brown
Thorax	Blackish brown	Thorax mostly white but have some greyish white shading	Metathorax dorsally with two spots of black scales	More or less developed with posterior tuft of shortly raised scales	Adorned with a loose posterior tuft consisting of long, upcurved, pale grey scales
Labial Palpi	Three segmented, protruding forward	Upturned, second segment is rough scaled ventrally, with fuscous black exteriorly	Upturned, second segment of labial palpi is narrowly tinted with black fuscous	Segments medially widened with short scales	Three segmented, each segment becomes progressively thinner towards tip, upturned
Male genitalia					
Uncus	Short, curved downwards	Long, tubular and membranous	Tubular, short, dilated in apical 1/3rd	Not well developed	Sharp, bipartite
Valva	Long, broad basally, pointed apically	Moderate, broad basally	Broad, ovate at the apex, gradually narrowed towards the base	Greatly inflated, widened gradually towards apex	Elongate, ovate, wide distally but dilated
Tegumen	Narrow, developed into lateral lobes with deep convex rows of setae (socii)	Broad, transparent, rounded apically	Narrow with lateral arms	Broad, rounded basally	Wide, weakly sclerotized
Saccus	V-shaped	V-shaped	U-shaped	V-shaped	U-shaped
Sacculus	Broad, highly sclerotized	Studded with 12-15 stout setae with dense field of heavy setae in costal region	Narrow, tapered with a weakly protruded saccular margin	Swollen, round shaped	Short vertical, rectangular shape
Gnathos	Absent	Absent	Broad, strongly sclerotized	With two small lateral processes	Weakly sclerotized
Juxta	Not well developed	Trapezoidal, elongated	Narrow, elongated	Inverse-trapezoidal	Wide triangular
Aedeagus	Elongate, broad basally, blunt apically, with dense setae sub apically, vesica with a group of cornuti ending in a robust apical spine	Moderately long, with a pair of heavy cornuti each either bifurcate or trifurcate	Very long, slender, strongly, curved basally with long and slender thorn-like cornuti	Long, curved, robust in basal 1/3rd, narrowed gradually in middle, vesical with a dense elongate patch of diagonally arranged cornuti	Long, sclerotized, evenly sinuate, bulged near the base, vesica membranous with 2-4 small, longitudinal cornuti
Female genitalia					
Anterior and posterior apophysis	Anterior apophysis twice the length of posterior apophysis	Both apophysis are very short	Anterior apophysis as long as posterior apophysis	Anterior apophysis longer than the posterior apophysis	Anterior apophysis slightly longer than posterior apophysis
Ductus bursae	Short, robust, sclerotized basally	Long, stout, sclerotized at basal 1/3rd portion	Long, narrow, transparent	Narrow in posterior half, curved, lightly sclerotized anteriorly	Narrow, short, with a lengthy ring-shaped sclerite anterior to ostium and a small lateral sclerite approximately at one-third from ostium
Corpus bursae	Round, slightly sclerotized at anterior 1/4th, with a pointed signum laterally	Globular with dentate patch signum	Ovate, with an appendix bursae, without signum	Distal 2/3rd with two short, curved, symmetrical, slightly sclerotized signa	Ovate, with a band of coarse spinules near entrance, with two elongated, curved, horn-shaped signa

metathorax with three black spots of scales dorsally instead of two black spots of scales in *C. sahyadriensis*. (Shashank et al., 2018; Pasam et al., 2023).

Family Gracillariidae Stainton, 1854

Genus *Conopomorpha* Meyrick, 1885

***Conopomorpha sinensis* Bradley, 1986**

(Figs. 4-6, 24-25, 28-30, 41, 46)

Distribution: India (Bihar, Haryana, Karnataka, Nagaland, Punjab, and West Bengal) (Dalui & Sarkar, 2021).

Material examined: INDIA: Nagaland: Medziphema, 25.75° N, 93.86°E, 17.05.2022, 10♂, 9♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 19.05.2022, 12♂, 11♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 06.06.2022, 10♂, 7♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 17.06.2022, 6♂, 5♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 19.06.2022, 5♂, 7♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 21.05.2023, 16♂, 14♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 31.05.2023, 13♂, 14♀, on litchi fruits, P. Mahesh. Medziphema, 25.75° N, 93.86°E, 03.06.2023, 9♂, 14♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 18.06.2023, 18♂, 18♀, on litchi fruits, P. Mahesh.

Damage symptoms: The newly emerged larva causes direct damage by boring into the fruits through peduncle by feeding on the pulp (Fig. 4). Larva usually does not enter much deeper into the pulp (Fig. 5). The infested fruits generally drop down before maturity and are easily identified by black spot near the pedicel. Indirectly, the larvae cause damage through making mines into the young leaves and shoots. Due to this, branches wither and drop. Adults usually rest under the horizontal branches (Fig. 6).

Description: Wingspan 12-15 mm in male and female; adults greyish brown with wing apex yellowish brown; head white; thorax greyish fuscous posteriorly; patagium white; labial palpi white, second segment short, scaled ventrally, third segment long, rough scaled; maxillary palpi white; antennae long, one and half-length of forewing, scape greyish fuscous dorsally; female abdomen dark fuscous on dorsal side, white laterally and ventrally, with a wedge like stripes dorsally extending forward from dorsum (Fig. 28); in male anal tuft of hairs yellowish white (Fig. 29); forewing with wing markings having the fifth and sixth line descending to dorsum and joining the falcate white line from tornus demarcating brown basal part of wing from pale orange-yellow apical area, 1/3rd apical part of costa with four or five white strigulae, scattered randomly along basal part of costa, cilia grey (Fig. 30); hindwing silver grey, darker in male, cilia grey, apex suffused white, in male entire underside from near base to apical area strongly irrorate with fine white scales, in female irrorations weaker; legs ochreous-white, legs obliquely stripped with fuscous-black (Figs. 24-25).

Male genitalia: Uncus tubular, membranous; valva broad basally; costa arched; cucullus narrowed distally, distal part scattered with 12-15 stout setae with a dense field of heavy setae in the costal area; tegumen highly reduced; saccus V-shaped; aedeagus long, stout, curved near the base, distal 1/3rd highly sclerotized, with a pair of heavy, sclerotized cornuti, each either trifurcate or bifurcate at the tip (Fig. 41).

Female genitalia: Anal papillae with hairs; ostium narrow, smooth; anterior and posterior apophyses short, slightly sclerotized; ductus bursae long, stout, sclerotized at basal 1/3; corpus bursae globular shape with an elongate, dentate patch signum (Fig. 46).

Remarks: Among the fruit borers, *C. sinensis* is an important pest of litchi (Jayanthi Mala et al, 2017). This species is distinguished from *C. cramerella* and other related species by the distinctive purplish fuscous-black hindwings and also by the presence of scattered white scales on the underside. In *C. sinensis*, male genitalia with distal sacculus studded with 12-15 stout setae whereas, absent in other related species viz., *C. cramerella*, *C. oceanica* and *C. litchiella* (Bradley, 1986).

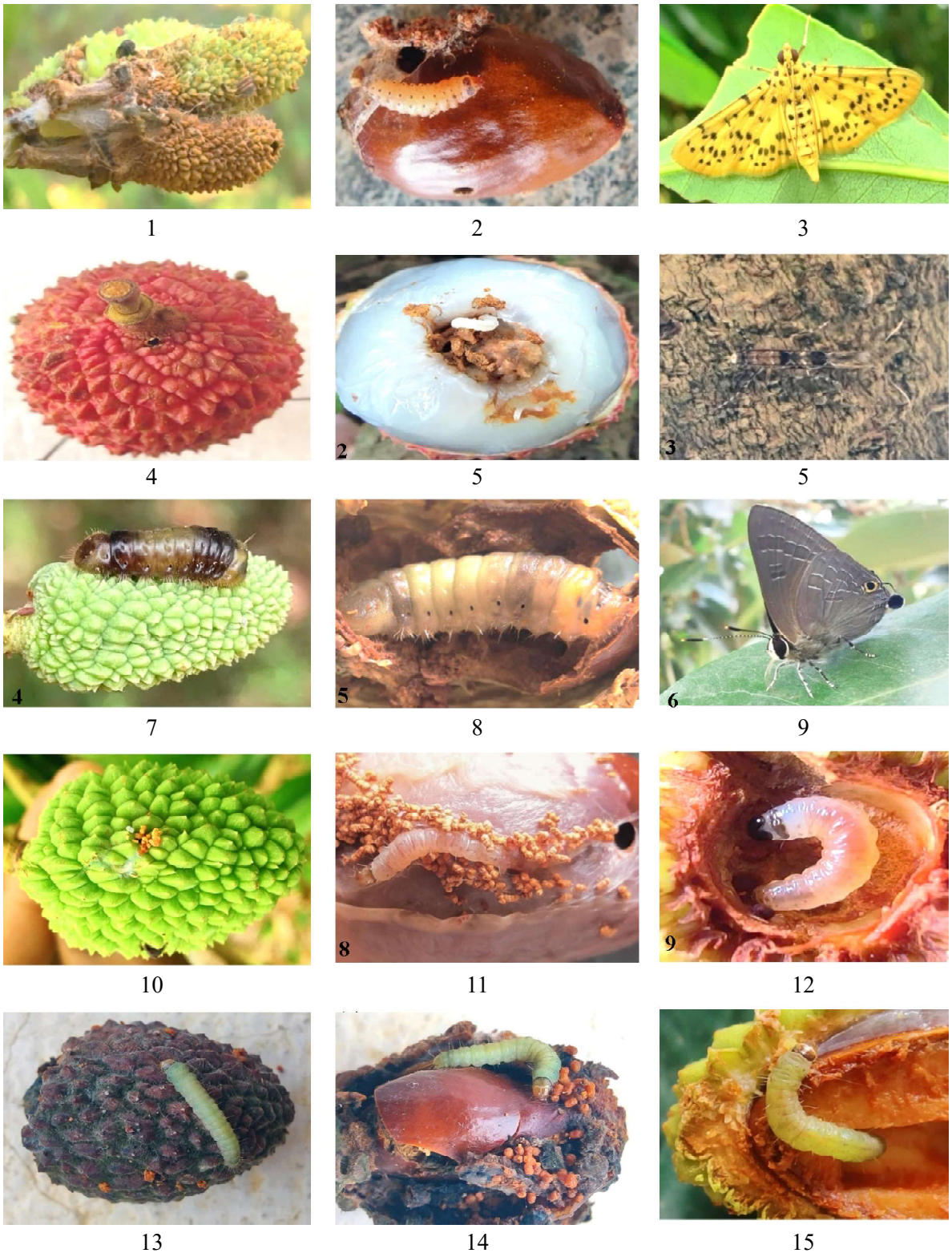
Family Lycaenidae Leach, 1815

Genus *Deudorix* Hewitson, 1863

***Deudorix epijarbus* (Moore, 1857)**

(Figs. 7-9, 18-19, 31-32, 42, 47)

Distribution: India (Assam, Andaman and Nicobar Islands, Jammu and Kashmir, Nagaland, Sikkim) (Waite & Hwang, 2002).



Figs. : 1-15: Damage symptoms;
1-3: *C. punctiferalis*, 4-6: *C. sinensis*; 7-9: *D. epijarbus*; 10-12: *C. ombrodelta*; 13-15: *T. zophophanes*

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Figs. : 16-25: Adult habitus;
16: *C. punctiferalis* (♂), 17: *C. punctiferalis* (♀), 18: *D. epijarbus* (♂), 19: *D. epijarbus* (♀), 20: *C. ombrodelta* (♂), 21: *C. ombrodelta* (♀), 22: *T. zophophanes* (♂), 23: *T. zophophanes* (♀), 24: *C. sinensis* (♂), 25: *C. sinensis* (♀)


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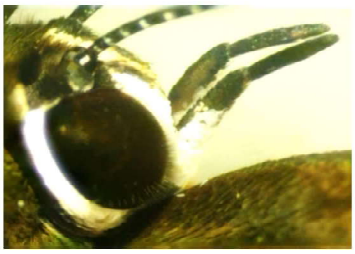
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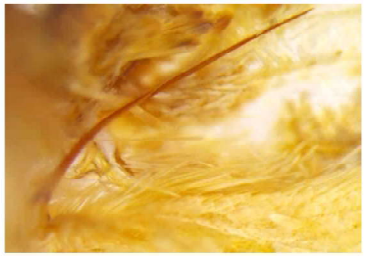
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Figs. : 26-39: Morphological characters;
26-27: *C. punctiferalis*, 28-30: *C. sinensis*, 31-32: *D. epijarbus*, 33-38: *C. ombrodelta*, 39: *T. zophophanes*

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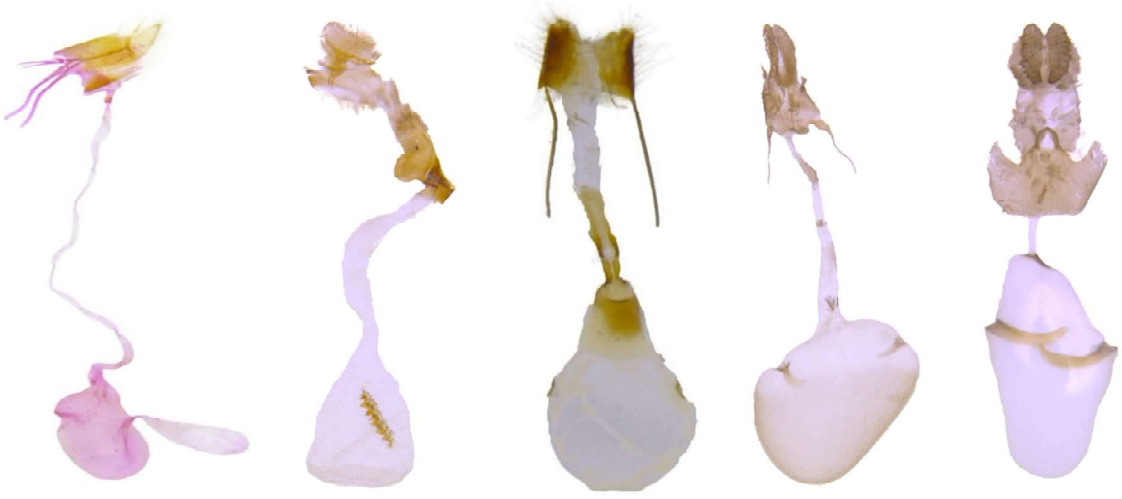
Figs. : 40-44: Male genitalia and aedeagus;
40: *C. punctiferalis*, 41: *C. sinensis*, 42: *D. epijarbus*, 43: *C. ombrodelta*, 44: *T. zophophanes*



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Figs. : 45-49: Female genitalia;
45: *C. punctiferalis*, 46: *C. sinensis*, 47: *D. epijarbus*, 48: *C. ombrodelta*, 49: *T. zophophanes*.

Material examined: INDIA: Nagaland: Dimapur, 25.55° N, 93.44°E, 07.05.2022, 2♂, 4♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 10.05.2022, 9♂, 5♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 04.06.2022, 1♂, 1♀, on litchi fruits, P. Mahesh. Medziphema, 25.75° N, 93.86°E, 08.07.2022, 10♂, 11♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 18.06.2023, 3♂, 2♀, on litchi fruits, P. Mahesh. Medziphema, 25.75° N, 93.86°E, 25.06.2023, 3♂, 2♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 26.06.2023, 2♂, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 03.07.2023, 1♂, 3♀, on litchi fruits, P. Mahesh.

Damage symptoms: The larvae were observed rolling the leaves of new growth, severely damaging and even destroying new growth flushes. Later, larvae were found boring into the young fruits and feeding on the pulp and nut of the fruit, thereby making it inedible (Figs. 7-8). Adults were lycaenids found resting on the surface of the leaf (Fig. 9).

Description: Male: Adult is a butterfly, upper surface scarlet-red; with a wing expanse of 38 mm; Head and thorax blackish brown; compound eyes well developed, edges encircled with white; antennae black, ringed with white, clubbed with a red tip; labial palpi 3 segmented, 1st segment small, blackish dorsally, whitish ventrally, 2nd segment large, stout, whitish, 3rd segment small, broad, blackish (Figs. 31-32); forewing upper surface orange being outlined with a broad black band on costal and outer margins, underside brown colour with stripes; hindwing costa, base and abdominal area covered with lilac scales; tail black, tipped with white, the veins often more or less finely black, underside greyish-brown, markings indicated by their white edges; most of the males have tail in a vertical manner. Female: Adult is a butterfly, upper surface fulvous-brown; with a wing expanse of 42 mm; compound eyes well developed, edges encircled with white; antennae black, ringed with white, clubbed with a red tip; labial palpi three segmented, 1st segment narrowly tinted with black, 2nd segment slightly broader than the 1st segment, 3rd segment little broader than the 2nd segment, brownish; forewing with fulvous suffusion below the median vein,; hindwing with the abdominal fold pale, entire wing is tinted with fulvous; tail black, tipped with white, the veins often more or less finely black, most of the females have tail in a horizontal and wavy manner (Figs. 18-19).

Sexual dimorphism/Identification of sexes: Male have the tail in a vertical manner, whereas in females, the tail is more horizontal and wavy manner. The upper side of the female is completely dark greyish brown, while the male upper surface is scarlet-red.

Male genitalia: Uncus not well developed; valva long, broad basally, pointed apically; tegumen usually developed into lateral lobes by a deep convexity, strongly dipping, with rows of setae laterally known as socii; aedeagus elongate, broad basally, blunt apically, with dense setae sub apically, vesica with a group of cornuti ending in a robust apical spine (Fig. 42).

Female genitalia: Anterior apophyses twice the length of posterior apophyses; ductus bursae short, robust, sclerotized basally; bursa copulatrix round, slightly sclerotized at anterior 1/4th, transparent 3/4th, with a pointed signum laterally (Fig. 47).

Remarks: *D. epijarbus* is a new distributional record for Nagaland and is considered a minor pest of litchi fruits (Srivastava et al., 2019).

Family Tortricidae Latreille, 1803

Genus *Cryptophlebia* Walsingham, 1900

***Cryptophlebia ombrodelta* (Lower, 1898)**

(Figs. 10-12, 20-21, 33-38, 43, 48)

Distribution: India (Chhattisgarh, Odisha, West Bengal) (Bradley, 1953; Pathania et al., 2020).

Material examined: INDIA: Nagaland: Medziphema, 25.75° N, 93.86°E, 05.05.2022, 9♂, 13♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 18.05.2022, 10♂, 11♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 24.05.2022, 9♂, 7♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 30.05.2022, 4♂, 5♀, on litchi fruits, P. Mahesh. Medziphema, 25.75° N, 93.86°E, 13.05.2023, 5♂, 6♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 12.06.2023, 4♂, 6♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 24.06.2023, 8♂, 11♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 30.06.2023, 5♂, 3♀, on litchi fruits, P. Mahesh.

Damage symptoms: The newly hatched larvae tunnel through the flesh of the fruit, causing extensive galleries (Fig. 10). The presence of larval excrement (frass) is a common symptom of internal damage (Fig. 11). Larvae primarily feed on the pulp of the fruit and tunnels towards the nut (Fig. 12). In severe infestation, premature fruit drop can be observed. Due to this, the fruits may become aesthetically unappealing, reducing their market value.

Description: Male: Wingspan 15-21 mm; head, labial palpi, maxillary palpi, antennae light pinkish brown; thorax darker grayish; abdomen has sex scales dorsally (Fig. 33); foreleg and midleg reddish brown, hind leg whitish cream, hind tibia greatly modified, covered with sex scales (Fig. 34); forewing moderately wide, pale brown with dark brown streaks in males, dark brown pre-tornal spot faded (Fig. 35); hindwing small, single frenulum, barely triangular, whitish near the base, upper surface covered with a pocket like sex scales (Fig. 36). Female: Adult wingspan 15-23 mm; head, antennae, labial palpi, maxillary palpi, thorax reddish brown in colour; foreleg and midleg reddish brown, hind leg reddish brown to sliver grayish; forewing moderately wide, coloring from pinkish grey to brown with a costal fold, the dark brown pre-tornal spot is distinctive (Fig. 37), two or three frenulum (Fig. 38); hindwing greyish brown (Figs. 20-21).

Male genitalia: Valva greatly inflated gradually widened towards apex; costa broad; cucullus dome-shaped on outer surface, with three strong marginal spines with distal one closer to ventral one and a tuft of hairs on distal end; gnathos small, hook-shaped; saccus V-shaped; juxta inverse-trapezoidal; tegumen broad, semi-triangular on upper 1/3, rectangular on lower 2/3; aedeagus long, curved, robust in basal 1/3rd, narrowed gradually in the middle, vesica with a dense, elongate patch of diagonally arranged cornuti (Fig. 43).

Female genitalia: Anal papillae broadened dorsally; sterigma narrow, V-shaped, having complete sclerotized ring below ostium; ostium slightly sclerotized laterally; ductus bursae slender at basal 1/3, gradually broadened towards corpus bursae; corpus bursae globular, anterior 2/3 strongly granulated, with two symmetrical signa, each signum large, sclerotized, curved-like (Fig. 48).

Remarks: *C. ombrodelta* known as macadamia nut borer is a serious pest of litchi (Bradley, 1953). This species was recorded for the first time in Nagaland. Adults of *C. ombrodelta* are often confused with *C. illepida*. These species can be separated only based on genital characters. In *C. ombrodelta*, the male genitalia valva has three large spines, and in the female genitalia, sterigma is narrow and V-shaped. In *C. illepida*, male genitalia valva has two large spines, and in female genitalia, the sterigma is wide, V-shaped, and separate (Bradley, 1953; Horak & Komai, 2016).

Genus *Thaumatotibia* Zacher, 1915

***Thaumatotibia zophophanes* (Turner, 1946)**

(Figs. 13-15, 22-23, 39, 44, 49)

Distribution: Australia (Horak & Komai, 2016); India (Nagaland (present study)).

Material examined: INDIA: Nagaland: Medziphema, 25.75° N, 93.86°E, 17.05.2022, 2♂, 3♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 22.05.2022, 5♂, 2♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 16.06.2022, 10♂, 6♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 29.06.2022, 1♀, on litchi fruits, P. Mahesh. Dimapur, 25.55° N, 93.44°E, 12.05.2023, 3♂, 5♀, on litchi fruits, P. Mahesh. Chumoukedima, 25.47° N, 93.46°E, 18.07.2023, 1♂, 1♀, on litchi fruits, P. Mahesh. Kohima, 25.40° N, 94.06°E, 20.07.2023, 1♂, 2♀, on litchi fruits, P. Mahesh. Medziphema, 25.75° N, 93.86°E, 22.07.2023, 3♂, 5♀, on litchi fruits, P. Mahesh.

Damage symptoms: After emergence, larvae tunnel through the flesh of the fruit (Fig. 13). The larval excrement (frass) is seen inside the fruit (Fig. 14). Initially larvae feed on the pulp of the fruit and then tunnel towards the seed of the fruit (Fig. 15). In severe infestation, premature fruit drops can be seen.

Description: Adult wingspan: male 13-15 mm, female 13.5-16 mm; male smaller than the female; head and thorax red to blackish brown; thorax with very loose, up-curved paddle shaped grey scales; in male, abdomen greyish brown with anal tuft of hairs; legs blackish brown with tiny white rings on tarsal segments except in hind legs; abdomen greyish brown; forewing subtriangular, moderately wide, grey-reddish brown with silvery scales, female, forewings have reddish brown studded bands in the costal region (Fig. 39); hindwing brownish grey to grey (Figs. 22-23).

Male genitalia: Valva elongate, ovate, wide distally but dilated; uncus sharp, bipartite; gnathos weakly sclerotized; tegumen wide, weakly sclerotized; cucullus outer surface slightly rounded, inner surface with a wide band of strong, long spines around distal margin; juxta wide, triangular; aedeagus long, sclerotized slightly, evenly sinuate, bulged near the base, narrowly tapering to tip; vesica membranous with 2-4 small, longitudinal cornuti (Fig. 44).

Female genitalia: Anterior and posterior apophyses present; ductus bursae narrow, short, with a lengthy ring-shaped sclerite anterior to ostium and a small lateral sclerite approximately at one-third from ostium; corpus bursae ovate, with a band of coarse spinules near the entrance, with two elongated, curved, horn-shaped signa (Fig. 49).

Remarks: The species, *T. zophophanes* is easily distinguished from *T. aclyta* and *T. maculata* by its forewings being dark without clear paler distal portion and in the male, hindwings grey and abdomen with an anal tuft. In the male genitalia, uncus bipartite, while absent in *T. aclyta* and *T. maculata*. In female genitalia, *T. zophophanes* can be easily recognized by ductus bursae being narrow, rather than anteriorly widened in *T. aclyta* and *T. maculata* (Horak & Komai, 2016). In India, so far, only two species of *Thaumatotibia* i.e., *Thaumatotibia encarpa* (Meyrick) (Pathania et al., 2020) and *Thaumatotibia ramamurthyi* Shashank and Reddy (Reddy & Shashank, 2022) have been reported. In addition, *T. zophophanes* was reported for the first time in India infesting litchi fruits.

In Nagaland (India) five species viz., *C. sinensis*, *C. ombrodelta*, *C. punctiferalis*, *D. epijarbus*, and *T. zophophanes* have been found infesting litchi orchards. Of these, it was found *C. sinensis* and *C. ombrodelta* were major pests, while *C. punctiferalis*, *D. epijarbus,* and *T. zophophanes* were minor. The above findings align with Jayanthi Mala et al. (2017), and Srivastava et al. (2019), who reported *C. sinensis* as a major pest of litchi. In India, there is very limited information on the pest status of *C. ombrodelta* on litchi. However, similar findings were reported by Waite & Hwang (2002), who reported *C. ombrodelta* as a severe pest of litchi in Hawaii and Australia. Moreover, among the species of *Cryptophlebia*, *C. ombrodelta* is the only species affecting litchi orchards in Nagaland. However, Bradley (1953) reported *Cryptophlebia peltastica* (Meyrick) and *Cryptophlebia illepida* (Butler) affecting litchi fruits alongside *C. ombrodelta*, and are restricted to Africa, Seychelles, Madagascar, Mauritius, Guam and Hawaii. *C. punctiferalis*, *D. epijarbus*, and *T. zophophanes* were considered minor pests in the present study which is contrast to Singh et al. (2018), who reported *C. punctiferalis* as a severe pest of litchi in Punjab and Himachal Pradesh, India.

Regarding the pest status of *D. epijarbus*, the findings were similar to those of Srivastava et al. (2018), who also reported its status as minor. However, there are no reports on pest incidence and occurrence of *T. zophophanes* on litchi. Horak (2006) first identified it in Queensland, Australia, infesting macadamia and avocado. Later, Gopurenko et al. (2021) found damaging lemon wood fruits in Papua New Guinea. The migration of *T. zophophanes* to India is not documented, but its introduction may have occurred through accidental entry through infested fruits or planting material (Jones, 2002). The internal feeding habits of these larvae cause significant economic losses by degrading fruit quality and inducing premature fruit drop. In the present study, it is found that larvae of *C. punctiferalis*, *C. ombrodelta*, and *T. zophophanes* damage fruits by feeding on the pulp and seeds, while *C. sinensis* larvae mine shoots and leaves during the off-season and bore into fruits during the fruiting season. In contrast, *D. epijarbus* larvae feed on leaves, flowers, and fruit, consuming both the pulp and seeds. These studies align with the results of Waite & Hwang (2002) and Srivastava et al. (2019).

Litchi growers face significant challenges in managing these pests due to their concealed larval feeding behaviour, often tedious into fruits, making early detection difficult. Continuous insecticide spray applications would be necessary because eggs can be present year-round, and dense foliage of litchi trees would prevent some fruits from receiving treatment. Due to various biotic and abiotic factors such as favourable environmental conditions, increased use of broad-spectrum pesticides, and the decline of natural enemies always, there is a chance of minor pests becoming severe pests. These factors make insecticidal options for managing fruit borers labour-intensive, expensive, and risky for non-target and beneficial insects (Namba, 1957). They could lead to pest population outbreaks and intensified crop damage.

To mitigate this risk, integrated pest management approaches other than insecticides, including the use of pheromone traps (Chang, 1995; Acebes-Doria et al., 2023), gamma irradiation techniques (Follett & Lower, 2000), conservation of natural enemies (Chakravarthy et al., 2018) should be adopted. Furthermore, minimizing pesticide use and promoting agroecological practices will help maintain ecosystem balance, prevent pest outbreaks, and ensure the production of safe and economically viable litchi.

CONCLUSION

The present study was the first of its kind, and it made an effort to study the lepidopteran fruit borers, which were reared on their hosts. The specimens were classified into four families, five genera, and five species based on the morphological and genital variations. Of these species, *T. zophophanes* was recorded for the first time in India, while, *C. ombrodelta* and *D. epijarbus* were the new records from Nagaland. Additionally, identification characters were provided for the accurate and easy identification of these species. We also provided coloured photographic illustrations and valid names for each species.

ACKNOWLEDGEMENT

The senior author is thankful to the University Grants Commission, New Delhi, for providing financial support in the form of a UGC Non-NET fellowship and to the Department of Entomology, College of Agriculture, Beemarayanagudi campus, University of Agricultural Sciences, Raichur, Karnataka, and the Department of Entomology, School of Agricultural Sciences, Medziphema campus, Nagaland University, Nagaland, for carrying out the research work.

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(***Received : 9.6.2024; Revised : 17.9.2025; Accepted : 22.9.2025)***