Article

Thoracic morphology of the pomegranate fruit borer (Lepidoptera: Lycaenidae) larva

Ravindrakumar D. Patil
Department of Zoology, Maratha Vidya Prasarak Samaj's K.T.H.M. College, Gangapur Road, Nashik, Maharashtra, India
E-mail: drpatil120170@gmail.com

Received 3 December 2022; *Accepted 10 January 2023*; *Published online 28 January 2023*; *Published 1 March 2023*

Abstract
The pomegranate fruit borer, *Deudorix isocrates* (Fab.) is a serious pest of pomegranate causing remarkable economic loss and reported from most of the pomegranate growing countries. The research work on this pest has been undertaken on its bio ecological aspects and management. There are the least reports available on its morphological studies. This is the first study has been done on morphological details of the thoracic region of the sequential larval instars. The description is based on detailed light microscopic study of cuticular features, spiracles and appendages. This study is important to understand identification marks of larval instars, larval metamorphosis and taxonomic features. With increase in size the larval instars show peculiar morphological changes in the prothoracic shield and prothoracic spiracles as identification mark of each larval instar and found important to understand development of respiratory organs. The microscopic studies on thoracic appendages revealed general lepidopterist type. Results add to our knowledge of thoracic metamorphosis during larval period and provide a standard for further research on the morphological characters of *Deudorix isocrates* (Fab.).

Keywords *D. isocrates*; pest; thoracic metamorphosis; prothoracic shield; prothoracic spiracles.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

The study on larval morphological characteristics is critical for a better understanding of their development and taxonomy. Although the larval stages of Lepidoptera have less structure than adults do, their morphological study is significant, particularly in the field of taxonomy and phylogenetic relationships (Hasenfuss and Kristensen, 2012). Most cultivated plants are damaged and attacked by larva of lepidopteran pest, which is the second most diverse insect pest after coleoptera (Rose and Singh, 2010). *Deudorix isocrates* (Fab.) (Lepidoptera: Lycaenidae) is a severe economic pest on pomegranate and guava (Kumar et al., 2017; Devi et al., 2021). *D. isocrates* has been studied for a long time in terms of ecological and economic aspects, its larva has received very little attention. *D. isocrates* larva have had very few morphological and biological studies.Lepidopteran classification mainly relied on morphological observations of adults, despite the fact that recent studies have repeatedly helped to resolve classifications based on immature morphology (Kitching, 1984; Scoble, 1995; Freitas and Brown, 2004; Duarte et al., 2005; Willmott and Freitas, 2006). The purpose of this study is to offers thorough thoracic morphology which will helpful in taxonomic study of lycaenids and to find morphological features for perfect identification of the pest.

2 Materials and Methods

Eggs of *Deudorix isocrates* were collected from the field during the field survey and reared in glass Petri plates. After hatching the larvae were reared in the laboratory to obtain sequential instars. The larval instars were determined by observing casting of the skin during each consecutive moult. From each instar stage some larvae were used for permanent mounting preparation while remaining larvae were reared to obtain later instar stages. The live specimens were used to record general morphological features of thoracic region. To study microscopic details randomly selected larvae from each instar were killed by insect killing jar and preserved in 10% formaldehyde. The preserved specimens were used for permanent mounting preparations. The preserved specimens were rinsed in distilled water, dissected to separate thoracic region and appendages and boiled in 10%KOH to make it translucent. The material was again rinsed in distilled water, dehydrated by ascending grades of alcohol, cleared in xylene and mounted in DPX. The morphological details were studied using a compound microscope with ocular micrometer to record measurementsand illustrations were prepared by Camera lucida.

3 Results

Thorax of the larva consists of three segments. General surface of these segments including terga, pleura and sterna is characteristically pigmented as a species-specific feature.The pro and mesothoracic terga up to 2nd instar are whitish which becomes pale brown in 3rd and yellow with brown tinge in 4th instar stage (Fig. 1) of larva. The brown pigmentation of metathoracictergum becomes darker from 1st to last instar. The prothoracic pleuron shows brown band just above the prothoracic spiracle and continues in meso and metathoracic pleura. The general thoracic surface is very poorly sclerotized except central portion of prothoracic tergum and clothed with various types of setae. The tergal region of thoracic segments is extended laterally, which conceals the thoracic appendages. Prothoracic tergum is extended a bit anteriorly. The extended portion covers the head capsule. There is only one pair of spiracles in thoracic region of the larva. The pair is present in prothorax. It is placed in a shallow depression, which is formed on lateral sides of the prothoracic tergum. Each thoracic segment bears a pair of “walking legs”.

The central sclerotized portion of prothoracic tergum is peculiarly subjected to changes in pattern of sclerotizationand pigmentation from instar to instar (Figs. 2 to 5). The central sclerotized part of prothoracic tergum is referred here as a prothoracic shield. Morphologically, these features of prothoracic shield are significant and helpful for identification of a specific instars in field.

In 1st instars stage, the prothoracic shield is localized to a small single, oval plate (Fig. 2). The sclerotization is weak and colour is pale. The microscopic observations reveal relatively dark brown pigmentation at anteriomesal portion of the oval plate. There is a pair of long, translucent setae like hair, distributed on the plate. In 2nd instar (Fig. 3) the sclerotization is enhanced and a single plate becomes relatively hard. The anterior half of the plate extends laterally whereas posterior region becomes roughly semicircular. The laterally extended portion of both the sides and the anteriomesal portion are very much dark brown thus the prothoracic shield becomes easily visible. Moderately long hair are distributed in bilateral symmetry in relation to the median axis. In 3rd instars stage (Fig. 4), sclerotization further enhances and the prothoracic shield becomes relatively much harder than that of previous instars. The dark, reddish brown pigment is distributed roughly throughout the surface hence, it becomes remarkably distinct. Though it appears a single plate, the microscopic observations suggest that the plate tends to split in to two halves due to an unsclerotized narrow strip that is formed along the median axis. There are numerous well sclerotized, dark brown, short hairs distributed throughout the surface of plate. These hairs are distributed in bilateral symmetry in relation to the median axis.In full-grown larva, the prothoracic shield is highly sclerotized in such a way that the sclerotized region shows two horizontally placed, triangular halves by the side of unpigmented median strip along central axis of the tergum (Fig. 5). Each half is roughly triangular with dark black colouration at each corner and along central axis while rest part of the triangle is gray in colour.

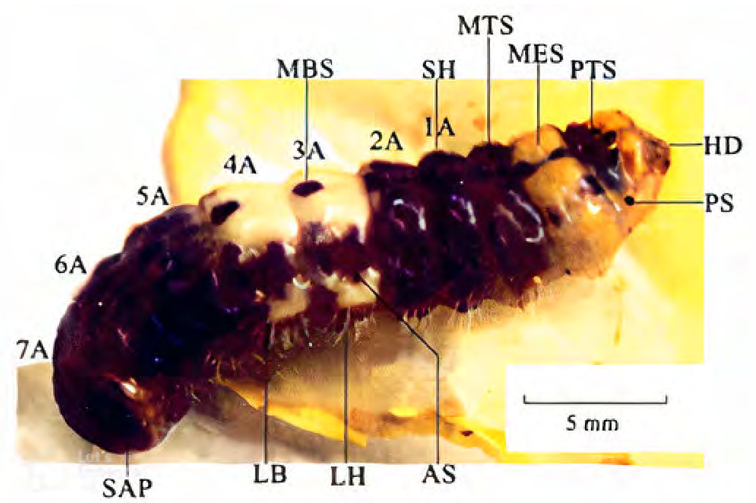

Fig. 1 Last (4th) instar larva of *D. isocrates* (Fab.). **1A-7A:** Abdominal segments; **AS:** Abdominal spiracles; **HD:** Head; **LB:** Lateral colour band; **LH:** Lateral hair; **MBS:** Median brown spot, **MES:** Mesothoracic segment; **MTS:** Metathoracic segment; **PS:** Prothoracic spiracle; **PTS:** Prothoracic segment; **SAP:** Suranal plate; **SH:** Short brown hairs.

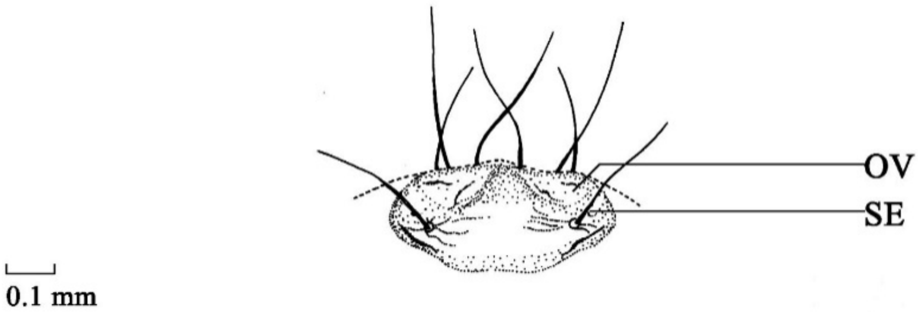

Fig. 2 Prothoracic shield of 1st instar larva of *D. isocrates*. **OV:** Oval Plate; **SE:** Seta.

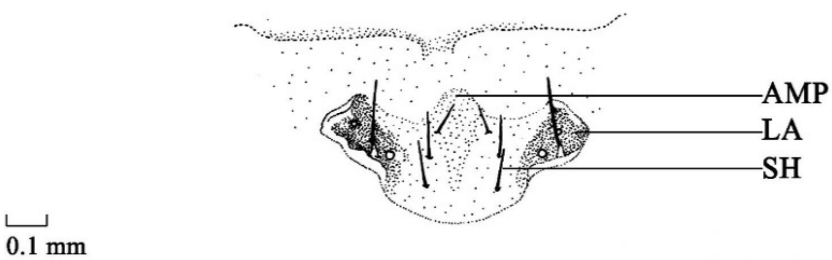

Fig. 3 Prothoracic shield of 2nd instar larva of *D. isocrates*. **AMP:** Anterior median pigmented area; **LA:** Lateral pigmented area; **SH:** Sclerotized hair.

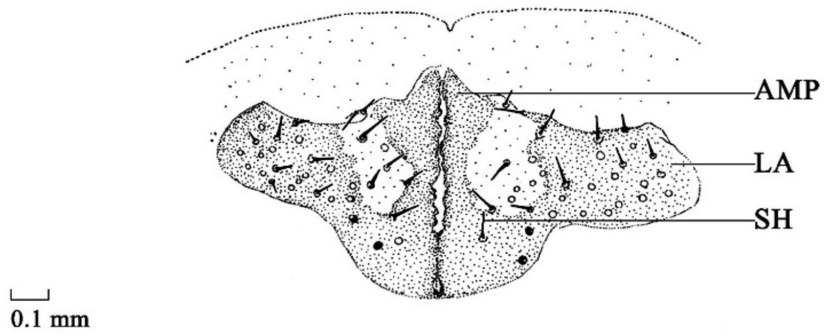

Fig. 4 Prothoracic shield of 3rd instar larva of *D. isocrates*. **AMP:** Anterior median pigmented area; **LA:** Lateral pigmented area; **SH:** Sclerotized hair.

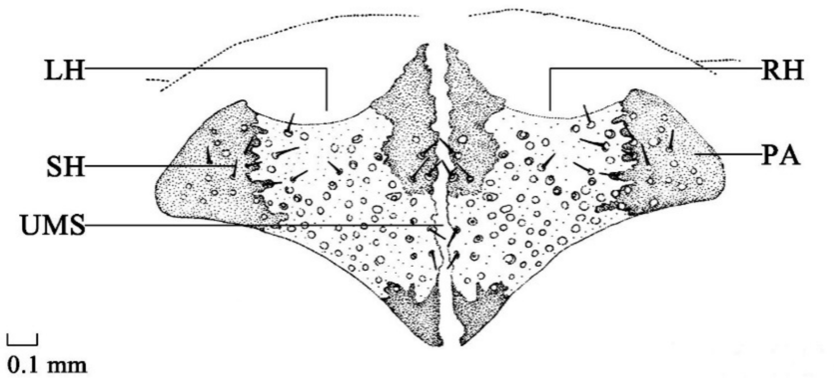

Fig. 5 Prothoracic shield of 4th instar larva of *D. isocrates*. **LH:** Left half; **PA:** Pigmented area; **RH:** Right half; **SH:** Sclerotized hair; **UMS:** Unsclerotized median streak.

The microscopic observations of prothoracic shield (Fig. 5) reveal that each half defines four angles. However, in gross it appears triangular. The sclerotized halves are clothed with numerous short, stout, sclerotized hairs, which are pigmented with brown.

There is a pair of spiracles situated on lateral aspect of the prothoracic segment hence called as the prothoracic spiracle. There is no any report on detailed morphology of prothoracic spiracles in *D. Isocrates*.

In general, the prothoracic spiracle consists of peritreme, the atrium in which the actual spiracular orifice is enclosed and the closing apparatus which is situated at the inner end of atrium. Out of these structures, the surface view of prothoracic spiracle shows all parts except the closing apparatus. It is visible in the KOH treated material. The structural elements of closing apparatus are assembled on outer wall of the tracheal opening in to the atrium.

With increase in size (Table 1) morphologically the prothoracic spiracle changes from instar to instar. In 1st instar, it is circular (Fig. 6). In 2nd instar it becomes oval (Fig. 7) Inboth the instars it remains wide open. It is surrounded by sclerotized peritreme. The wall of atrium shows crosswise striations, which run from peritreme to the spiracular opening. In 3rd instar the spiracular opening is occluded due to formation of trabeculae (Fig. 8). The trabeculae run towards the center and most of them are branched, terminally. The terminal branches form network, which is more or less limited towards the central part of the spiracle. The trabecular branches join with each other. Thus, the sclerotized sheet is formed. This formation occupies the spiracular orifice leaving a narrow vertical spiracular aperture. The sclerotized sheet is fringed with sharply pointed bristles. These are the phases of development of spiracular structure from 1st instars to 3rd instars.

Table 1 Morphometric observations of thoracic structures of *D. isocrates* larva.

Larval Instar	Average Bodylength in mm (n=10)	Average breadth at thoracic segments in mm (n=10)		Size of prothoracic spiracles in mm (n=10)	
		Prothoracic segment	Meso and Metathoracic segment	Average height	Average Width / diameter
1st instar	2.38 (1.50-4.50)	*	*		0.029** (0.026 - 0.032)
2nd instar	6.9 (5.00-9.50)	1.76 (1.25 - 2.50)	1.95 (1.25 - 2.80)	0.066 (0.064 – 0.070)	0.053 (0.051 - 0.058)
3rd instar	11.51 (10.0 - 14.00	2.61 (2.00 - 3.00)	3.34 (2.00 - 4.00)	0.120 (0.102 – 0.140)	0.080 (0.077 - 0.09)
4th instar	23.01 (15.5 - 31.00)	4.23 (4.00 - 5.00)	5.23 (4.00 - 7.00)	0.333 (0.205 – 0.384)	0.211 (0.192 - 0.243)

Figures in parentheses are range values.
* Not measured being small size.
** Diameter is measured since the spiracle is circular.

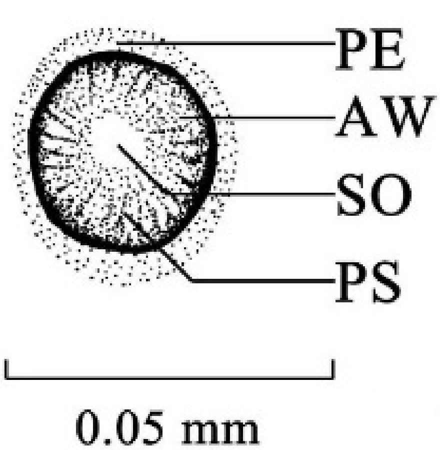

Fig. 6 External surface view of Prothoracic spiracle of 1st instar larva of *D. isocrates*. **AW:** Atrial wall; **PE:** Peritreme; **PS:** Pigmented weakly sclerotized streaks; **SO:** Spiracular opening.

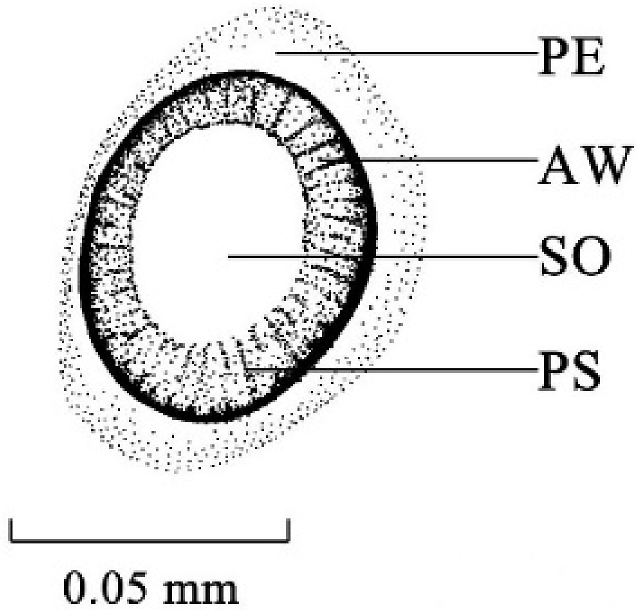

Fig. 7 External surface view of prothoracic spiracle of 2nd instar larva of *D. isocrates*. **AW:** Atrial wall; **PE:** Peritreme; **PS:** Pigmented weakly sclerotized streaks; **SO:** Spiracular opening.

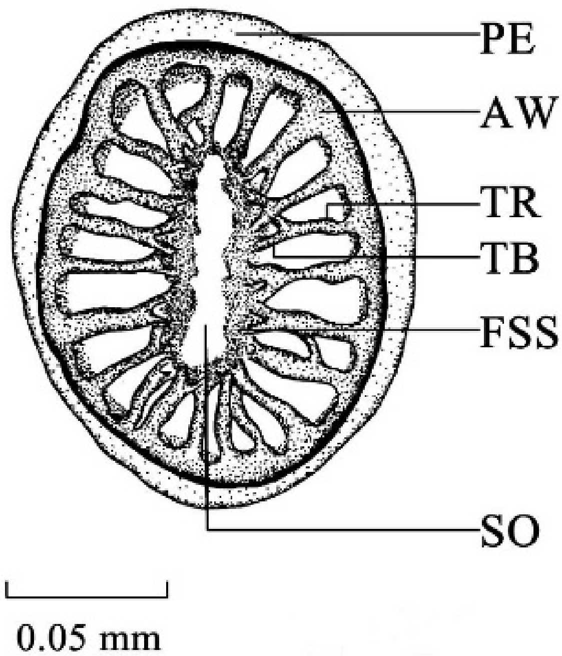

Fig. 8 External surface view of Prothoracic spiracle of 3rd instar larva of *D. isocrates*. **AW:** Atrial wall; **FSS:** Fringed sclerotized sheet; **PE:** Peritreme; **SO:** Spiracular opening; **TR:** Trabeculae; **TB:** Trabecular branch.

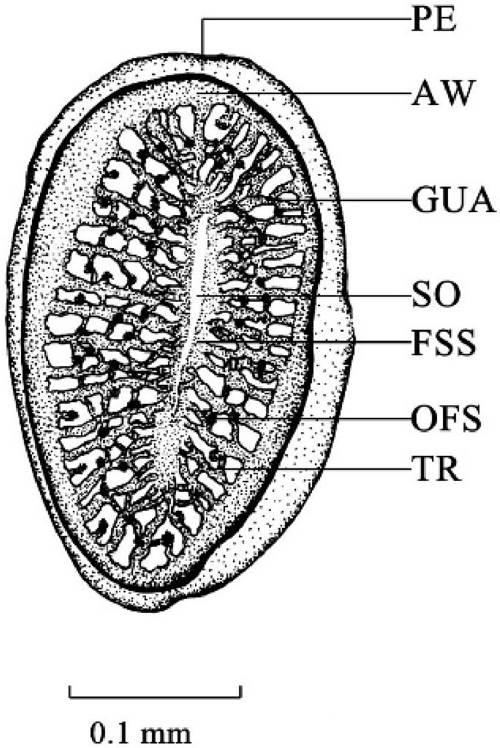

Fig. 9 External surface view of Prothoracic spiracle of 4th instar larva of *D. isocrates*. **AW:** Atrial wall; **FSS:** Fringed sclerotized sheet; **GUA**: Guarding apparatus; **OFS:** Oval fringed sclerotized spot; **PE:** Peritreme; **TR:** Trabeculae; **SO:** Spiracular opening.

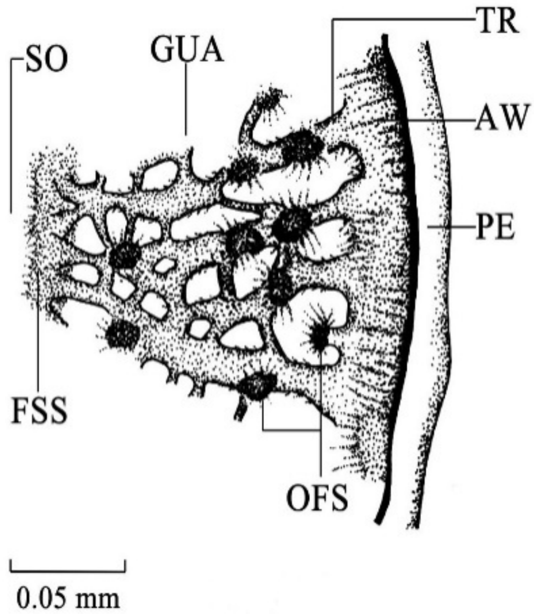

Fig. 10 Magnified view of Prothoracic spiracle of 4th instar larva of *D. isocrates*. **AW:** Atrial wall; **FSS:** Fringed sclerotized sheet; **GUA:** Guarding apparatus; **OFS:** Oval fringed sclerotized spot; **PE:** Peritreme; **SO:** Spiracular opening; **TR:** Trabeculae.

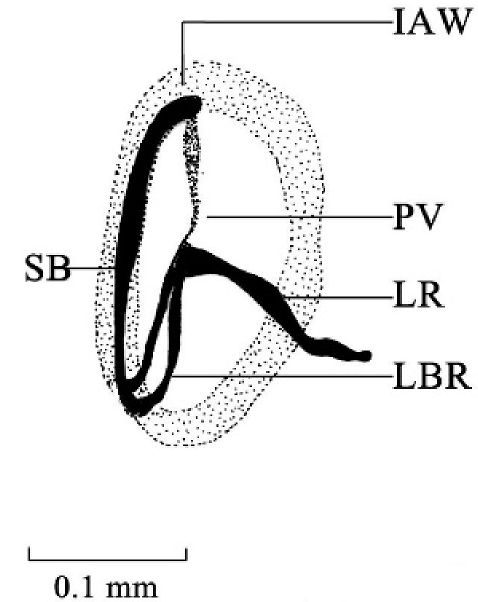

Fig. 11 Internal view of Prothoracic spiracle showing closing apparatus of 4th instar larva of *D. isocrates*. **IAW:** Inner atrial wall; **LBR:** Looped bar; **LR:** Lever; **PV:** Posterior valve; **SB:** Sclerotized bow.

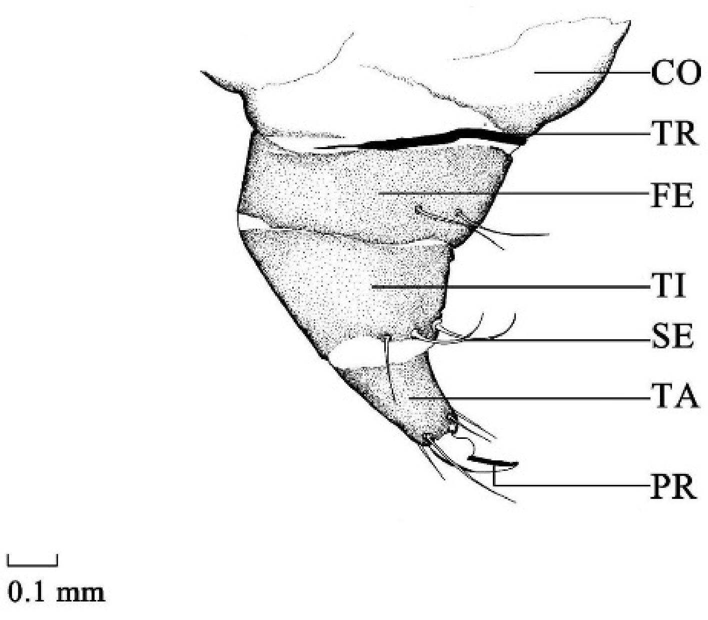

Fig. 12 Thoracic appendage of 4th instar larva of *D. isocrates*. **CO:** Coxa; **FE:** Femur; **PR:** Pretarsus; **SE:** Seta **TA:** Tarsus; **TI:** Tibia; **TR:** Trochanter.

In full-grown larva, the thoracic spiracle appears as dark black, oval spot by naked eyes but, microscopic observations reveal that it is not that simple. The oval spiracle (Fig. 9) is peripherally marked by the peritreme. The peritreme is present in the form of narrow sclerotized rim around the atrial wall. The atrial wall is projected outwardly and forms an elevated sclerotized ring on the general body surface. The atrial wall is produced into rigid, sclerotized processes. These rigid processes are fringed with minute, sclerotized and sharply pointed bristles. Such fringed processes are called trabeculae. The trabeculae are numerously branched while projecting towards the center of spiracle. The branched trabeculae form the network, which appears as the ‘guarding apparatus’. Some of the branches of trabeculae remain free and directing outwards. Thick endings of these branches appear as fringed oval or circular dark spots (Fig. 10) which are evenly distributed on the guarding apparatus. The ends of terminal branches of trabeculae merge with each other and form a fringed flattened sclerotized sheet around the spiracular orifice. The surrounding flattened sheet also fringed with short, sclerotized and sharply pointed bristle. In this manner the guarding apparatus encloses the spiracular orifice, which is present in the form of vertical slit like opening.

The closing apparatus (Fig. 11) consists of different sclerotized elements. These elements are situated at the inner end of an atrium and assembled on outer wall of tracheal opening in to the atrium. There is a sclerotized bow. It lies anteriorly and encircles the anterior half of the tracheal opening. The posterior valve is provided with outwardly projected well sclerotized lever. The lever hinges on the looped sclerotized bar. Other ends of looped bar hinge with the ventral end of sclerotized bow.

There are three pairs of cone shaped ventrally directed thoracic appendages. Each thoracic segment bears one pair. Each appendage articulated to the pleural region of each thoracic segment. Each appendage (Fig. 12) is formed of five parts; the coxa, the trochanter, the femur, the tibia and the tarsus. All appendages are short and stumpy. They are articulated with thoracic pleura by conspicuous, oval lobe like coxa. Both the proximal and distal ends of coxa are wider than the length. The wall of coxa is sclerotized at inner angle. This restricted region appears brown. There are a few setae and sclerotized hairs along its proximal region. Along its distal border there is partially sclerotized incomplete ring, the trochanter. It lies along inner angle between coxa and femur. Distal to the incomplete ring of trochanter lies the femur. It is small, uniformly sclerotized with light brown colour. It is also wider than its length. The part is roughly cylindrical and bears a few setae towards distal end. Distally femur articulates with tibia. Tibia is slightly elongated than the femur. It is wider at its proximal end but tapers proportionately towards the distal end. It is also uniformly sclerotized and looks brown. It bears a few long setae. Some setae are straight while some are curved. The tibia articulates with the tarsus distally. It is terminal tapering part of “cone”. Its sclerotization and colour are similar to that of other parts. Distally the tarsus bears a pretarsus. It is a single highly sclerotized, curved, pointed claw. At the proximal inner surface, the claw bears a round, lobe like protuberance. It seems it is characteristic of lepidopterous claw. The features of thoracic appendages of 1st to 4thinstars are similar in all respects. However, there is gradual increase in size from 1st to 4th instar.

4 Discussion

The pigmentation of thoracic terga and pleura in each instar stage of *D. isocrates* larva is appeared as species specific character and helpful to distinguish them from each other and to identify the pest species during early stage of its development. In lycaenids comparatively larger prothoracic segment than meso and metathoracic segment is reported earlier (Eaton, 1982; Ballmer and Wright, 2008) but in *D. isocrates* the prothoracic segment is smaller than meso and metathorax. Laterally extended tergal plates of thoracic segments (Richards and Davies, 1977) are the specialized lycaenids characters found in *D. isocrates*. Presence of prothoracic shield, prothoracic spiracle and three pairs of appendages are the general characteristics of lepidopteran larvae (Todd, 2013; Stehr, 1987; Graca and Solis, 2018; Marquis et al., 2019; Greeny et al., 2009; Kaminski, 2008; Kaminski and Carvalho-filho, 2012) present in *D. isocrates* as a general lepidopterous characteristics but their microscopic features are specialized. The thoracic terga are unsclerotized except the central region of prothoracic tergum. Hence it is termed as a prothoracic shield (MacKay, 1962). Sometimes it has also been termed as prothoracic tergal plate (Eaton, 1982) and prothoracic plate (Barao and Moreira, 2010). In the present study the term 'prothoracic shield' is used according to its heavy sclerotization. Including Lycaenidae the studies on prothoracic shield of lepidopteran larvae (Scoble, 1995; Duarte and Robins, 2009) reported its significance in identification and classification of caterpillars. In *D. isocrates* larvae the microscopic details appeared as diagnostic features to identify this pest at larval stage as well as to distinguish sequential larval instar stages from each other. The gradual changes in prothoracic shield during larval development are also reported in other groups of Lepidoptera (Moraes et al., 2012). In 1st instar larva the prothoracic spiracles are circular and become elliptical in later instar stages. The similar observation has been reported in *H. armigera* (Queiroz-Santos et al., 2018). On external surface the spiracle exhibits peritreme and filter apparatus (Schmitz and Wasserthal, 1999; Wasserthal, 2003) which is also labelled as guarding apparatus (Snodgrass, 1935; Richards and Davies, 1977) or sieve plate (Forster, 2010) in different species of lepidopteran larva. The present study is the first report on instarwise gradual development of filter apparatus and its microscopic details. The filter apparatus is composed with finest divisions of repeatedly branched processes. The repeatedly branched processes have been called as trabeculae (Tonapi, 1994; Forster, 2010). In *D. isocrates* larva the trabeculae and their terminal branches develop in 3rd instar. The network of branching trabeculae, fringed terminal spots and fringed sheet which occludes the spiracular orifice develop during the 4th instar. The closing apparatus of spiracle composed with a sclerotized bow, looped bar and a lever (Tonapi, 1959; Srivastava, 1975; Richards and Davies, 1977; Eaton, 1982; Nikam and Khole, 1989; Chapman, 1998; Schmitz and Wasserthal, 1999; Wasserthal, 2003) is produced from the inner wall of atrium and the closing mechanism is operated by muscles. These lepidopterist elements of closing apparatus are present in the prothoracic spiracle of *D. isocrates* larva. The cone shaped thoracic locomotory appendages in *D. isocrates* are five segmented terminally bear hook shaped tarsal claw (Barao and Moreira, 2010; Queiroz-Santos et al., 2018). In present study it is referred as a pretarsus. The present study is helpful for the understanding of detailed morphology of larval thorax, metamorphosis during larval period, diagnostic features of larvae for perfect identification of the pest during early stages of *D. isocrates*.

Acknowledgements
The author is grateful to Dr. P.V. Joshi (Professor, Dept. of Zoology Savitribai Phule Pune University) for his sincere help and guidance.

References

Ballmer GR, Wright DM. 2008. Life history and larval chaetotaxy of *Ahmetia achaja* (Lepidoptera, Lycaenidae, Lycaeninae, Theclini, Cheritrina). Zootaxa, 1845: 47-59

Barão KR, Moreira GRP. 2010. External morphology of the immature stages of *Neotropical heliconians*: VIII. *Philaethria wernickei* (Röber) (Lepidoptera, Nymphalidae, Heliconiinae). Revista Brasileira de Entomologia, 54(3): 406-418

Chapman RF. 1998. The Insects: Structure and Function (4th edn). Cambridge University Press, USA

Devi GT, Emmanuel N,Viji CP,Sekhar DSS. 2021. Seasonal incidence of fruit borers (*Conogethes punctiferalis* and *Deudorix isocrates*) in guava cv. Taiwan white. Journal of Entomology and Zoology Studies, 9(2): 282-286

Duarte M, Robbins RK. 2009. Immature stages of *Calycopis bellera* (Hewitson) and *C. janeirica* (Felder) (Lepidoptera, Lycaenidae, Theclinae, Eumaeini): Taxonomic significance and new evidence for detritivory. Zootaxa, 2325: 39-61

DuarteM, Robbins RK, Mielke OHH. 2005. Immature stages of *Calycopis caulonia* (Hewitson, 1877) (Lepidoptera, Lycaenidae, Theclinae, Eumaeini), with notes on rearing detritivorous hairstreaks on artificial diet. Zootaxa, 1063: 1-31

Eaton JL.1982. Exoskeleton and muscular morphology of the larval thorax of *Manduca sexta* L. (Lepidoptera: Sphingidae). Annals of the Entomological Society of America, 75: 313-322

Förster TD. 2010. Spiracular control in moth pupae passive generation of respiratory patterns. Dissertation, Humboldt-Universität Berlin, Germany

Freitas AVL, Brown KSJ. 2004. Phylogeny of the Nymphalidae (Lepidoptera). Systematic Biology, 53: 363-383. DOI: 10.1080/10635150490445670

Graça MB, Solis MA. 2018. Order Lepidoptera. In: Thorp and Covich's Freshwater Invertebrates (Fourth Edition). 325-338, Academic Press, USA

Greeney H F, Hill RI, Hualinga MR, et al. 2009.The immature stages and natural history of *Veladyris pardalis* (Salvin, 1869) in eastern Ecuador (Lepidoptera, Nymphalidae, Ithomiinae). Journal of Insect Science, 9(1): 1-6. DOI: 10.1673/031.009.3501

Hasenfuss I, Kristensen NP. 2012. Skeleton and muscles: immatures. Teilb and Part 36 Vol 2: Morphology, Physiology, and Development (Willy Kükenthal, ed). Boston: 133-164, De Gruyter, Berlin, Germany. DOI: https://doi.org/10.1515/9783110893724.133

Kaminski LA. 2008 Immature stages of *Caria plutargus* (Lepidoptera: Riodinidae), with discussion on the behavioral and morphological defensive traits in nonmyrmecophilous riodinid butterflies. Annals of the Entomological Society of America, 101(5): 906-914

Kaminski LA, Carvalho-Filho FS. 2012. Life History of *Aricoris propitia* (Lepidoptera: Riodinidae)—A Myrmecophilous Butterfly Obligately Associated with Fire Ants. 1-10, Hindawi Publishing Corporation Psyche. DOI:10.1155/2012/126876

Kitching IJ. 1984. An historical review of the higher classification of the Noctuidae (Lepidoptera). Bulletin of the British Museum of Natural History (Entomology), 49: 153-234

Kumar KP,Kamala JPD, Verghese A, et al. 2017. Facultative myrmecophily in *Deudorix isocrates* (Fabricius) (Lepidoptera: Lycaenidae). Journal of Entomology and Zoology Studies, 5: 870-875

MacKay MR. 1962. Additional larvae of the North American Olethreutinae (I) (Lepidoptera: Tortricidae). The Canadian Entomologists, 98: 626-642

Marquis RJ, Passoa SC, Lill JT, et al. 2019. Illustrated guide to the immature Lepidoptera on oaks in Missouri. FHAAST-2018-05. US Department of Agriculture, Forest Service, Forest Health Assessment and Applied Sciences Team, USA

Moraes AR, Greeney HF, Oliveira PS, et al. 2012. Morphology and behavior of the early stages of the skipper, Urbanus esmeraldus, on Urera baccifera, an ant–visited host plant. Journal of Insect Science, 12(52):1-18

Nikam TB, Khole VV. 1989. Insect Spiracular Systems. Ellis Horwood Entomology and Acarology, Chichester, London,UK

Queiroz-Santos L, Casagrande MM, Specht A. 2018. Morphological characterization of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae: Heliothinae). Neotropical Entomology. DOI: https://doi.org/10.1007/s13744-017-0581-4

Richards OW, Davies RG. 1977. Imm's general text book of Entomology, Vol. 1, Structure, Physiology and Development. Richard Clay (The Chaucer Press) Ltd. Bungay, Suffolk, UK

Rose HS, Singh D. 2010. Cephalic chaetotaxy of the last instar larva of a pyralid: *Syllepte derogata* (Fabricius) (Lepidoptera). Journal of Threatened Taxa, 1(12): 672-673. DOI: 10.11609/JoTT.o2151.672-3

Schmitz A, Wasserthal LT. 1999. Comparative morphology of the spiracles of the Papilionidae, Sphingidae and Saturniidae (Insecta: Lepidoptera). International Journal of Insect Morphology, 28: 13-26

Scoble M. 1995. The Lepidoptera: Form, Function and Diversity. 66-67, Oxford University Press, London, UK

Srivastava KP. 1975. On the respiratory system of the lemon butterfly *Papilio demoleus*. Journal of the Australian Entomological Society, 14: 363-367

Stehr FW. 1987. Order Lepidoptera. In: Immature Insects Vol. 1 (Stehr FW, ed). 288-305, Hunt Publishing Company, Dubuque, Kendall, USA

Snodgrass RE. 1935. Principles of Insect Morphology. McGraw Hill, New York, USA

Todd MG. 2013. Basic adult and larval morphology Taxonomic Workshop for Early Detection of Important Tortricidae and Other Lepidopteran Agricultural and Silvicultural Pests. 15-17, UMass Amherst, USA

Tonapi GT. 1959. On the structure and mechanism of the spiracular regulatory apparatus in the adult *Corcyra cephalonica*. Current Science, 28(119): 457-458

Wasserthal LT. 2003. Respiratory System In Teilband/Part 36 Vol 2: Lepidoptera: Moths and Butterflfly Morphology, Physiology, and Development. Gruyeter, Germany. DOI: https://doi.org/10.1515/9783110893724.189

Willmott KR, Freitas AVL. 2006. Higher-level phylogeny of the Ithomiinae (Lepidoptera: Nymphalidae): classification, patterns of larval hostplant colonization and diversification. Cladistics, 22: 297-368